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RESEARCH ARTICLE

Effects of *Thermocyclops decipiens* and *Artemia* Nauplii for Larval Rearing of *Macrobrachium rosenbergii* (De Man, 1879)

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Key words:

M. rosenbergii
Live-feed
Growth parameters
Biochemical profile

Abstract: This study examines the effects of the freshwater cyclopoid *Thermocyclops decipiens* and *Artemia* nauplii on the growth and survival of *Macrobrachium rosenbergii* (De Man, 1879) larvae during the rearing phase. *M. rosenbergii* larvae were divided into three groups and fed exclusively with either *Artemia* nauplii or *T. decipiens*, and a mixed diet (50% *T. decipiens* and 50% *Artemia* nauplii) in triplicate. The results indicated that *M. rosenbergii* larvae reached 90% post larvae (PL) on the 23rd day of the mixed diet feeding regime, followed by 88% and 82% PL on the 24th and 26th days when fed with *Artemia* nauplii and *T. decipiens*, respectively. The highest length and weight of *M. rosenbergii* PL were observed in the mixed diet treatment with 14.37±0.51mm and 0.76±0.04mg, respectively. The specific growth rate and percentage weight gain were significantly ($p < 0.05$) higher in the mixed feeding treatment. However, the survival of larvae was highest (69.89±4.55%) in the *Artemia* nauplii treatment. The larval stage index (LSI) of *M. rosenbergii* larvae fed on different feeding regimes was mixed diet > *Artemia* nauplii > *T. decipiens.* The biochemical constituents of *M. rosenbergii* PL showed that protein concentration was higher in the larvae fed with *T. decipiens*, while carbohydrate and lipid content were also high in mixed feeding regimes. Results indicated that the larval stage index and growth parameters of *M. rosenbergii* larvae were highest in the mixed diet treatment.

Anahtar kelimeler:

M. rosenbergii
Canlı yem
Büyüme parametreleri
Biyokimyasal profil

Dev Tatlısu Karidesi'nin (*Macrobrachium rosenbergii* De Man, 1879) Larval Yetiştiriciliğinde *Thermocyclops decipiens* ve *Artemia* Nauplii'nin Etkileri

Öz: Bu çalışma, tatlısu siklopoidi *Thermocyclops decipiens* ve *Artemia* nauplii'nin *Macrobrachium rosenbergii* (De Man, 1879) larvalarının yetiştirme döneminde büyümesi ve hayatta kalması üzerindeki etkilerini incelemektedir. *M. rosenbergii* larvaları üç gruba ayrıldı ve *Artemia* nauplii, *T. decipiens* ve karma bir diyet (%50 *T. decipiens* ve %50 *Artemia* nauplii) ile 3 tekerrürlü olarak beslendi. Sonuçlar, karma diyetle beslenen *M. rosenbergii* larvalarının, 23. gününde %90 PL aşamasına ulaştıklarını ve bunu sırasıyla 24. günde %88 ile *Artemia* nauplii ve 26. günde %82 ile *T. decipiens* ile beslenen larvaların takip ettiğini göstermiştir. *M. rosenbergii* PL'nin en yüksek boy ve ağırlığı sırasıyla 14.37±0.51mm ve 0.76±0.04mg ile karma diyet uygulamasında gözlendi. Spesifik büyüme oranı ve yüzde ağırlık artışı, karma besleme uygulamasında önemli derecede daha yüksekti ($p < 0.05$). Bununla birlikte, *Artemia* nauplii uygulamasında larvaların yaşama oranı en yüksek (%69,89±4,55) olmuştur. Farklı besleme rejimlerinde beslenen *M. rosenbergii* larvalarının larva evre indeksi (LSI) karma diyet > *Artemia* nauplii > *T. decipiens* şeklinde gerçekleşmiştir. *M. rosenbergii* PL'nin biyokimyasal bileşenleri, *T. decipiens* ile beslenen larvalarda protein konsantrasyonunun daha yüksek olduğunu, karma besleme rejimlerinde karbonhidrat ve lipid içeriğinin de yüksek olduğunu göstermiştir. Sonuçlar, *M. rosenbergii* larvalarının larva evre indeksi ve büyüme parametrelerinin karma diyet uygulamasında en yüksek olduğunu göstermiştir.

Introduction

The giant freshwater prawn, *Macrobrachium rosenbergii* and *Macrobrachium malcolmsonii*, are the commercially important aquaculture species in India. The utilization and nutritional quality of food are critical to the success of prawn larval rearing. (Yufera et al., 1984; Freeman, 1990). Choice of food, on the other hand, is the bottleneck for the larval rearing of prawn larvae (Alam et al., 1991). Food and feeding affect the growth and survival of the early stages of larvae (Alam et al., 1996). Effective *M. rosenbergii* culture is a major issue, particularly the supply

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of food and nutrition to their larvae (Hanson and Goodwin, 1977). *Artemia* nauplii are suitable for early stages of fish, as reported by many authors (Aniello and Singh, 1982; Sandifier et al., 1976; New, 1990), and demand is increasing as a result of the unpredictability of supply and the high cost of their cysts (Bengtson et al., 1991).

The reliance on live food necessitates challenges with adequate food supply and management during the prawn larval phase. (Jones et al., 1993; Dhont et al., 2010; Valenti et al., 2010). *Artemia* nauplii are utilized for *M. rosenbergii* larval rearing, and in such conditions, the production of larvae is high-cost. Other zooplankton have been used as live feed for the early stages of finfish and shellfish (Manickam et al., 2020). Alam et al. (1993) suggested that *Moina micrura* be considered as a supplement to *Artemia* nauplii, and Ling (1969) stated that rotifers, cladocerans, and copepods may be suitable live feed to *M. rosenbergii* larvae. However, zooplankton mass production continuous systems is a major problem (Rasdi et al. 2020). In our study, mass culture *T. decipiens* was used for the rearing of *M. rosenbergii* larvae. Therefore, reliable continuous culture method is adopted to maintain the *T. decipiens* densities during culture.

Suitably prepared live feed plays an important role in the rearing of *M. rosenbergii* larvae. In the last two decades, *M. rosenbergii* has been studied in relation to cultural aspects. Zooplankton contains more nutrients than *Artemia* nauplii (Rajkumar et al., 2004). The nutritional values of zooplankton are evaluated by various authors (Watanabe et al., 1983; Safiullah, 2001; Aman and Altaff, 2004; Manickam et al., 2017). Hence, the present study aims to determine the effects of *T. decipiens* on the growth and survival of *M. rosenbergii* larvae. Our findings have the potential to contribute to the development of improved larval rearing techniques for more efficient hatchery production of *M. rosenbergii.*

Material and Methods

Culture of *T. decipiens*

Zooplankton samples were collected using a bolten silk plankton net (50 µm) from Chetpet Pond, Chennai, India, during the early hours of the day. They were transported to the laboratories immediately. *T. decipiens* was sorted out from the samples using a binocular stereomicroscope. The inoculum of *T. decipiens* (50nos./l) was introduced into the culture tanks (Altaff and Sivakumar, 2003; Sivakumar, 2015). *T. decipiens* were cultured using a combination of chicken manure (150ppm) and mixed algae (*Pennate* sp., *Eurastrum* sp. and *Stephanodiscus* sp.;4.25 x 10^4 cells/ml) in 25 l fiberglass tanks. The cultured species were harvested from the culture tank and fed to the prawn larvae.

Hatching of *Artemia* nauplii

The *Artemia* cysts were hatched out in a cone-shaped culture tank under controlled conditions. The water medium was maintained at 25 ppt salinity, pH 8 and temperature ranged between 28-30 ºC. A luminous bulb placed above the hatching cone provided sufficient heating for hatching. For optimum hatching results, the cysts were illuminated (2000 lux illumination) during the entire incubation period. Constant aeration was provided and a 3-4 ppm oxygen level was maintained. A total of 75 mg cysts were introduced into the hatching medium and incubated for 24 hours. After hatching, instar I was used for the rearing of *M. rosenbergii* larvae.

Preparation of egg custard

One hundred grams of fish meal were blended using a blender. It was passed through a muslin cloth; six whole eggs were added and blended; the mixture was steamed with 250 ml of water until it solidified into custard followed by the other ingredients added as shown in Table 1. The screened egg custard was stored for a few days.

Table 1. Formulation of egg custard

Ingredients	Formula
Fish meal (gm)	100
Skimmed milk (gm)[1]	250
Whole (yolk and white) chicken eggs Nos.)	6
Wheat flour (g)[2]	250
Vitamin C (mg)	250
Vitamins A and D (ml)[3]	2.5
Vitamin B complex (mg)	125
Tetracycline (mg)	250
Calcidol (ml)[4]	10

[1] Amul, India
[2] Wheat flour is a powder made from the grinding of wheat
[3] Vitamin A and D each 1.25ml
[4] Every 5 ml of calcidol contains Calcium Carbonate Eq to Elem.Cal 125 mg Vitamin D3 62.5 IU Elemental Magnesium (as Hydroxide) 10 mg Elemental Manganese (as Sulphate) 0.5 mg Elemental Zinc (as sulphate) 2.5 m Elemental Boron(as sodium borate) 62.5 mcg

Experimental setup

M. rosenbergii, larval rearing experiment was conducted for 26 days at Aqua-Nova Hatcheries, Kanathur, Chennai, India. Water quality parameters were maintained as follows: salinity 12 ppt, temperature 28 - 31ºC and hardness of 60 - 100 ppm.. The culture water was filtered and chlorinated for 3 to 4 days and then dechlorinated before use.

For the experiment, 25 l of 12 ppt dechlorinated water was filled in conical tanks. A total of 300 larvae (1 day after hatching (DAH); 1.90-1.96 mm) were introduced into each tank. The experimental tanks were provided with continuous vigorous aeration except during feeding and cleaning. *M. rosenbergii* larvae were fed with *Artemia* nauplii (Treatment I), *T. decipiens* (Treatment II), and a mixed diet (50% *T. decipiens* and 50% *Artemia* nauplii) (Treatment III) in triplicate. Experiments were conducted when larvae reached the post larvae stage. The feed was broadcast thrice daily at 7.00 hrs, 13.00 hrs, and 18.00 hrs. The number of live-food organisms provided for the different stages of *M. rosenbergii* larvae is as follows (Table 2).

Table 2. *M. rosenbergii* larvae feeding program

Larval Stages	Feeding Regimes		
	Control	Experimental feed	
	Artemia nauplii	*T. decipiens*	Mixed diet
Stage 2 and 3	10-16 individuals/larva	10-16 individuals/larva	10-16 individuals/larva
Stage 4 to 7	20-46 individuals/larva	20-46 individuals/larva	20-46 individuals/larva
Stage 8 to PL	46-60 individuals/larva	46-60 individuals/larva	46-60 individuals/larva

For the larvae in the control and experimental tank, egg custard was provided as supplement feed at 10.30 hrs, and 22.30 hrs. During the experimental period, 40% of the tank water was replenished daily in the morning hours, when excess feed and faecal matter of the larvae were removed.

In addition, 1 ppm tetracycline was administered to each tank once a day. Daily measurements of dissolved oxygen (Lutron DO-5510 Electronic Dissolved Oxygen Meter) and salinity (Dual scale salinity refractometer ATC) were taken. When the larvae reached the post-larval stage, they were gradually acclimatized from brackish water to freshwater to avoid the physiological shock of sudden transfer from brackish water to freshwater.

Biochemical analysis

At the end of the experiments, a total of 10 PL were collected from each tank for biochemical parameters such as protein (Lowry et al., 1951), carbohydrate (Roe, 1955), and lipid (Folch et al., 1957).

Data collection and statistical analysis

M. rosenbergii larvae were sampled at end of the experiments (larvae that reached to PL) to measure length, weight, and survival on 5th, 10th, 15th, 20th, and 26th, day. The total length (TL) was measured using a 30-cm (0.1 mm) ruler. Analytical balances (precision of 0.01 g) were used to record body weight (BW). The larvae's specific growth rate (SGR), percentage weight gain (PWG), survival rate (Dash et al., 2014) and condition factor (Htun-Han, 1978) were calculated using the following equations:

$$SGR = \frac{\ln(\text{final weight of the larvae}) - \log(\text{initial weight of the larvae})}{\text{Experimental periods in days (t)}}$$

where:

SGR % = percentage increase in body weight per larvae per day

$$Percentage\ weight\ gain\ (PWG) = \frac{\text{Final weight of the larvae} - \text{Initial weight of the larvae}}{\text{Inital weight of the larvae}} x100$$

$$Survival\ (\%) = \frac{\text{Number of live fish counted}}{\text{Number of fish stocked}} x100$$

Condition factor

$$Condition factor\ (CF) = \frac{\text{Weight of the larvae}}{\text{Length of the larvae}^3} x100$$

Larval stage index (LSI) was calculated according to the following formula (Manzi et al., 1977)

$LSI = (\sum Si\ x\ ni)/N^{-1}$

where,

S_i is the larval/PL stage (I= 1–12), ni= number of animals in stage S_i and N= total number of animals observed. LSI= ranges varied from 1 to 10.

The experimental data was collected at the end of the experiment and statistically analyzed. Prior to analysis, the data were checked for normality and variance homogeneity using Levine's test. At the end of the experiment, the length and weight of the post-larvae from different feeding regimes were measured. Survival of the larvae was determined on the 5th, 10th, 15th, 20th, and 26th days of experimentation. The data was presented as mean ± standard deviation. Data were subjected to one-way ANOVA followed by Tukey's test to determine which treatments differed from each other ($p<0.05$). Random ANOVA was performed to calculate the survivorship of *M. rosenbergii* larvae (IBM SPSS for Windows, version 21.0. Armonk, NY: IBM Corp).

Results

M. rosenbergii larvae growth parameters are presented in Table 2. The effect of different feeding regimes was significantly different at the end of experimental period ($p < 0.05$). The length and weight of the *M. rosenbergii* larvae were 14.37±0.51 mm and 0.76±0.04 mg respectively, in the mixed diet feeding regimes and it was higher compared to those of other treatments (Table 3). The results of all the twelve stages gradually increased their length and weight linearly. However, during the larval stages I–IV, faster growth and high survival were recorded in *Artemia* nauplii treatments (Fig. 1). Subsequently, larval development was higher than those recorded in the mixed feeding regimes, and also 90% PL stage was reached on 23rd day of the experiment. However, larvae fed exclusively on either *Artemia* nauplii or *T. decipiens* reached 88% and 82% PL on the 24th and 26th

days, respectively. The final length and weight of larvae fed with different feeding regimes were significantly different ($p<0.05$). However, Tukey's test showed that the weight of the larvae fed with *Artemia* nauplii was not significantly different ($p>0.05$) compared to *T. decipiens* treatment. Regression analysis between the length and weight of *M. rosenbergii* larvae showed a positive relationship in three different feeding regimes (Figs 2a-c).

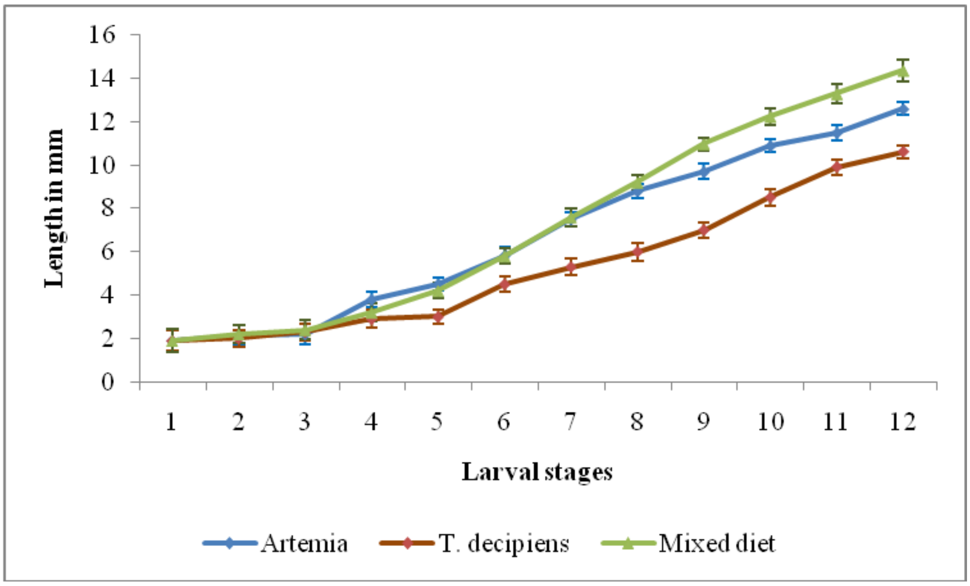

Figure 1. Length of different larval stages of *M. rosenbergii* larvae in different feeding regimes

Table 3. Growth and survival of *M. rosenbergii* larvae with different feeding regimes

	***Artemia* nauplii**	***T. decipiens***	**Mixed diet**	**F**	**P**
Initial length (mm)	1.96 ± 0.53^{a}	1.95 ± 0.05^{a}	1.94 ± 0.04^{a}	0.111	0.897^{NS}
Final length (mm)	12.60 ± 0.30^{a}	10.60 ± 0.30^{b}	14.37 ± 0.51^{c}	72.098	0.00*
Initial weight (mg)	0.14 ± 0.02^{a}	0.13 ± 0.02^{a}	0.14 ± 0.01^{a}	0.056	0.946^{NS}
Final weight (mg)	0.68 ± 0.05^{ab}	0.62 ± 0.04^{b}	0.76 ± 0.04^{a}	9.257	0.02*
SGR (%)	6.51 ± 0.21^{ab}	6.16 ± 0.20^{b}	7.00 ± 0.30^{a}	9.222	0.02*
PWG (%)	409.36 ± 25.44^{ab}	306.75 ± 23.39^{b}	475.56 ± 42.34^{a}	9.058	0.02*
LSI	4.34	3.66	4.94	-	-
CF	1.79 ± 0.08^{a}	1.95 ± 0.07^{b}	1.77 ± 0.03^{a}	7.752	0.02*
Survivorship	χ^2 (9) = 25.901, p = 0.003; F (4,32) = 60.106, p = 0.000				

Values are represented as mean ± SD of triplicate. Letters denote significant differences ($p < 0.05$). – NS: Not Significant

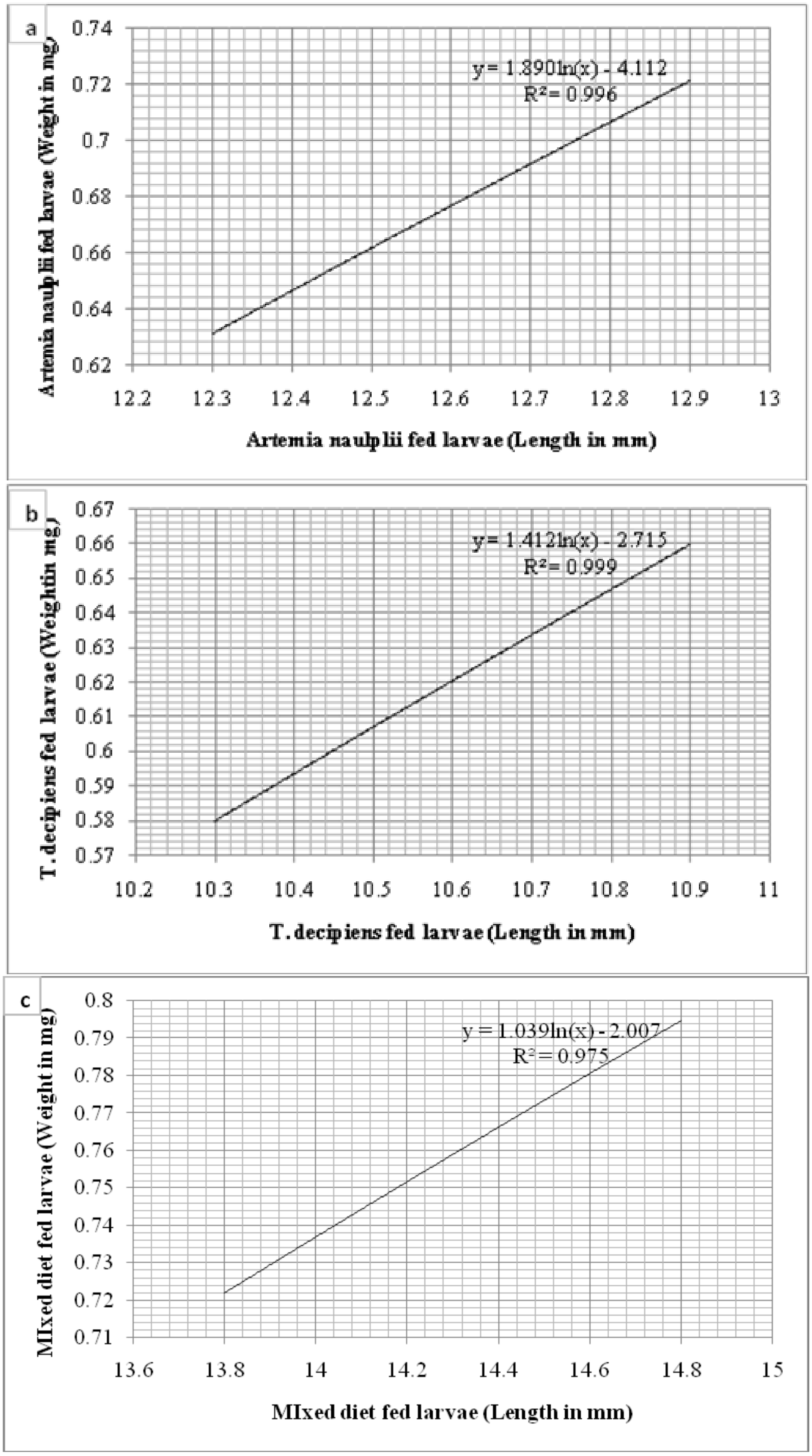

Figure 2. Regression analysis between length and weight of *M. rosenbergii* larvae fed in different feeding regimes

M. rosenbergii larvae had the highest specific growth rate and highest weight gain of 7.00 ± 0.30% and 475.56 ± 42.34%, respectively, in the mixed feeding treatment, followed by *Artemia* nauplii and *T. decipiens* treatments One-way ANOVA for growth parameters showed that their growth rates were significantly different ($p < 0.05$. The LSI of *M. rosenbergii* larvae in different feeding regimes showed the highest index (4.94) in mixed feeding regimes (Table 3). However, up to day 7 (DAH), the LSI was not significantly different between *Artemia* nauplii

(LSI = 3.2) and mixed diet (LSI = 3.6) feeding regimes (Table 4). The CF of all the larvae fed with either *Artemia* nauplii or mixed diet was isometric and their growth linearly increased throughout the experiment. However, larvae fed with *T. decipiens* showed the highest CF values (1.95 ± 0.07) with negative allometric growth. Tukey's test also confirmed that *T. decipiens* fed *M. rosenbergii* larval growth significantly differed from their linear growth compared with *Artemia* nauplii and mixed diet (Table 3).

Table 4. Larval stage index of *M. rosenbergii* larvae fed in different feeding regimes

Stages	Feeding Regimes		
	Artemia	*T. decipiens*	Mixed diet
1	1	1	1
2	1.8	1.4	1.8
3	2.7	2.1	2.7
4	3.2	2.8	3.6
5	3.5	3	4
6	4.2	3.6	4.8
7	4.9	4.2	5.6
8	5.6	4.8	6.4
9	5.4	4.5	6.3
10	6	5	7
11	6.6	5.5	7.7
PL	7.2	6	8.4

Survival rates of *M. rosenbergii* in three feeding regimes on various days were recorded as shown in Fig. 3. The highest survival was recorded in *Artemia* nauplii fed larvae, followed by mixed diets and *T. decipiens* fed larvae. The highest survival of 69.89 ± 4.55% was recorded in *Artemia* nauplii fed larvae, followed by mixed feeding regimes (48.11 ± 2.59%) and the lowest survival of 38.00 ± 5.03% was recorded in *T. decipiens* fed larvae on the 26th day. Tukey's test indicated that survival of larvae showed significant differences ($p < 0.05$) among their feeding regimes on the 5th and 26th days. However, no significant differences were observed between *T. decipiens* and mixed diet feeding regimes on the 10th, 15th, and 20th days ($p > 0.05$) (Fig. 3). The random ANOVA for survivorship of *M. rosenbergii* larvae fed with different feeds on various days significantly differed ($p < 0.05$) (Table 3). The general linear model (GLM) for the survival of *M. rosenbergii* showed that observed data was more than predicted values. Based on this calculation, the linear mortality rate increased (Figs 4a-e).

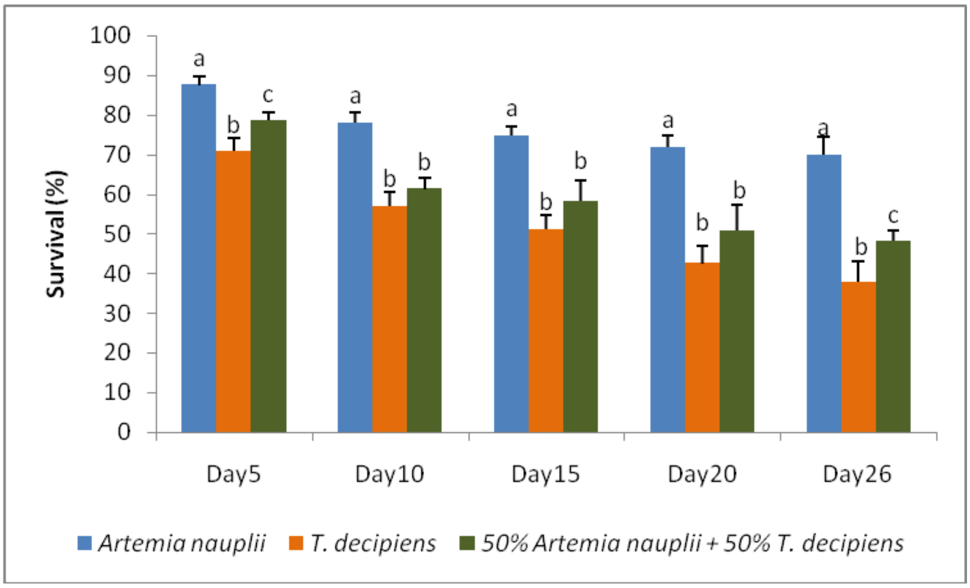

Figure 3. Effect of different feed on survival of *M. rosenbergii* larvae. Values are represented as mean ± SE. Letters denote significant differences ($p < 0.05$).

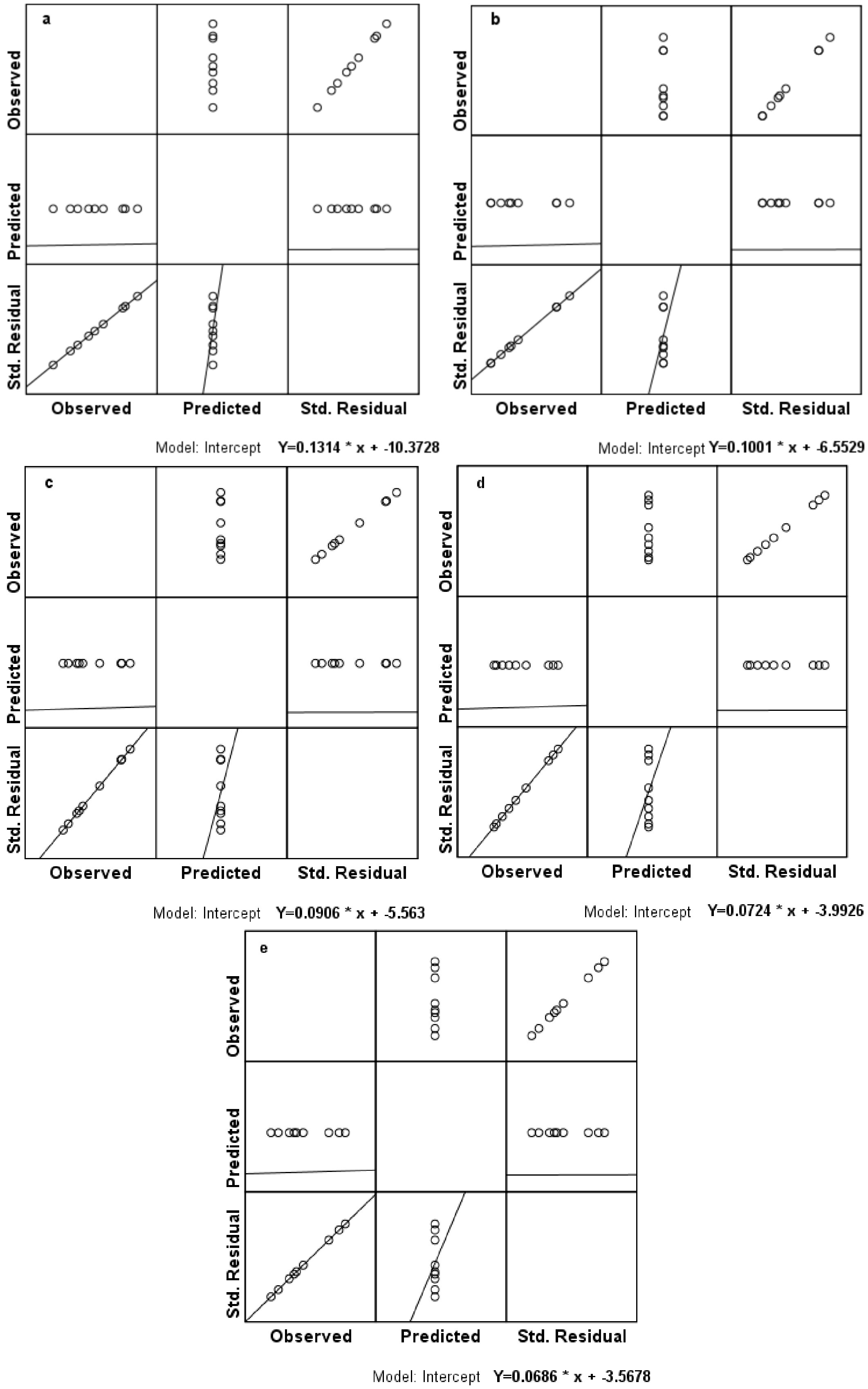

Figure 4. General linear model of survivorship of *M. rosenbergii* larvae fed in different feeding regimes; a. day 5, b. day 10, c. day 15, d. day 20, e. day 26

The biochemical profile of *M. rosenbergii* larvae fed with three different feeding regimes is presented in Table 5. The protein content of larvae fed with *T.decipiens* was higher (47.97 ± 0.35%), but carbohydrate (1.67 ± 0.03%) and lipid (8.03 ± 0.21) levels were higher in the mixed diet. Biochemical constituents of *M. rosenbergii* fed with different diets were significantly different (p < 0.05). Tukey's test showed that carbohydrate and lipid contents were not significantly different between *T. decipiens* and mixed diet. Protein content, on the other hand, was significantly higher (p < 0.05) in the *Artemia* nauplii fed group than those in other treatments (Table 5).

Table 5. Biochemical composition of *M. rosenbergii* larvae

	Protein (%)	Carbohydrate (%)	Lipid (%)
Artemia nauplii	43.74 ± 0.58^{a}	1.43 ± 0.06^{a}	7.35 ± 0.13^{a}
T. decipiens	47.97 ± 0.35^{b}	1.65 ± 0.05^{b}	7.14 ± 0.09^{b}
Mixed diet	46.57 ± 0.60^{c}	1.67 ± 0.03^{b}	8.03 ± 0.21^{b}
F	50.914	23.793	29.333
p	0.000^{*}	0.001^{*}	0.001*

Values are represented as mean ± SE. Letters denote significant differences ($p < 0.05$).

Discussion

In the present study, *M. rosenbergii* post larval production was successfully achieved using *Artemia* nauplii, mixed diet, as well as with *T. decipiens* diet. Results of the present study showed higher growth of *M. rosenbergii* larvae fed exclusively with *Artemia* nauplii; however, weight, SGR, and PWG were not significantly different in larvae fed either Artemia or *T. decipiens* (p > 0.05). In the *T. decipiens* treatment different life stages such as nauplii, copepodids and adults were introduced into the larval rearing tank as feed. The larger size of the adult *T. decipiens* (850-1100 µm) may have prevented feeding by *M. rosenbergii* larvae. This may be a reason for slower growth observed in *T. decipiens* fed larvae. CF also confirmed the negative allometric growth parameters in larvae fed exclusively with *T. decipiens.* In treatments fed with either *Artemia* nauplii or a mixed diet, isometric growth of the larvae was observed. Similar to the weight of the larvae, SGR and PWG were not significantly (p > 0.05) different between *T. decipiens* and *Artemia* nauplii fed larvae. However, SGR and PWG were significantly (p < 0.05) higher in the mixed diet than those in other feeding regimes.

The present study indicated higher survival of the *M. rosenbergii* larvae fed with *Artemia* nauplii than other feeds. However, it is worth noting that the total length of *M. rosenbergii* post-larvae fed on a mixed diet was higher but the survival rate was lower than that of *M. rosenbergii* larvae fed on the *Artemia* nauplii diet. Alam et al. (1993) reported that *M. rosenbergii* larvae fed on *Moina* had high mortality. In the present study, larvae fed on a diet of *T. decipiens* had higher mortalities larvae fed on*Artemia* nauplii showed a significantly higher survival rate than those of other feeding regimes. Islam *et al.* (2000) reported a high survival percentage of larvae fed on *Artemia* nauplii with egg custard compared to those fed exclusively on *Artemia* nauplii and rotifers. Manickam et al., (2020) reported that *M. rosenbergii* larvae fed with a mixture of rotifers, cladocera, and copepoda had significantly higher survival and growth than those fed only *Artemia.* Similarly, other researchers reported higher growth and survival when larvae were fed with live feeds (Sunyoto et al., 1995; Aman and Altaff, 2004; Santhanam et al., 2004; Simhachalam et al., 2015).

In the biochemical profile, protein was the major component followed by lipids and carbohydrates in *M. rosenbergii* (Roustaian et al., 2001). In the present study, a similar pattern was found in all the feeding regimes. The biochemical compositions of live feed play a significant role in larval rearing; protein, carbohydrates, and lipids ensure the physiological status of organisms. The zooplankton are a better source of biochemical constituents for aquatic organisms (Tidwell et al., 1997; Manickam et al., 2017). The present study results showed higher biochemical contents in *M. rosenbergii* larvae fed with *T. decipiens*.

From the results of the present study, it can be suggested that *M. rosenbergii* postlarvae can be produced with a mixed diet, which will reduce the cost of live-feed substantially in seed production. Furthermore, the higher total length of the post-larvae fed with a mixed diet indicates superior nutritional status of the developing larvae by the mixed diet compared to a single diet. However, the survival percentage of *M. rosenbergii* was high in *the Artemia* feeding regime. As *M. rosenbergii* is the most intensively cultured species, its seed production using only indigenous live-feed organisms or in combination with *Artemia* nauplii may provide cost-effective culture methods.

Conclusion

The hatchery seed production of *M. rosenbergii* post larvae was possible with a live feed of cyclopoid copepod. A low percentage of survival was recorded with this feed compared to *Artemia* nauplii. However, production of *M.*

rosenbergii post larvae using a mixed diet might result in the cost-effective production of seeds.

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Conflicts of Interest

The authors declare that they have no conflict of interest.

Author Contributions

Sivakumar K: Conceptualization, Methodology, Investigation, writing- original draft Muthupriya M**:** Investigation, writing – reviewing data curation and editing Altaff K: Supervision, Validation and Formal analysis.

Ethics Approval

The material used in this article is invertebrate species therefore ethics committee approval is not required for this study.

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RESEARCH ARTICLE

Cyanobacterial Communities in Mucilage Collected from Çanakkale Strait (Dardanelles): Metagenomic Approach

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Metagenome
Cyanobacteria

Abstract: In this study, cyanobacterial communities in mucilage samples collected from three stations in the Dardanelles Strait were analyzed with a metagenomic approach. Mucilage samples were collected at the beginning of June 2021 from three points of the Dardanelles (Station 1: 40°6'42.78"N, 26°23'57.00"E; Station 2: 40°9'8.09"N, 26°24'16.19"E; Station 3: 40°6 '21.62"N, 26°22'41.25"E). The dominant cyanobacteria were *Prochlorococcus marinus* (39.17%), *Synechococcus* sp. (20.85%), *Lyngbya* sp. (12.00%), *Trichodesmium erythraeum* (7.33%), *Aphanocapsa* sp. (4.33%) and *Leptolyngbya* sp. (3.33%), which constituted 87.00 % of the total number of sequences. In this study, cyanobacteria species that can cause harmful algal blooms and have toxic effects on the mucilage structure have been determined. The Marmara Sea and the Dardanelles Strait, which have been affected by serious disturbances, including industrial activities, anthropogenic impacts, tourism and artificial lighting, will never be fully restored to their former ecological state. In addition, cyanobacteria species in the mucilage may cause harmful algal blooms and have toxic effects that threaten the future well-being of coastal populations and ecosystem stability. Thus, the government and local authorities should pay more attention to combating the mucilage.

Anahtar kelimeler:

Müsilaj
Deniz agregaları
Deniz karı
Metagenomik
Siyanobakteriler

Çanakkale Boğazı'ndan Toplanan Müsilajda Siyanobakteri Toplulukları: Metagenomik Yaklaşım

Öz: Bu çalışmada Çanakkale Boğazı'nda üç istasyondan toplanan müsilaj örneklerindeki siyanobakteri toplulukları metagenomik yaklaşımla analiz edilmiştir. Müsilaj örnekleri, Çanakkale Boğazı'nın üç farklı noktasından (İstasyon 1: 40°6'42.78"K, 26°23'57.00"D; İstasyon 2: 40°9'8.09"K, 26°, 24'16.19"D; İstasyon 3: 40°6 '21.62"K, 26°22'41.25"D) Haziran 2021 başında toplanmıştır. Toplam dizi sayısının %87.00'sini oluşturmuş baskın siyanobakteriler *Prochlorococcus marinus* (%39.17), *Synechococcus* sp. (%20.85), *Lyngbya* sp. (%12.00), *Trichodesmium erythraeum* (%7.33), *Aphanocapsa* sp. (%4.33) ve *Leptolyngbya* sp. (%3.33) olarak belirlenmiştir. Bu çalışma ile müsilaj yapısında zararlı alg patlamalarına neden olabilecek ve toksik etkilere sahip olabilecek siyanobakteri türleri tespit edilmiştir. Endüstriyel faaliyetler, insan kaynaklı etkiler, turizm ve yapay aydınlatma dahil olmak üzere ciddi rahatsızlıklardan etkilenen Marmara Denizi ve Çanakkale Boğazı, hiçbir zaman eski ekolojik durumuna tam olarak geri döndürülemeyecektir. Bu nedenle, devlet ve yerel yönetimler müsilajla mücadeleye daha fazla önem vermelidir.

Introduction

Cyanobacteria is a group of prokaryotic organisms, and they are essential for the water environment. Although cyanobacteria are commonly found in freshwater lakes and reservoirs, climate change and anthropogenic pressure may cause their populations to increase in marine environments (Bobrova et al., 2016; Alvarenga et al., 2017). Cyanobacteria blooming wildly in lakes and marine environments with high concentrations of phosphorus may produce cyanotoxins in concentrations that will poison or kill mainly fish and shellfish, even humans (Stewart et al., 2006; Backer et al., 2015).

The presence of different cyanobacteria genus and/or algal blooms in marine environments in Turkey and nearby geography have been reported (Uysal, 2001; Taş et al., 2006; Spatharis et al., 2012; Kalaitzidou et al., 2015; Teneva et al., 2015; Uysal, 2016; Vinogradova et al., 2017). Previously, cyanobacteria communities were observed in the form of mucilage in the Northeast Atlantic Ocean (Lampitt et al., 1993), in the Sargasso Sea (Lundgreen et al., 2019) and in the Marmara Sea (Toklu-Alicli et al., 2020) as well.

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Anabaena, Aphanoteche, Blennothrix, Blennothrix, Calothrix, Chroococcus, Dermocarpa, Gloeocapsa, Gloeocapsopsis, Gomphosphaeria, Heteroleibleinia, Leibleinia, Leptolyngbya, Lyngbya, Merismopedia, Microcoleus, Microcystis, Oscillatoria, Phormidium, Planktothrix, Pseudanabaena, Rivularia, Schizothrix, Spirocoleus, Spirulina, Symploca, Synechococcus, Trichocoleus, Coelosphaerium, Scytonematopsis, Scytonema, Pannu, Entophysalis, Xenococcus, Tapinothrix, Trichodesmium, Microchaete, Dichothrix, Isactis, Prochlorococcus and *Nostoc* members have been reported among the cyanobacteria recorded in Turkish seas (Uysal, 2000; Polat et al., 2000; Develi and Kıdeyş 2000; Uysal, 2001; Taşkın et al., 2001; Aktan and Aykulu 2003; Aysel et al., 2004; Feyzioglu et al., 2004; Okudan and Aysel 2005; Parlakay et al., 2005; Aysel et al., 2005a; Aysel et al., 2005b; Aysel et al., 2005c; Aysel et al., 2005d; Uysal, 2006; Aysel et al., 2006a; Aysel et al., 2006b; Aysel et al., 2006c; Aysel et al., 2006d; Taş et al., 2006; Eker-Develi et al., 2006; Uysal and Köksalan 2006; Bayindirli and Ulysal 2007; Karaçuha and Gönülol 2007; Aysel et al., 2008; Yildirim and Sukatar 2009; Polat and Uysal 2009; Kurt et al., 2010; Kopuz et al., 2012; Aktan and Balkıs 2014; Feyzioğlu et al., 2015; Ulcay et al., 2015; Güreşen et al., 2015; Balkis and Taş 2016; Kısa and Pabuçcu 2016; Yücel et al., 2017; Balci and Balkis 2017; Yücel et al., 2018; Güreşen et al., 2020; Kocum, E. 2020; Balkıs-Ozdelıce et al., 2021).

In this study, cyanobacterial communities in mucilage samples collected from three stations in the Dardanelles Strait were analyzed by means of a metagenomic approach.

Material and Methods

Mucilage samples were collected at the beginning of June 2021 from three points of the Dardanelles (Station 1: 40°6'42.78"N, 26°23'57.00"E; Station 2: 40°9'8.09"N, 26°24'16.19"E; Station 3: 40°6 '21.62"N, 26°22'41.25"E) (Figure 1). The temperature, pH, and dissolved oxygen of sea waters were measured using a portable meter (WTW Multi-parameter portable meter MultiLine® Multi 3620 IDS SET). Samples were collected onboard a coast guard ship using a 5L Niskin bottle from a maximum depth of 2 m according to the ISO 5667-9 method (ISO 5667-9, 1992).

Figure 1. Sampling points in the Dardanelles (Google Earth Map) (Yilmaz et al., 2021)

Mucilage samples were brought to Çanakkale Onsekiz Mart University, Faculty of Marine Sciences and Technology, Ecotoxicology Laboratory under cold chain conditions for DNA isolation. Samples were centrifuged at 10,000 × g for 10 min and separated. Accumulated fresh samples were immediately used for DNA extraction. DNA isolation from mucilage samples was performed with GenElute™ Soil DNA Isolation Kit (Sigma-Aldrich, St. Louis, MO). DNA degradation and concentration were monitored using spectrometry (OD260/280), fluorometry (Qubit® 2.0 Fluorometer), and 1% agarose gel electrophoresis.

The cyanobacterial 16S rRNA gene was amplified by PCR, using the cyanobacterial specific primers CYA359f GGGGAATYTTCCGCAATGGG and CYA781r GACTACWGGGGTATCTAATCCCWTT (Nübel et al., 1997). The first PCR reactions were performed in a triplicate 25 µL mixture containing 12.5 µL of 2X KAPA HotStart ReadyMix (Roche, Switzerland), 5 µL of each primer (1 µM), and 2.5 µL of template DNA. The PCR program was as follows: 95 °C for 3 min followed by 25 cycles of 95 °C for the 30s, 55 °C for 30 s, 72 °C for 30 s, and a 5 min extension at 72 °C and a final hold at 4 °C. The second PCR reactions were performed in a triplicate 50 µL mixture containing 25 µL of KAPA HiFi HotStart ReadyMix, 5 µL Nextera XT1, 5 µL Nextera XT2, 5 µL of cleaned PCR product and 10 µl PCR Grade water. The second PCR program was as follows: 95°C for 3 min followed by 8 cycles of 95°C for 30 s, 55°C for 30 s, 72°C for 30 s, and a 5 min extension at 72°C and a final hold at 4°C.

The sequencing (2 × 250 bp) was performed on the MiSeq platform. The processing and quality control was conducted using DADA2 (Callahan et al., 2016). Chimaera check was conducted with DADA2. Amplicons with a quality of ≥Q20 were retained, and amplicons were filtered and trimmed with DADA2. Taxonomic assignment was performed against the SILVA 138 ribosomal RNA gene database (Quast et al., 2013) with a confidence threshold of 70%.

Results

The seawater temperature, pH and dissolved oxygen at the sampling stations are shown in Table 1. The temperature, pH and dissolved oxygen measurements were similar in all stations. The mean temperature, pH and dissolved oxygen values in the surface layers of the three stations were recorded as 21.87±0.65 ºC, 8.17±0.10, and 8.52±0.24 mg/L, respectively.

The dominant cyanobacteria communities at the order level were Synechococcales and Oscillatoriales (Figure 2). Synechococcales levels were recorded as 68%, 67%, and 68% for Station 1, Station 2, and Station 3, respectively. Oscillatoriales levels were recorded as 22%, 17%, and 19% for Station 1, Station 2, and Station 3, respectively.

The dominant cyanobacteria were *Prochlorococcus marinus* (39.17%), *Synechococcus* sp. (20.85%), *Lyngbya* sp. (12.00%), *Trichodesmium erythraeum* (7.33%), *Aphanocapsa* sp. (4.33%) and *Leptolyngbya* sp. (3.33%) which constituted 87.01 % of the total number of sequences (Figure 3). *Prochlorococcus marinus* and *Synechococcus* sp. levels varied between 38%-41% and 19%-23% for the stations, respectively. *Lyngbya* sp., and *Trichodesmium erythraeum* levels varied between 11%-14% and 6%-8% for the stations, respectively. *Aphanocapsa* sp. and *Leptolyngbya* sp. levels varied between 4%-5% and 3%-4% for the stations, respectively.

Table 1. Seawater temperature, pH and dissolved O_2 in the field

Stations	Temperature (ºC)	pH	Dissolved Oxygen (mg O_2/L)
Station 1	21.9	8.06	8.53
Station 2	21.2	8.25	8.75
Station 3	22.5	8.21	8.27

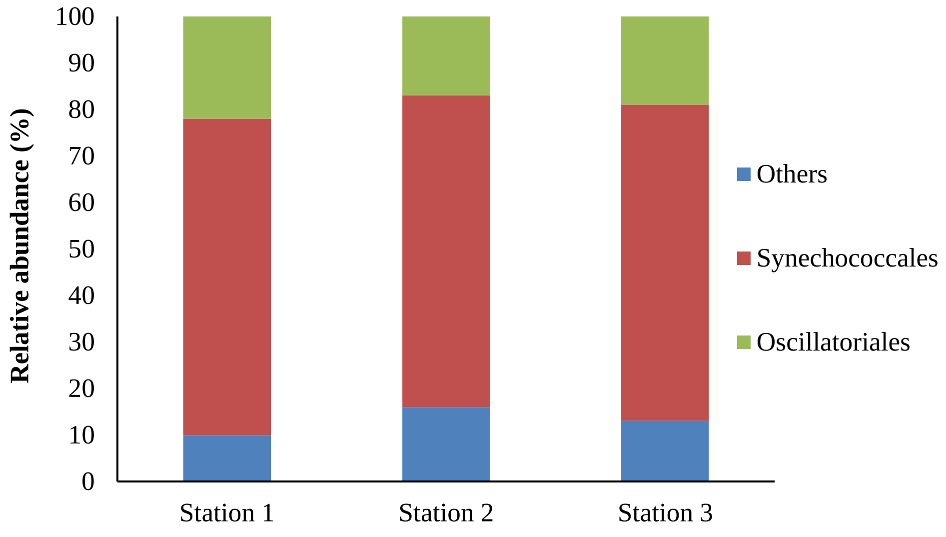

Figure 2. Cyanobacteria communities at the order level in mucilage samples

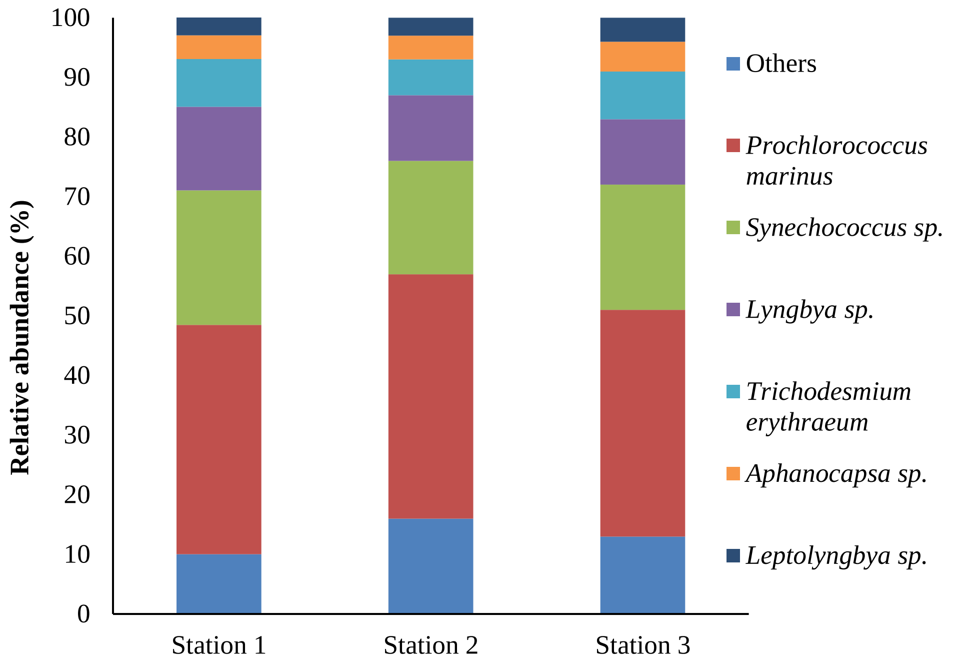

Figure 3. Cyanobacterial communities in mucilage samples

Discussion

In this study, it was determined that cyanobacteria species that may cause harmful algal blooms and have toxic effects are found in the mucilage structure. It is undeniable that humans and other living things shall suffer more in the future due to harmful algal blooms due to the deterioration of the natural balance caused by environmental pollution. *Prochlorococcus marinus* was determined as dominant among the cyanobacteria species in the mucilage structure. *P. marinus* caused an algal bloom for the first time in 2002 in lagoon areas in the Northwestern Sea (Zaitsev and Nesterova 2003; Shiganova, 2008).

Transparent exopolymer particles (TEP), which are extracellular acidic polysaccharides that may form during phytoplankton blooms, are associated with mucilage formation. In laboratory experiments, it has been determined that *P. marinus* has a high TEP production potential (Iuculano et al., 2017). In this study, *Synechococcus sp.* was determined as the second dominant group. It was reported that the mucilage forming ability of *Synechococcus sp*. and *P. marinus*, which are capable of producing TEP, was increased by heterotrophic bacteria (Cruz and Neuer 2019).

Yücel et al. (2018) determined that *Prochlorococcus* is more dominant than small eukaryotes and *Synechococcus* in the Northeastern Mediterranean Sea. Synechococcus density was high during mucilage formation in the Marmara Sea (Gulfs of Bandırma and Erdek) between August 2007 and August 2008 (Toklu-Alicli et al., 2020). In this study, the predominance of *Prochlorococcus* over *Synechococcus* may be associated with the effect of many environmental factors. However, it is known that the density of *Synechococcus* increases more in colder waters (13–16 °C) than *Prochlorococcus*. In our study, the water temperatures in the three sampling stations varied in the range of 21.2-22.5 °C.

The other dominant strains such as *Lyngbya* sp. and *Trichodesmium erythraeum* were detected in mucilage structure in different studies. For example, in the presence of 24-25 °C warm southern water body and 20-22 °C colder northern water body in the Saragossa Sea, *Trichodesmium, Synechococcus*, and *Prochlorococcus* distribution in marine snow particles were 13%, 1.8%, and 2.0%, respectively (Lundgren et al., 2019). Metaxatos et al. (2003) determined the cyanobacteria genus as *Microcystis aeruginosa* > *Chroococcus gelatinosus* > *Synechocystis sallensis* > *Trichodesmium erythraeum* > *Lyngbya agardhii*, respectively, according to their density, in the mucilage structure collected at an average water temperature of 23.5 °C in September 1999 in Euboikos Gulf, Aegean Sea.

Trichodesmium erythraeum originates from Indo-Pacific and the Red Sea. For Turkey, the first detection of this organism was made in the Aegean Sea in 1990, where it reached via the Suez Canal and entered the alien species list (Çınar et al., 2011).

In this study, *Aphanocapsa* sp. and *Leptolyngbya* sp. were less abundant in mucilage samples. In the Tuscan Archipelago (between the Ligurian Sea and the Tyrrhenian Sea), between May 1999 and July 2002, the genus *Leptolyngbya*, *Lyngbya* and *Rivularia* were found most frequently in benthic mucilage samples compared to the genus *Oscillatoria*, *Symploca*, *Aphanocapsa and Gloeocapsa* (De Philippis et al., 2005). *Aphanocapsa* caused harmful algal blooms in freshwater reservoirs (de J Magalhães et al., 2019). De Philippis et al. (2005) assumed that this genus, which was detected in a saltwater environment, was previously not reported because it may be challenging to identify in samples containing high levels of suspended matter and therefore, cannot be included in the count. In this study, *Aphanocapsa sp.* was found in the mucilage structure in Dardanelles Strait. Previously, *Aphanocapsa litoralis* (Ulcay et al., 2015) was recorded in the Eastern Mediterranean Sea (Northern Cyprus), and different *Aphanocapsa* genus was recorded in the Black Sea (Aysel et al., 2004).

In this study, cyanobacteria genus identified metagenomically in the mucilage structure have been shown to exhibit toxic effects on different organisms. Some genera may cause other lethal effects, disorders in preference behaviours, and changes in behaviour mobility in fish (Hamilton et al., 2014). For example, *P. marinus* isolated from the Sargasso Sea was found to have the ability to produce the neurotoxic non-proteinous amino acid β-Methylamino-L-alanine (Cox et al., 2005). It was observed that the marine Synechococcus genus might have a toxic effect on marine invertebrates (Martins et al., 2007).

Lyngbya caused acute toxic effects on zebrafish embryos (Berry et al., 2004) and dermatitis in humans (Osborne et al., 2001). *T. erythraeum* produces toxins carried by some fish, and its soluble toxins in seawater may pose a health hazard to humans (Endean et al., 1993). It was also reported that *T. erythraeum,* which has cytotoxic and genotoxic effects, damages human lymphocyte DNA and has a toxic effect on *Artemia salina* (Narayana et al., 2014).

Leptolyngbya genus causes pathogenic microbial mat black band disease, which infects corals worldwide and produces toxins (Myers et al., 2007). *Crossbyanol B*, a toxic brominated polyphenyl ether isolated from *Leptolyngbya crossbyana*, had a harmful effect on *Artemia salina* (Choi et al., 2010).

Conclusion

An investigation of the diversity and ecology of cyanobacteria in the mucilage obtained from Dardanels was conducted. *Prochlorococcus marinus* was the most common cyanobacterial species, followed by *Synechococcus* sp.. The Marmara Sea and Dardanelles Strait, impacted by severe disturbances, including industrial activities, anthropogenic influence, tourism and artificial illumination, have never been completely restored to their former ecological state. In addition, cyanobacteria species in the mucilage may cause harmful algal blooms and have toxic effects that threaten the future well-being of coastal populations and ecosystem stability. Thus, the government and local authorities should pay more attention to combating the mucilage using coastal monitoring tools.

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Conflict of Interest

The authors declare that they have no conflict of interest.

Author Contributions

S. Yılmaz and M.A. Küçüker collected the Mucilage samples. S. Yılmaz analysed the data. All authors contributed to the study conception, design and writing.

Ethics Approval

Ethics committee approval is not required for this study.

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RESEARCH ARTICLE

Effect of Different LED Light Sources on Growth and Pigment Composition of *Dunaliella salina* Teodoresco (Chlorophyceae)

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Biochemical composition

Abstract: In this study, the effects of red, blue, and yellow LED lights on cell number, growth rate, pigment, and crude oil contents of the green algae, *Dunaliella salina* Teodoresco, isolated from Ayvalık (Balıkesir) saltworks, were investigated. The highest cell number and growth rate were found algae grown in the red LED treatment as 335.3 x 10^4 cell ml^{-1} and 4.30 $days^{-1}$, respectively. The highest chlorophyll *a* and β-carotene contents of *D. salina* cells were determined in the control group as 10.70 and 3.49 mg l^{-1}, respectively. The highest crude oil content was determined as 18% in the yellow LED treatment. Our results showed that LED lamps positively affect the growth and biochemical composition of *D. salina*.

Anahtar kelimeler:

Dunaliella salina
Yetiştiricilik
LED Işık Kaynakları
Büyüme
Biyokimyasal Kompozisyon

Farklı LED Işık Kaynaklarının *Dunaliella salina* Teodoresco (*Chlorophyceae*) Büyüme ve Pigment İçeriğine Etkisi

Öz: Bu çalışmada Ayvalık (Balıkesir) tuz üretim tesisinden izole edilen yeşil alglerden *D. salina* Teodoresco'nın kırmızı, mavi, sarı LED (Light Emitting Diode) ışık kaynakları kullanılarak Değiştirilmiş Johnson (DJ) ortamında yetiştiriciliği yapılmıştır. Deneme gruplarının büyüme hızı, pigment ve yağ içeriklerinde meydana gelen değişimler izlenmiştir. Denemeler süresince en yüksek hücre sayısı ve büyüme hızı kırmızı LED lamba altında sırasıyla 335,3 x 10^4 hc ml^{-1} ve 4,30 $gün^{-1}$ olarak elde edilmiştir. *Dunaliella salina* hücrelerinin en yüksek klorofil *a* ve β-karoten içerikleri sırasıyla 10,70 ve 3,49 mg l^{-1} olarak kontrol grubunda tespit edilmiştir. En yüksek ham yağ içeriği ise, sarı LED lamba uygulamasında %18 olarak bulunmuştur. Yapılan çalışma sonucunda LED lambaların *D. salina*'nın büyümesi ve biyokimyasal kompozisyonu üzerine olumlu etkilerinin olduğu saptanmıştır.

Giriş

Tek hücreli yeşil alg (*Chlorophyta*) olan *Dunaliella salina* β-karoten, gliserol ve yağ asitleri bakımından zengin, özellikle tuzlalar ve tuz göllerinde dağılım gösteren bir alg türüdür. (Ben-Amotz ve Avron, 1983; Dudu vd., 2001; Ben-Amotz, 2004; Oren, 2006; Ak vd., 2008). *Dunaliella*; flagellatlara sahip, ökaryotik ve hücre çeperi olmayan bir cins olma özelliği ile *Volvocales* ordosunun diğer cinslerinden ayrılmaktadır. Hücrelerinin elastik bir plazma membranı ile çevrili olması *Dunaliella* türlerinin hücre şeklinin değişmesinde ve osmotik değişimlere karşı adaptasyonunda bir avantaj sağlamaktadır. Osmoregülasyon ile hücre dışı osmotik basınca karşı hücre içindeki gliserol konsantrasyonu değişim göstermektedir (Jimenez vd., 1991; Borowitzka ve Borowitzka, 1992). *Dunaliella* türlerinin stres koşulları altında kuru ağırlığının %10'u kadar *β*-karoten sentezlemesi nedeniyle önemli bir antioksidan kaynağı olarak üretimi yapılmaktadır. Ekonomik değere sahip *Dunaliella* türlerinin yetiştiriciliği sonucu elde edilen *β*-karoten gıda endüstrisinde, eczacılık, kozmetik, tıp alanlarında ve biyomedikal araştırmalarda kullanılmaktadır (Bosma ve Wijffels, 2003). *β*-karotenin endüstriyel üretimdeki ihtiyacı büyük oranda laboratuvar koşullarında sentetik yollarla üretilen formundan karşılanmaktadır. Ancak doğal karotenlere olan talebin artması, araştırmacıları farklı doğal kaynaklardan *β*-karoten üretimine yönlendirmiştir (Vega vd., 1996).

LED; ışık yayan diyotların (light emitting diodes) kısaltılmış tanımıdır. LED'ler, çok dar bir emisyon tepe noktası ile ışık üreten katı hal yarı iletkenlerdir. İleri akım uygulandığında, iki yarı iletken katman arasında fotonlar üretilir. Bu katmanlarda kullanılan malzemeye bağlı olarak fotonlar farklı enerjilere ve dolayısıyla farklı dalga boylarına sahiptir (Glemser vd., 2016). LED lambalar floresan lamba ile karşılaştırıldığında, uyumlu ışık üretmek için uygun bir armatüre sahip floresan lambalar için

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gereken ekipman mekanik olarak daha karmaşıktır, daha büyük boyut gerektirir ve bu nedenle aydınlatılan alanın ölçeğinin küçültülmesine izin vermemektedir. Ayrıca, floresan lambalarda civa içeriği görülmektedir ve LED kaynaklarının açılıp kapanma esnasında titreşim etkisi göstermediği çeşitli çalışmalar sonucunda saptanmıştır (Oruç, 2011; Glemser vd., 2016). Kim vd. (2019) LED lambalarının avantajlarını, ısıya duyarlı mikroalglerin maksimum büyümesini kolaylaştırmak için yeterli ışık emisyonu ile düşük enerji tüketimi ve düşük ısı üretimi olarak bildirmişlerdir.

Işık kaynağı olarak LED lambaların dalga boyu, bitkilerin klorofil üretmesini karşılayacak düzeyde olduğu Paudel vd. (2008) tarafından bildirilmiştir. Mikroalglerin büyüme pigment içerikleri üzerine ışık kaynaklarının ve ışık şiddetlerinin etkisi üzerine çalışmalar gerçekleştirilmiştir (Cuaresma vd., 2009; Chen vd., 2015; Wu vd., 2016). Yapılan çalışmalarda optimum büyüme ve pigment birikimi için gerekli olan ışık kaynağının ve ışık şiddetinin mikroalg türüne bağlı olarak değiştiği belirlenmiştir (Li vd., 2020; Xi vd., 2020).

D. salina alg β-karoten birikimi üzerine ışık, sıcaklık, tuzluluk ile ortamda bulunan azot ve fosfat konsantrasyonlarına etki ettiği farklı çalışmalarda bildirilmektedir (Wu vd., 2016; Singh vd., 2016; Durmaz ve Pirinç, 2017; Han vd., 2019). Ayrıca, *D. salina* hücre içi osmotik basıncı sağlamak için fotosentez yoluyla gliserol biriktirmektedir (Ben-Amotz vd., 1982). Üretilen gliserol mikroalglerin depo yağı olarak bilinen triaçilgliseridlerin sentezlenmesinde kullanılmaktadır (Sharma vd., 2012). Yüksek miktarda gliserol biriktirme yeteneğine sahip olan *Dunaliella* türleri o nedenle yağ üretimi için de uygun olabileceği çeşitli çalışmalarda bildirilmiştir. Jin vd. (2012) aydınlatıcı olarak farklı veya tek LED ışık kaynağının kullanılmasının yüksek yağ içeriğine sahip *D. salina* biyoması üretmek amacıyla kullanabileceğimizi bildirmiştir.

Dunaliella kültürünün kapalı fotobiyoreaktörlerde fizibilitesini araştırmak için yapılan çeşitli çalışmalarda, fotobiyoreaktörlerin *Dunaliella*'nın büyümesi ve β-karoten birikimi aşaması için karotenoidlerin üretiminde önemli bir rol oynamaya başlayacağını bildirilmektedir (Prieto vd., 2011; Xu ve Harvey 2019). Fotobiyoreaktörlerde, yapay ışığın yoğunluğu ve kalitesi, özellikle mikroalglerin ototrofik büyümesi için tasarımcı tarafından dikkate alınması gereken iki kritik faktördür. Blanken vd. (2013) çeşitli spektral niteliklere sahip floresan lambaların en çok tercih edilen ışık kaynağı olduğunu bildirmesine karşın gelişen teknoloji ile birlikte alg kültürlerinde algin büyümesini destekleyen ve enerji gideri floresan lambalara göre daha az olan ışık kaynakların kullanımına yönelinmiştir. Önemli bir antioksidan kaynağı olan *D. salina*'nın strese girmeden büyüme koşullarının iyileştirilmesi üretim maliyetinin azaltılması açısından önem taşımaktadır. Alg kültürlerinde en önemli maliyet giderlerinden biri besin tuzlarından sonra enerji maliyetidir. Bu maliyeti azaltmak amacıyla, LED teknolojisi alg üretiminde kullanımına yönelik çalışmalar yapılmaktadır (Xi vd., 2020; Öztaşkent ve Ak, 2021). Bu nedenle, günümüzde ışık yayan diyotlar (LED'ler) en önemli ışık kaynaklarından biri haline gelmiştir. Kırmızı, mavi ve beyaz gibi farklı ışık spektrumlarına sahip LED'lerin alg yetiştiriciliğinde kullanılmasına yönelik çalışmaların yapılmasına ihtiyaç duyulmaktadır.

Çalışma kapsamında Ayvalık tuzlasından izole edilen *D. salina*'nın (*Chlorophyceae, Volvocales*) yetiştiriciliğinde farklı renkteki LED lambalar kullanılarak algin büyüme hızı, pigment ve ham yağ içerikleri üzerine olan etkisi araştırılmıştır.

Materyal ve Yöntem

Mikroalg ortamı ve yetiştiriciliği

D. salina algi Ayvalık tuz gölünden izole edilmiştir (Balıkesir, Türkiye). Algin tanımlaması Borowitzka ve Siva (2007)'e göre yapılmıştır.

Deneme kültür koşulları

D. salina'nın büyüme hızı, pigment ve ham yağ içeriklerine LED lambaların etkilerini belirlemek amacıyla; ışık kaynağı olarak kırmızı, mavi, sarı LED lambalar kullanılmıştır. Floresan lambalar ise kontrol grubu olarak tercih edilmiştir. Denemelerde kültür ortamı olarak Değiştirilmiş Johnson (DJ) ortamı kullanılmış ve tuzluluk 2M olacak şekilde ayarlanmıştır. Değiştirilmiş Johnson ortamı (Johnson vd., 1968); ana maddeleri 1,5 g l^{-1} $MgCl_2 \cdot 6H_2O$, 0,035 g l^{-1} K_2HPO_4, 1,5 g l^{-1} $NaNO_3$, 0,2 g l^{-1} $CaCl_2 \cdot 2H_2O$, 0,043 g l^{-1} $NaHCO_3$, 0,2 g KCl ile 10 ml l^{-1} demir solüsyonu (189 mg l^{-1} Na_2EDTA, 244 mg l^{-1} $FeCl_3.6H_2O$) ve 1 ml l^{-1} iz element solüsyonundan (1,215 g l^{-1} $CoCl_2.6H_2O$, 3,426 g l^{-1} H_3BO_3, 0,432 mg l^{-1} $MnCl_2.4H_2O$, 31,19 mg l^{-1} $(NH_4)_6Mo_7O_{24}.4H_2O$), 31,5 mg $ZnSO_4.7H_2O$ oluşmaktadır.

Denemeler steril 1 litrelik cam kaplarda, 3 tekrarlı olarak gerçekleştirilmiştir. Kültürler 24:0 (A/K) saat fotoperiyotta aydınlatılmıştır. Kullanılan tüm ışık kaynakları için ışık şiddeti 100 µmol foton m^{-2} s^{-1} olarak ışık ölçer yardımıyla (LiCor, Li-250) ayarlanmıştır. Denemeler 25,00 ± 1,00 ºC sıcaklığına ayarlanmış kültür dolabı içerisinde gerçekleştirilmiş olup gruplar sürekli hava ile karıştırılmıştır.

Analizler

Yapılan çalışma süresince hücre sayısı, büyüme hızı, klorofil *a* ve β karoten değerleri günlük olarak analiz edilmiştir. Kuru ağırlık değerleri Zhu ve Lee (1997)'ye göre hesaplanmıştır. Hücre sayıları 3 tekrarlı olarak Neubauer sayma lamı ile gerçekleştirilmiştir.

Büyüme hızı, pigment ve yağ içeriklerinin belirlenmesi

Spesifik büyüme hızı (µ) logaritmik büyüme fazında aşağıdaki formüller uygulanarak hesaplanmıştır.

$\mu = \ln X_1 - \ln X_2 / t_1 - t_2$

Formülde X_1 ve X_2, sırasıyla t_1 ve t_2 zamanlarındaki kuru ağırlık değerlerini belirtmektedir.

Pigment ve ham yağ içeriklerinin belirlenmesi

Klorofil *a* içeriği % 90'lık aseton kullanılarak Scor-Unesco (1966) yöntemine göre tespit edilmiştir. β-karoten içeriği ise Ben-Amotz ve Avron (1983)'a göre hesaplanmıştır.

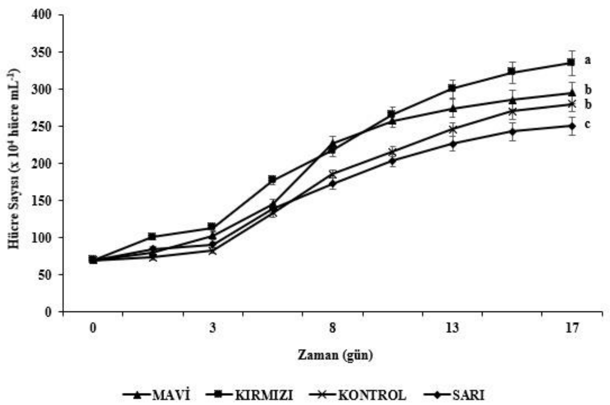
Alglerin toplam yağ içeriği Folch vd. (1957) yöntemi ile belirlenmiştir.

İstatiksel analiz

Elde edilen veriler SPSS paket programı yardımıyla ANOVA kullanılarak değerlendirilmiştir (Özdamar, 1997). Tüm sonuçlar ortalama ± standart sapma şekilde ifade edilmiş olup farklar P≤0,05 olduğunda anlamlı kabul edilmiştir.

Bulgular ve Tartışma

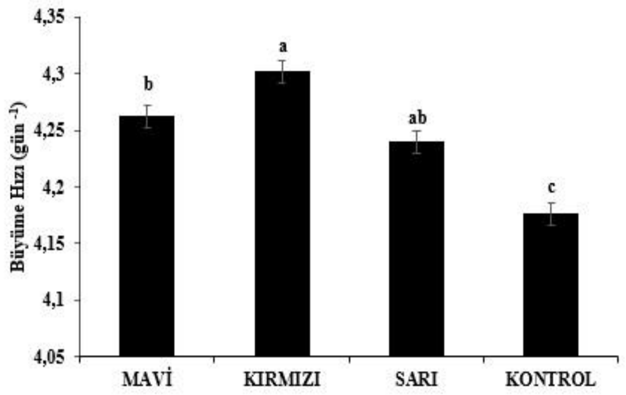
Çalışmalar süresince kültürlerden alınan örneklerin hücre sayıları izlenmiştir (Şekil 1). *D. salina* kültürlerindeki en yüksek hücre sayısı kırmızı LED dalga boyu kullanılan gruplarda 335,3 x 10^4 hc ml^{-1} olarak belirlenmiştir. En düşük hücre sayısı ise sarı LED dalga boyu kullanılan gruplarda 250,7 x 10^4 hc ml^{-1} olarak tespit edilmiştir. Deneme sonunda grupların ulaştığı hücre sayıları arasında istatistiksel farklılıklar belirlenmiştir (P<0,05).



Şekil 1. Farklı LED lambalar kullanılarak yetiştirilen *D. salina* kültürlerinin hücre sayılarında meydana gelen değişimler (Farklı harfler (a-b) istatistiksel yönden farklılığı göstermektedir (P<0,05) (± standart hata) (n=3))

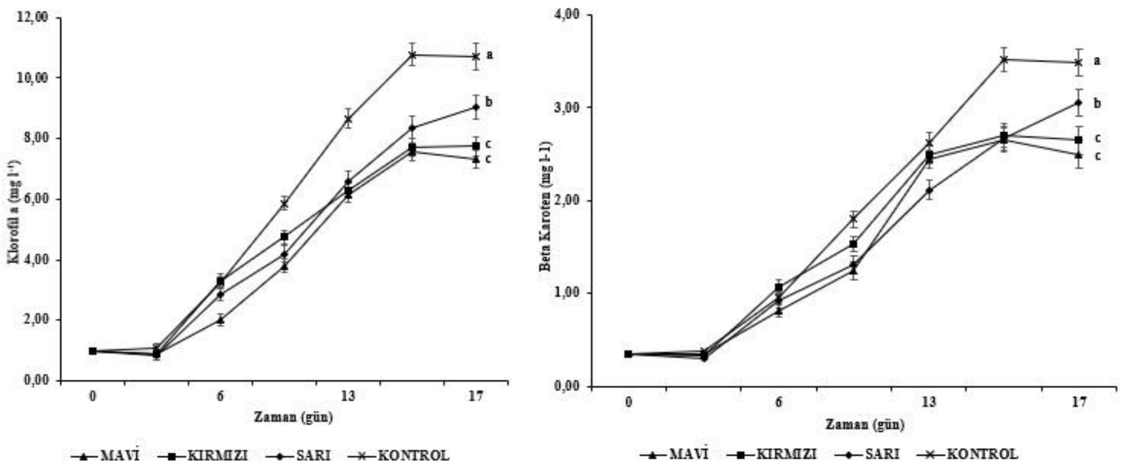
LED lambaların *D. salina* kültürlerinin büyüme hızı, pigment ve yağ içeriklerine etkilerinin araştırıldığı çalışmada en yüksek büyüme hızı kırmızı LED dalga boyuna sahip lambaların kullanıldığı grupta 4,30 $gün^{-1}$ olarak belirlenmiştir (Şekil 2). En düşük büyüme hızı ise floresan lambanın kullanıldığı kontrol grubunda 4,17 $gün^{-1}$ olarak tespit edilmiştir. Çalışma sonucunda, deneme gruplarının büyüme hızları arasında istatistiksel yönden anlamlı farklılıkların olduğu belirlenmiştir (P<0,05).

D. salina'nın biyokimyasal içerikleri ve büyüme hızı tuzluluk, sudaki besin tuzu yoğunluğu ve sıcaklık gibi çevresel faktörlerden etkilenmektedir (Can vd., 2016; Lamers vd., 2012; Singh vd., 2016). Ayrıca, ışığın da alglerin büyüme hızını etkileyen en önemli çevresel faktörlerden biri olduğu bildirilmiştir (Öztaşkent ve Ak, 2021). Yapılan çalışmalarda kültürlerde kullanılan ışığın şiddeti ve cinsinin alglerin büyüme hızını, pigment ve yağ kompozisyonunu değiştirdiği belirlenmiştir (Ben-Amotz ve Shaish, 1992; Ak vd., 2008; Fu vd., 2012). Farklı kültür koşullarında gerçekleştirdikleri denemelerde *D. salina*'nın büyüme hızı değerlerini 0,7-1,0 bölünme $gün^{-1}$ olarak bildirmişlerdir (Ben-Amotz vd., 1982; Ginzburg ve Ginzburg, 1981). Denemelerde elde edilen büyüme hızı sonuçlarının yukarıda belirtilen çalışmalardan daha yüksek olduğu gözlenmiştir. *Dunaliella* türlerinin büyüme özellikleri coğrafik bölgelere, türe ve suşa göre farklılık gösterebileceği Borowitzka ve Borowitzka (1992) tarafından bildirilmiştir. *D. salina* türünün de dahil olduğu yeşil algler sınıfındaki baskın pigmentler klorofil *a* ve klorofil *b*'dir (Han vd., 2019). Chappelle vd. (1992) bu klorofiller, belirli dalga boylarında ana anten pigmentleri olan klorofil-*a* ve klorofil-*b* tarafından absorbe edilmektedir. Han vd. (2019), kırmızı LED lambaların *D. salina*'nın büyümesi için diğer dalga boylarından daha etkili olduğunu bildirmiştir.



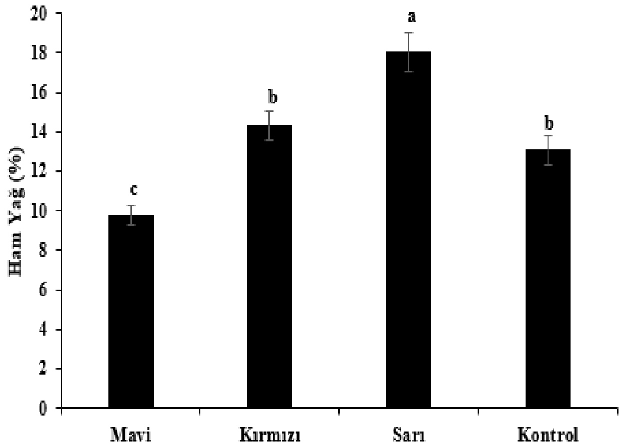
Şekil 2. Farklı LED lambalar kullanılarak yetiştirilen *D. salina* kültürlerinin büyüme hızlarında meydana gelen değişimler (Farklı harfler (a-b) istatistiksel yönden farklılığı göstermektedir (P<0,05) (± standart hata) (n=3))

Denemeler süresince kontrol grubu olarak kullanılan floresan lambaların klorofil *a* ve β karoten içerikleri 10,70 mg l^{-1} ve 3,49 mg l^{-1} olarak tespit edilmiştir. En düşük klorofil *a* ve β karoten içerikleri ise mavi LED dalga boyu kullanılan grupta sırasıyla 7,31 mg l^{-1} ve 2,50 mg l^{-1} olarak belirlenmiştir (P<0,05). Moulton vd. (1987) ve Borowitzka ve Borowitzka (1992) ile benzerlik göstermektedir. Işık şiddeti ile klorofil *a* içerikleri arasında ters bir ilişkinin bulunduğu Falkowski (1983) ve Garcia vd. (2007) tarafından bildirilmiştir. Fu vd. (2013), yüksek yoğunluktaki kırmızı LED (660 nm) ışığın, *D. salina* kloroplastlarına hasar vermesi nedeniyle hücrelerin karotenoid miktarının da buna bağlı olarak yükselmediği düşünülmektedir (Coesel vd., 2008; Lamers vd., 2008; Fu vd., 2013).



Şekil 3. Farklı LED lambalar kullanılarak yetiştirilen deneme gruplarının klorofil *a* ve β-karoten miktarlarında meydana gelen değişimler (Farklı harfler (a-c) istatistiksel yönden farklılığı göstermektedir (P<0,05) (± standart hata) (n=3))

Denemelerde en yüksek yağ içeriği sarı LED lambaların kullanıldığı deneme grubunda %18 olarak tespit edilmiştir. En düşük yağ içeriği ise mavi LED lambaların kullanıldığı grupta %9,8 olarak saptanmıştır. Deneme gruplarının ham yağ içeriklerinin istatistiksel olarak anlamlı farklılıkların olduğu belirlenmiştir (P<0,05). *D. salina* ile ilgili farklı çalışmalarda ham yağ içeriği %15-45 arasında değiştiği, azotun sınırlandığı durumlarda ise algin yağ içeriğinin %55'lere yükseldiği bildirilmektedir (Weldy ve Huesemann, 2007; Chen vd., 2015). Mikroalgin yağ ve β-karoten içerikleri arasında bir ilişki olduğu Ben-Amotz (2004) tarafından bildirilmiştir. Çalışma sonucunda elde ettiğimiz ham yağ değerlerinin Weldy ve Hussemann (2007) bildirdiği %16 ile %44 değerleri içerisinde olduğu saptanmış.



Şekil 4. Deneme gruplarının ham yağ miktarında meydana gelen değişimler (Farklı harfler (a-c) istatistiksel yönden farklılığı göstermektedir (P<0,05) (± standart hata) (n=3))

Sonuç

Bu çalışmada mavi, kırmızı ve sarı LED lambaların *D. salina*'nın büyümesi, pigmenti ve biyokimyasal kompozisyonuna etkileri değerlendirilmiştir. Florasan lamba ve LED ışık kaynakları enerji tüketimine ve maliyetine göre farklılıklar göstermektedir. Ekonomik öneme sahip olan mikroalglerin yetiştiriciliğinde etkili ışık kaynağının kullanımı algin üretimin maliyetini düşürmesi nedeniyle önem taşımaktadır. Düşük kurulum maliyetleri ve uzun ömürlü özellikleri nedeniyle LED ışık kaynakları tercih edilmelidir. Çalışma sonucunda *D. salina* yetiştiriciliğinde kırmızı LED lamba kullanımının algin büyüme hızını sarı LED'lerin ise ham yağ içeriğini arttırdığı, LED lamba kullanılan deneme gruplarının pigment içeriklerinin floresan lamba kullanılan kontrol grubuna göre daha düşük olduğu belirlenmiştir. Çalışma sonucunda *D. salina* üretiminde alg hücrelerinin büyüme hızını arttırmak ve kültür süresini kısaltarak üretim maliyetlerinin azaltılması amacıyla LED lambaların kullanılabileceği saptanmıştır.

Teşekkür

Bu çalışma, ÇOMU BAP tarafından FYL-2014-419 numaralı proje kapsamında desteklenmiştir. Çalışma, İlknur AK'ın danışmanlığında yürütülen ve Koray BENAS tarafından hazırlanan "Farklı LED Işık Kaynaklarının *Dunalıella salina* Teodoresco (*chlorophyceae*) Büyüme ve Pigment İçeriğine Etkisi" başlıklı yüksek lisans tezi kapsamında gerçekleştirilmiştir.

Çıkar Çatışması

Yazarlar çıkar çatışması olmadığını beyan etmektedir.

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Bu çalışma için etik kurul iznine gerek yoktur.

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RESEARCH ARTICLE

Hydrochemical and Bacteriological Status of a High Altitude Karstic Cave Stream (Güvercinkaya Cave: Çanakkale, Türkiye) with Aquatic Macroinvertebrates Findings

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Abstract: Caves are laboratories for many disciplines that work in natural sciences including mineralogy, biology, hydrogeology, and archaeology. In this study, bi-monthly samplings were carried out from three smapling locations within and around the Güvercinkaya Cave, a high-altitude cave located in nortwestern Turkey, to evaluate the hydrochemical and microbiological properties and the aquatic macroinvertebrates of the cave stream. Some parameters of the water including pH, electrical conductivity, temperature, oxidation-reduction potential, dissolved oxygen were measured in-situ, while elemental (70 in total) and ionic composition of water were analyzed in the laboratory. Microbiological analyses of the cave stream were examined through analyses of total bacteria, total coliforms, fecal coliforms, fecal Streptococcus, and Escherichia coli. According to the Piper diagram of hydrochemical data, the cave stream had mainly Ca-Mg-HCO3 character, on the other hand, the Schoeller diagram indicated a common water source in Güvercinkaya cave due to the similar components of the main ionic components of the water. As a result of microbiological analysis, fecal contamination was determined, indicating an active wildlife in the cave. Additionally, several aquatic macroinvertebrates taxa, *Rhynchelmis limosella*, Dugesia sp., *Gammarus uludagi* which have non-troglobiont character were found in the cave stream. *Rhynchelmis limosella* detected in this study is the first record for the Turkish fauna.

Anahtar kelimeler:

Karstik Mağara
Yeraltı Suyu
Hidrokimya
Bakteriyel Bulaşma
Sucul Makroomurgasızlar

Yüksek Rakımlı Karstik Bir Mağara Deresinin (Güvercinkaya Mağarası: Çanakkale, Türkiye) Hidrokimyasal ve Bakteriyolojik Durumu ile Sucul Makroomurgasız Bulguları

Öz: Mağaralar maden bilimi, biyoloji, hidrojeoloji ve arkeoloji dahil olmak üzere doğa bilimlerinin pek çok disiplini için bir laboratuvar niteliğindedir. Bu çalışmada, Türkiye'nin kuzeybatısında yer alan yüksek rakımlı bir mağara olan Güvercinkaya Mağarası'nın seçilen bölümlerinden, hidrokimyasal ve mikrobiyolojik özellikleri ile sucul makroomurgasızlarının değerlendirilmesi için iki aylık periyotlarda bir yıl örneklemeler yapılmıştır. Suyun pH, elektriksel iletkenlik, sıcaklık, oksidasyon-redüksiyon potansiyeli, çözünmüş oksijen gibi bazı parametreleri yerinde ölçülürken, elementler (toplam 70 adet) ve suyun bazı iyonları laboratuvarda analiz edilmiştir. Mikrobiyolojik analizlerde toplam bakteri, toplam koliform, fekal koliform, fekal Streptococcus ve *Escherichia coli* analizleri yapılmıştır. Hidrokimyasal verilerin Piper diyagramı değerlendirildiğinde, mağara deresinin esas olarak Ca-Mg-HCO3 karakterine sahip olduğunu, Schoeller diyagramının ise ana iyonik bileşenlerin, aynı modeki takip etmesinden dolayı ortak bir su kaynağını işaret ettiği görülmüştür. Mikrobiyolojik analizler sonucunda, mağarada aktif bir yaban hayatı olduğunu gösteren dışkı kaynaklı bir kontaminasyon belirlenmiştir. Ayrıca mağara deresinde, troglobiont olmayan sucul omurgasızlardan *Rhynchelmis limosella*, Dugesia sp. ve *Gammarus uludagi* tespit edilmiştir. Bu çalışmada tespit edilen *Rhynchelmis limosella* Türkiye faunası için ilk kayıttır.

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Introduction

Caves are common geological formations of karst regions, and is commonly assocated with limestone which is found in one-fourth of the world (LaMoreaux et al., 1997). They play an important role in human life since the earliest times in history. Today, caves could be accepted as laboratories for scientists working in the fields of natural and life sciences such as mineralogy, biology, hydrogeology and archaeology. Regarding their natural characteristics, the principal difference of the cave ecosystems from the surface ecosystems is the lacking of light (Simon, 2019) which drives autochthonous food webs through primary producers (Azad and Borchardt, 1969; Biswas, 2010). Thus, cave-dwelling organisms mostly rely upon allochthonous and detrital energy sources making them susceptible to changes in environmental parameters when compared to surface fauna (Mammola et al., 2019).

Karst aquifers (like springs and caves streams) are of importance as a groundwater source for drinking and irrigation especially in Mediteraanean countries (Ford and Williams, 2007; Bakalowicz, 2015). Since majority of basins are located in unpolluted, low-populated areas, they can provide large amounts of high quality water for human consumption (D’Angeli et al., 2017). Therefore, research efforts have mostly focused on hydrochemistry (Stevanović, 2015; Mukherjee and Singh 2020) and microbiology of karst aquifers (Savio et al., 2019; Hershey et al., 2019). On the other hand, assessment of karst regions in terms of biological aspects has been one of the most studied topics including troglobiont or stygofauna which often exhibit specialized physiological adaptations, behavioral adjustments, and morphological changes (Barr, 1968; Biswas, 1992; Sket, 2008; Brancelj et al., 2020; Boyd et al., 2020).

Biospeleological researches dated back to early XIX. century (1830) in Europe, mainly Slovenia, followed by other countries onwards (Sket, 2008). In Turkey, studies on cave ecosystems started with Dr. Abdullah Bey in Yarımburgaz Cave in İstanbul in 1865 (Kunt et al., 2010). These studies focused on areas such as geology (Alagöz, 1944; Aygen, 1959; İzbırak, 1979; Şengör, 1986; Nazik, 1989) and biology (Balık et al., 2002; Taşdemir and Ustaoğlu, 2005; Özkan, 2009; Danyer et al., 2013; Erkakan and Özdemir, 2014). However, data on karst aquifers, caves and groundwaters in Turkey are still limited.

In the last two decades, efforts on cave research has increased significantly in Turkey (Kunt et al., 2010). Turkey is characterized by a very complex geology, whose main features are still poorly understood despite an increasing amount of geological data (Okay, 2008). Due to its geological evolution, Turkey has a variety of cave types including sea caves and caves of soluble rock. The latter is the most common type that generally forms within the limestone, in other words, carbonate rocks. Carbonate and sulfate rocks that are prone to dissolution are made up of 40% of Turkish territory (Nazik et al., 2003).

Güvercinkaya Cave (GC) is located near the Kazdağı National Park, in the northwest of Turkey in Çanakkale, (Figure 1). The cave has a year-round hydrologic regime considered as a cave stream opening with a waterfall to the surface (Figure 2). The major sources of water are groundwater vents, meltwater and seasonal precipitation that reaches the cave through cracks; therefore it has a very variable flowing regime according to the seasons. The only study about the cave was conducted by a group of French speleologists in 2001, however, the cave has frequently been visited by many European explorers since 1809 (Wolozan, 2003).

In this study, we aimed to asses the hydrochemical and bacterial structure, and macroinvertebrate fauna of the GC karstic stream. This study is also the first interdisciplinary study in Turkey's high altitude water cave ecosystem, which can fill a knowledge gap.

Material and Methods

Study area

Kazdağı Mountain range with its highest peak of 1770 m is located in the Biga Peninsula and separates the Aegean and Marmara regions of Turkey. Part of Kazdağı Mountain has been declared a national park due to its rich diversity of flora and fauna in 1994 (Odabaşı and Georgiev, 2014). The study area, GC, is located at Kazdağı Mountain within the city borders of Çanakkale, northwest of Turkey. The cave is located on the north-facing slope of Kazdağı Mountain range at an altitude of 938 m above sea level. The nearest settlement to the cave is the Evciler village, which is located at a lower altitude 12 km further. Access to the region is very difficult as it is surrounded by high hills (Figure 1). The coordinates of the sampling sites were given in Table 1.

Sampling

In this study, a bi-monthly (6 times in total) sampling was carried out to obtain the chemical and microbiological water quality parameters between November 2015 and October 2016. Benthos sampling was carried out twice, during the lower flow rate periods in November 2015 and October 2016. For field studies, three sampling sites were chosen within and around the cave. The first sampling site (GC1) was located under the the natural entrance of the cave that was receiving very limited sunlight indirectly. The second sampling site (GC2) was located at the siphon, mouth of the main water source of the cave stream, approximately 60 meters away from the cave entrance. The depth of GC2 was 8 m and thus, samples were collected by diving. The third sampling site (GC3) was a pool formed by cascading water located at the outlet of the cave (Figure 2). Benthic macroinvertebrate samples were taken using a standardized multi-habitat sampling procedure (Hering et al., 2004) from available habitats by D-frame hand-net only if suitable environmental conditions were provided. A cave diving was performed during the benthos sampling in the second sampling site (CG2).

Figure 1. Study area on the map

Table 1. Coordinates (UTM ED50) and altitudes (above sea level) of the sampling sites

Coordinates (Decimal degree - WGS84)		Altitude (m)	Water Type	Name of the Location	Code of the Location
39.718182 N	26.806879 E	911	Groundwater	Entrance of the cave	GC1
39.718114 N	26.805171 E	948	Groundwater	Sump of the cave	GC2
39.718353 N	26.806494 E	906	Surface water	The waterfall (outlet)	GC3

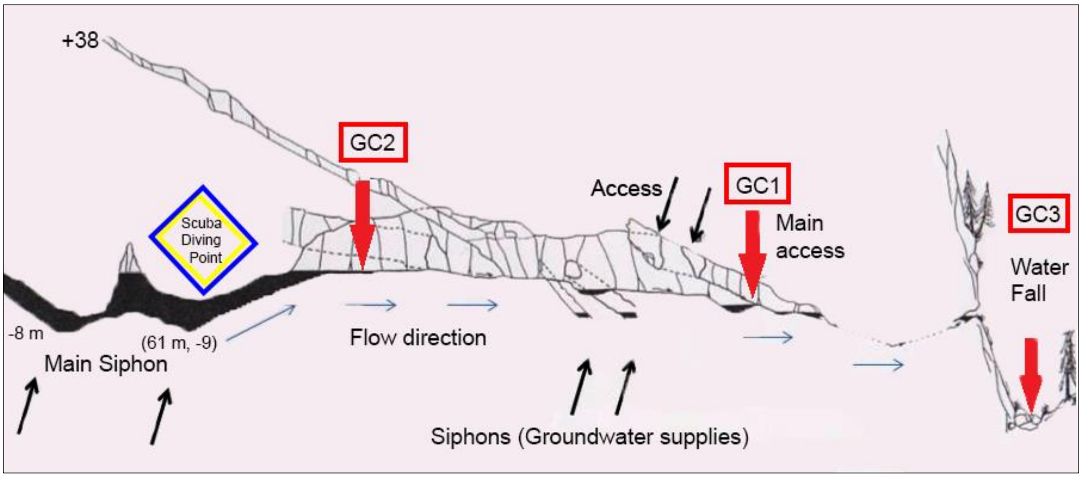

Figure 2. Location of sampling sites in the Güvercinkaya Cave (Modified from Wolozan, 2003)

Hydrochemical analysis

Bi-monthly samplings were carried out to obtain data about hydrochemical conditions of the study site. Some of the parameters such as temperature, pH, electrical conductivity (EC), and dissolved oxygen (DO) were measured in-*situ* using portable multi-parameter equipment (Hach-Lange 40d). The water samples were filtered using a manual vacuum pump with a filter paper (0.42μm) and transferred from the field to the laboratory within insulated coolers for analysis of sulfate (SO_4), bicarbonate (HCO_3), and carbonate (CO_3) following the standart methods of APHA (1999) (Table 2). Aliquots were acidified to pH<2 and placed into 50 mL polypropylene centrifuge tubes to analyze 70 elements comprising; Ag, Al, As, Au, B, Ba, Be, Bi, Br, Ca, Cd, Ce, Cl, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Ge, Hf, Hg, Ho, Ln, K, La, Li, Lu, Mg, Mn, Mo, Na, Nb, Nd, Ni, P, Pb, Pd, Pr, Pt, Rb, Re, Rh, Ru, S, Sb, Sc, Se, Si, Sm, Sn, Sr, Ta, Tb, Te, Th, Ti, Tl, Tm, U, V, W, Y, Yb, Zn, and Zr.

Table 2. Summary of analytical methods used for water analysis and benthos sampling in this study

Sampling/Analysis	Abbreviation	Unit	Method	Analytical Method	Device	Reference
Benthos sampling	-	m^2	BS EN 16150:2012	-	D-Frame Handnet	AQEM Consortium, 2002
Bicarbonate	HCO_3^-	mg L^{-1}	APHA 2320 B.	Titration Method		APHA, 1999
Carbonate	CO_3^{2-}	mg L^{-1}	APHA 2320 B.	Titration Method		APHA, 1999
Ammonium Nitrogen	NH_4^+	mg L^{-1}	APHA 4500-NH_3 F.	Spectrophotometric	Spectrophotometer	APHA, 1999
Nitrate Nitrogen	NO_3^-	mg L^{-1}	APHA 4500-NO_3 E.	Cadmium reduction method	Spectrophotometer	APHA, 1999
Nitrite Nitrogen	NO_2^-	mg L^{-1}	APHA 4500-NO_2^- B.	Colorimetric method	Spectrophotometer	APHA, 1999
Sulphide	S^{2-}	mg L^{-1}	APHA 4500-S_2^- A.	Turbidimetric Method	Spectrophotometer	APHA, 1999
Sulphate	SO_4^{2-}	mg L^{-1}	APHA 4500-$SO4^{2-}$E.	Turbidimetric Method	Spectrophotometer	APHA, 1999
Elements	See the text	μg L^{-1}		Spectrometry	ICP-MS	APHA, 1999
Total Bacteria (37°C)	TB	cfu/mL	APHA 9215C	Spread Plate Method	Incubator	APHA, 1999
Fecal *Streptococcus*	FS	cfu/mL	APHA 9230	Spread Plate Method	Incubator	APHA, 1999
Total Coliforms	TC	mpn/100 mL	APHA 9221	Most Probable Number	Incubator	APHA, 1999
Fecal Coliforms	FC	mpn/100 mL	APHA 9221	Most Probable Number	Incubator	APHA, 1999
Escherichia coli	*E. coli*	mpn/100 mL	APHA 9221	Most Probable Number	Incubator	APHA, 1999

Bacterial analysis

Several bacteriological analyses including Total Bacteria (TB), Total Coliforms (TC), Fecal Coliforms (FC), Fecal *Streptococcus* (FS), and *Escherichia coli* were performed following the standart methods on the water samples from the sampling sites (Table 2). For TB, the standard "spread-plate" method was employed on plate count agar with an incubation temperature of 37 °C for 24-48 hours in aerobic conditions. The Most-Probable-Number technique was used with a single bottle containing a 100-mL sample portion for the determination of coliforms (TC and FC). Enriched LST broth and confirmation test was carried out in BGLB broth for TC (37 °C for 24-48 h) and in EC broth for FC (44 °C for 24-48 h). Indol production was tested for *E. coli*. Results were expressed as Colony Forming Unit (cfu/mL) and Most Probable Number (mpn/100 mL).

Statistical analysis

Some parameters of hydrochemical data including HCO_3, CO_3, SO_4^{2-}, Ca, Mg, Na, Cl, and K were subjected to AquaChem software (Waterloo Hydrogeologic, version 2014.2) that yielded the Piper plot, a Trilinear Diagram, to visualize the ions in the water based on their abundances. The Shoeller diagram was drawn to show the hydrochemical differences of water from different sources (sites) using AquaChem software. The in-*situ* measured parameters and some chemical values of water in the sampling sites were presented in the tables (3-5) with descriptive statistics e.g. mean, standart deviation (STD), minimum (Min.), and maximum (Max.). Parameters that appear to be clearly different from each other were subjected to the Student-t test using Microsoft Excel 97-2003.

Results and Discussion

Hydrochemical parameters

The hydrochemical data along with some of the descriptive statistics i.e. mean, standart deviation (STD), minimum (Min), and maximum values (max) are presented in Table 3, 4, and 5. Among all data, only temperature showed seasonal fluctuations between 8.1 and 10.8 °C. The water temperature was between 8.1 and 8.7 °C in GC1 and GC2 inside the cave, whereas 8.4 and 10.8 °C were recorded from in GC3, located just outside the cave. The difference in temperature values between GC1 and GC3 was significant ($p<0.05$) (Table 6). The pH values of the water samples ranged from 7.42 to 8.64 indicating alkaline conditions. The pH values of the samples from all the sampling sites are in the permissible limits according to the Turkish Water Pollution Control Regulation (TWPCR, 2004). The results indicated that bicarbonate ($HCO3^-$) was the dominant parameter over the ionic parameters ($HCO_3^- > SO_4^{2-} > NO_3^- > CO_3^{2-}$). The EC values varied between 223 and 498 μS/cm, however, the mean EC value was below 300 μS/cm. According to the EPA of United States, the conductivity of freshwater outside the ranges of 150 – 500 μmhos/cm (=μS/cm) may not support suitable conditions for certain species of aquatic organisms (https://archive. epa.gov/water/archive/web/html/vms59.html). The EC values of the present study indicated that the cave stream showed a lower level of ionic activity. The mean EC value in the present studywas lower when compared to those in other karst water studies of Wang et al., (2019) and Vardanjani et al., (2018), who found EC values in higher ranges (340 to 757 μS/cm).

The equilibrium states of ions in the water can be understood from Eh and pH measurements that give an idea about the processes controlling the formation and movement of many minor and trace elements in groundwater quality investigations (Freeze and Cherry, 1979). Eh values in our data (except for July 2016), showed that oxidation (cations predominate) conditions are dominant in the water.

The dissolved oxygen values were varied between 1.09 and 9.93 mg/L in the sampling sites of GC. Since surface waters are in contact with the atmosphere, DO balance can be maintained. However, in groundwater, DO might be consumed by the oxidation of rocks and biological activities (Mazor, 2004). In the present study, we determined that the DO content varies depending on the flow rate in the cave system. The highest DO level in the sampling sites was obtained during higher flow rate periods (from February to May), while the lowest DO levels coincided with lower flow rate periods (from July to November) (Table 3 and 4). Similar results regarding the dissolved oxygen level of groundwater were also reported from the study of Stroj et al., (2020).

The presence of ammonium nitrogen (NH_4^+), which indicates wastewater contamination, poses a risk for aquatic organisms. In the study area, NH_4^+ values were lower than 0.015 mg/L in February, March, July, and October 2016, while higher values (0.031 and 0.061 mg/L, respectively) were measured in November 2015 and May 2016 Caves are typically used by bats as permanent shelters (Zukal et al., 2017). According to Berková and Zukal (2006) and Zukal et al., (2017), bats in temperate regions tend to hibernate in November and departure period (flight activity) is between April and June. In this study, during November 2015 and May 2016 higher NH_4^+ levels were detected due possibly to lower flow rates in the cave stream. However, it was determined that NO_2^- and NO_3^- values were below the measurement limits (NO_2^- <0.005 mg/L and NO_3^-<0.23 mg/L) in the gauging sites throughout the course of the study. Ammonium nitrogen in groundwater is converted to nitrate under aerobic conditions (Chen and Liu, 2003) and low NO_3^- and NO_2^- levels may be due to the running water in the cave stream.Sulfate (SO_4^{2-}), bicarbonate (HCO_3^-), and carbonate (CO_3^{2-}) were very low in the study area, while sulfide (S^{2-}) was not detected (Table 3, 4, 5).

According to the *Piper Diagram* (Figure 3) produced by AquaChem (Calmbach, 1997), the water of the sampling area is rich in Ca- HCO_3^- or Ca-Mg- HCO_3^-. Considering the element analysis data (Appendix 1), all the parameters included in TWPCR (2004) and Turkish standards (TS 266, 2005) are between acceptable levels for surface waters.

The Schoeller Diagram (Schoeller, 1962) is used to determine the source of groundwater by evaluating the composition of the water in terms of milliequivalent (mEq) liter. Due to several water sources in the cave, water samples from different sampling sites were subjected to Schoeller analysis (Figure 4). The parallel lines of the sampling sites in the Schoeller Diagram indicate that the groundwater sources entering the cave come from the same aquifer.

Table 3. Hydrochemical parameters of sampling site 1 (GC1)

	Nov.15	Feb.16	Mar.16	May.16	Jul.16	Oct.16	Mean	STD	Min.	Max.
pH	7.42	7.94	8.06	7.46	7.81	7.83	7.75	0.26	7.42	8.06
EC (µS/cm)	284.00	223.00	249.00	249.00	265.00	261.00	255.17	20.36	223.00	284.00
T (°C)	8.20	8.20	8.30	8.71	8.10	8.10	8.27	0.23	8.10	8.71
Eh (mV)	258.00	6.20	122.00	266.00	-144.00	-10.00	83.03	162.30	-144.00	266.00
DO (mg/L)	-	-	-	6.28	4.27	1.12	3.89	2.60	1.12	6.28
SO_4 (mg/L)	5.00	4.00	2.00	5.00	8.00	5.00	4.83	1.94	2.00	8.00
HCO_3 (mg/L)	110.00	159.00	170.00	170.00	171.00	167.00	157.83	23.84	110.00	171.00
CO_3 (mg/L)	0	0	0	0	0	0	0	0	0	0
NH_4-N (mg/L)	0.031	<0.015	<0.015	0.056	<0.015	<0.015	0.0435	0.0177	0.031	0.056
NO_3)mg/L)	0	<0.23	<0.23	<0.23	<0.23	<0.23	0			
NO_2 (mg/L)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005				
S_2 (mg/L)	0	0	0	0	0	0	0	0	0	0
Flow (m^3/s)	0.25	3.50	3.50	2.50	0.70	0.70	1.86	1.49	0.25	3.50

Table 4. Hydrochemical parameters of sampling site 2 (GC2)

	Nov.15	Feb.16	Mar.16	May.16	Jul.16	Oct.16	Mean	STD	Min.	Max.
pH	7.94	-	8.07	7.57	7.73	8.07	7.88	0.20	7.57	8.07
EC (µS/cm)	282.00	-	251.00	251.00	265.00	273.00	264.40	12.19	251.00	282.00
T (°C)	8.10	-	8.10	8.10	8.20	8.40	8.18	0.12	8.10	8.40
Eh (mV)	220.00	-	121.00	290.00	-128.30	156.00	131.74	142.24	-128.30	290.00
DO (mg/L)	-	-	-	4.25	2.73	1.09	2.69	1.29	1.09	4.25
SO_4 (mg/L)	4.00	-	1.00	3.00	6.00	6.00	4.00	1.90	1.00	6.00
HCO_3 (mg/L)	210.00	-	168.00	178.00	176.00	192.00	184.80	14.78	168.00	210.00
CO_3 (mg/L)	0	-	0	0	0	0	0	0	0	0.00
NH_4-N (mg/L)	0.04	-	<0.015	0.06	<0.015	<0.015	0.05	0.01	0.04	0.06
NO_3)mg/L)	<0.23	-	<0.23	<0.23	<0.23	<0.23				
NO_2 (mg/L)		-	<0.005	<0.005	<0.005	<0.005				
S_2 (mg/L)	0	-	0	0	0	0	0	0	0	0.00
Flow (m^3/s)	0.50	-	2.50	2.50	0.70	0.60	1.36	0.93	0.50	2.50

Table 5. Hydrochemical parameters of sampling site 3 (GC3)

	Nov.15	Feb.16	Mar.16	May.16	Jul.16	Oct.16	Mean	STD	Min.	Max.
pH	8.04	7.86	8.10	8.07	8.64	8.23	8.16	0.27	7.86	8.64
EC (µS/cm)	281.00	230.00	248.00	498.00	241.00	246.00	290.67	103.00	230.00	498.00
T (°C)	8.40	8.40	8.50	9.20	10.80	8.60	8.98	0.94	8.40	10.80
Eh (mV)	230.00	6.30	122.00	196.00	-61.00	44.00	89.55	112.94	-61.00	230.00
DO (mg/L)	-	-	-	9.93	2.72	1.11	4.59	4.70	1.11	9.93
SO_4 (mg/L)	4.00	4.00	3.00	5.00	7.00	6.00	4.83	1.47	3.00	7.00
HCO_3 (mg/L)	177.00	159.00	168.00	168.00	160.00	162.00	165.67	6.77	159.00	177.00
CO_3 (mg/L)	0	0	0	0	8.00	6.00	2.33	3.67	0	8.00
NH_4-N (mg/L)	0.04	<0.015	<0.015	0.06	<0.015	<0.015	0.05	0.02	0.04	0.06
NO_3)mg/L)	<0.23	<0.23	<0.23	<0.23	<0.23	<0.23				
NO_2 (mg/L)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005				
S_2 (mg/L)	0	0	0	0	0	0	0	0	0	0.00
Flow (m^3/s)	0.30	3.50	3.50	2.50	0.70	0.60	1.85	1.49	0.30	3.50

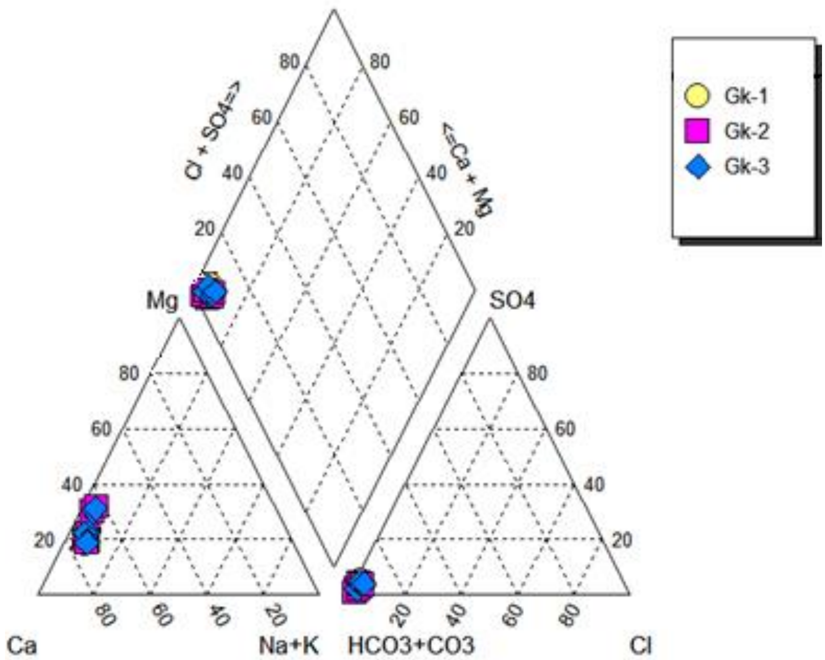

Figure 3. Piper Diagram of water samples from the study area

The histogram plot showing the course of major ions pointed out that the main ions remained homogeneous throughout the study (Figure 5). This is because the study area is a groundwater-fed waterbody to a large extent.

Table 6. Comparison the mean values of hydrochemical data between sampling sites by Student-t-Test

Groups compared	pH	EC (µS/cm)	T (°C)	DO (mg/L)	SO_4 (mg/L)	HCO_3 (mg/L)	Flow (m^3/s)
	p-value	p-value	p-value	p-value	p-value	p-value	p-value
GC1 vs GC2	0.201	0.542	0.311	0.184	0.142	0.220	0.474
GC1 vs GC3	0.039*	0.135	0.446	0.696	1.000	0.541	0.695
GC2 vs GC3	0.107	0.110	0.504	0.422	0.089	0.045	0.495

*Significantly different due to the p-value<0.05.

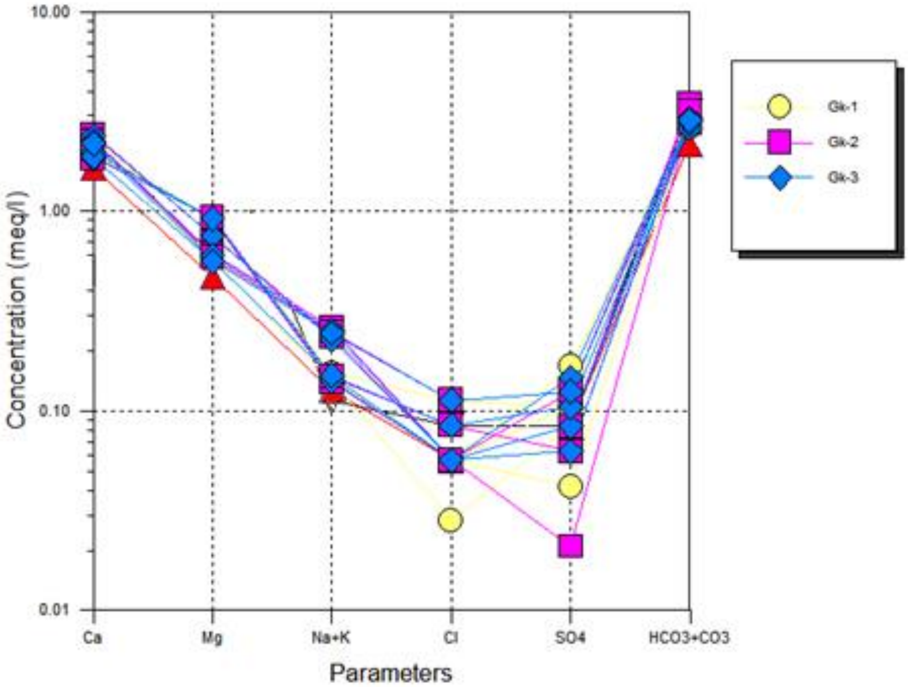

Figure 4. Schoeller Diagram of water samples from the study area

Bacteriological conditions of water

Until recently, many people thought that the environments below the surface were perfectly sterile. However, caves have been contaminated by surface-dwelling microorganisms, many of which reach the environment through surface runoff, air currents, animals, and humans. For this reason, it is difficult to know whether the microorganisms belong to the subsurface environments (Gounot, 1994). In the present study, microbiological parameters of water including total bacteria in (TB), total coliform (TC), fecal coliform (FC), *Escherichia coli* (*E. coli*), fecal streptococci (FS) varied at different sampling periods and sampling points (Table 7). According to the data, the FC and *E. coli* were not found in the sampling sites. Besides, the highest values of the remaining parameters were measured in November 2015 (Nov.15), February 2016 (Feb.16), and October 2016 (Oct.16) during lowest flow period. The fecal streptococci belong to the genera *Enterococcus* and *Streptococcus* are gram-positive bacteria that are predominately found in animals (Houssain, 2014), while *E. coli* is usually found in human and animal feces and could reach water sources (Bennett et al., 2018). Since the study site is in a remote area and *E. coli* could not be detected, this contamination could be of animal origin. Coca Moreno et al., (1996) and Cabral and Marques (2006) found positive correlations between NH_4-N and several microbiological indicators such as total and fecal coliforms, fecal streptococci, and enterococci. Besides, Ponnimbaduge-Perera et al., (2019) demonstrated that bat droppings caused major changes in chemical and microbiological water quality parameters. In the present study, we found parallelism correlation between ammonia and fecal streptococci, as in previous studies (Tables 3-5 and 7). Our results indicated that since GC is used as hibernacula by the local bat population, the water quality was affected. According to TWPCR (2004), TC and FC values of the sampling sites were classified as high quality (I), but not drinkable for the criteria both of WHO (2004) and TS 266 (2005).

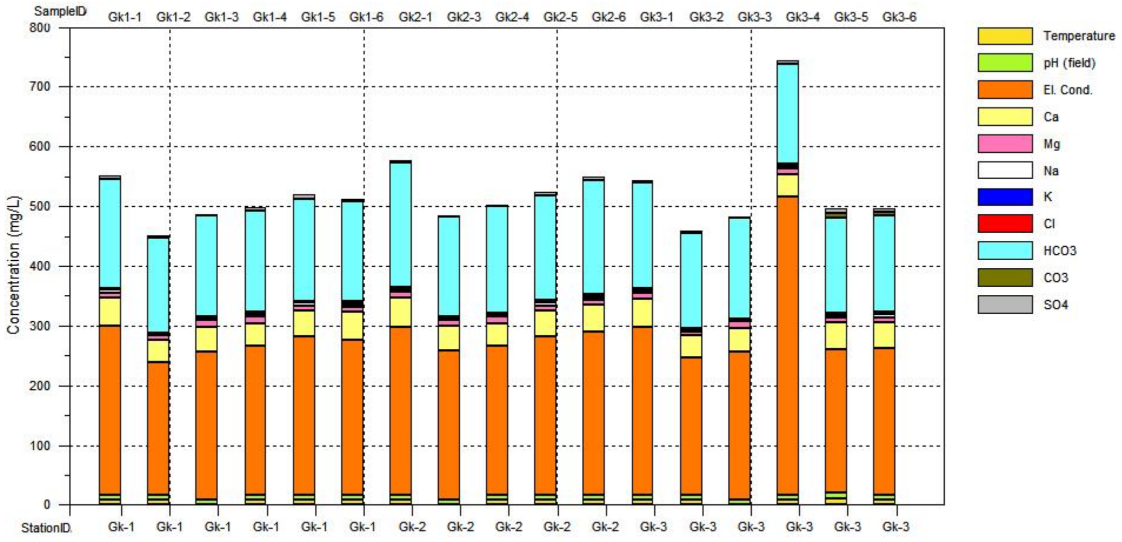

Figure 5. Comparison of major ions and some parameters of water by sampling sites

Table 7. Microbiological parameters of water from the sampling sites

	Parameters/Date	Nov.15	Feb.16	Mar.16	May.16	Jul.16	Oct.16
	TB (cfu/mL)	1110	50	10	50	60	6
	TC (mpn/100mL)	43	7	7	15	15	43
GC1	FC (mpn/100mL)	0	0	0	0	0	0
	E. coli (mpn/100mL)	0	0	0	0	0	0
	FS (cfu/mL)	50	0	0	0	0	0
	TB (cfu/mL)	2480	n.m.	n.m.	50	50	850
	TC (mpn/100mL)	1100	n.m.	n.m.	15	4	75
GC2	FC (mpn/100mL)	0	n.m.	n.m.	0	0	0
	E. coli (mpn/100mL)	0	n.m.	n.m.	0	0	0
	FS (cfu/mL)	50	n.m.	n.m.	0	10	35
	TB (cfu/mL)	2920	550	100	150	160	250
	TC (mpn/100mL)	460	43	43	15	75	15
GC3	FC (mpn/100mL)	0	0	0	0	0	0
	E. coli (mpn/100mL)	0	0	0	0	0	0
	FS (cfu/mL)	70	0	0	0	10	270

***n.m**: Not measured.

Aquatic macroinvertebrates

In total, four benthic macroinvertebrate taxa were found in the sampling sites (Table 8) including *Rhynchelmis limosella* Hoffmeister, 1843 (GC2) and an unidentified enchytraeid (GC1), *Dugesia* sp. (GC1), and *Gammarus uludagi* Karaman, 1975 (GC1 and GC3). Macroinvertebrates were obtained in the first period of sampling (November-2015) during the low flow period.

Table 8. Aquatic macroinvertebrates of the Güvercinkaya Cave

Taxa	Sampling Site	Individual Num.
Rhynchelmis limosella	GC2	1
Enchytraeid*	GC1	1
Dugesia sp.	GC1-GC3	8
Gammarus uludagi	GC1-GC3	16

*Deformated individual

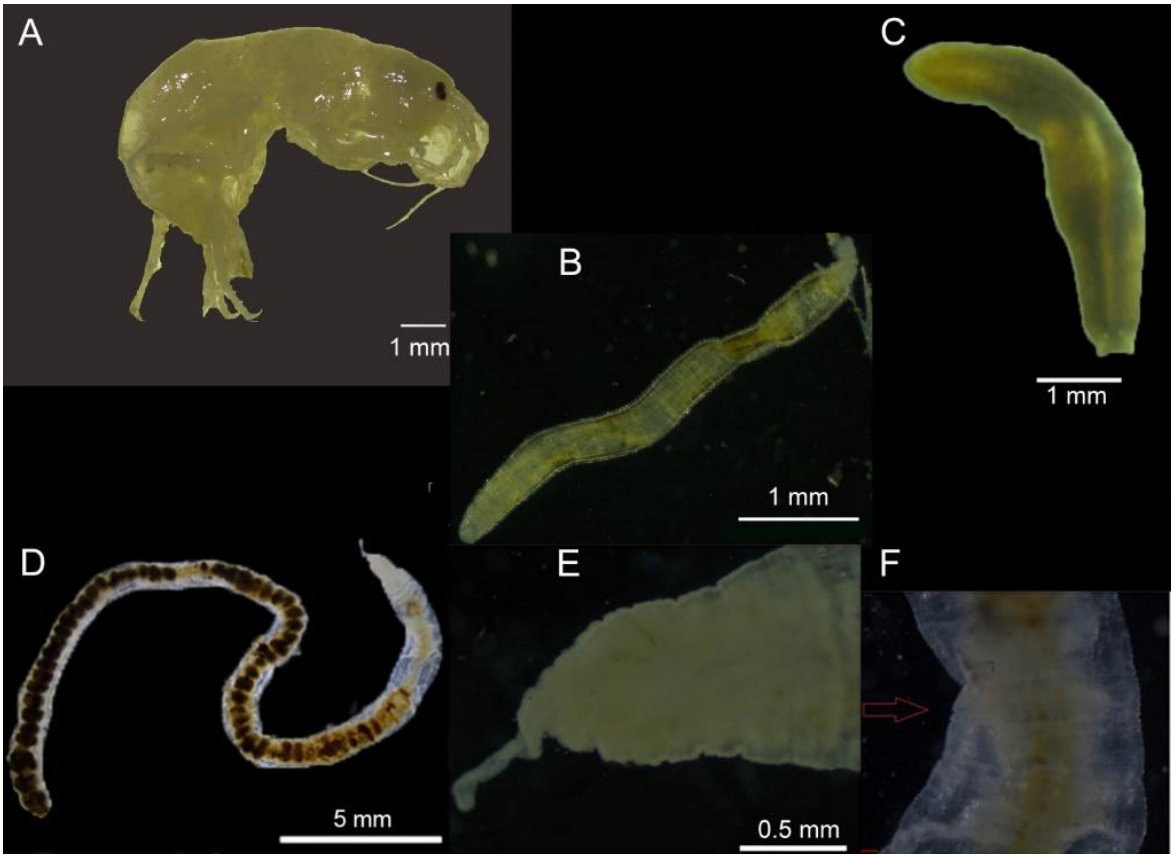

Figure 6. Aquatic macroinvertebrates of the Güvercinkaya Cave: A. *Gammarus uludagi*, B. Enchytraeid, C. *Dugesia* sp., D. *Rhynchelmis limosella*, E. *R. limosella* proboscis, F. *R. limosella* genital opening

Cave-dwelling organisms usually possess specialized physiological and morphological adaptations due to darkness, stable physical and chemical factors and limited energy sources (Barr, 1968; Biswas; 1992; Biswas 2010). A wide variety of adaptations can be seen in cave species. Some organisms are obligate to the cave environment and unable to live in other ecosystems (=troglobiont), while some organisms temporarily use the cave environment (troglophile or trogloxene) (Sket, 2008). In this study, the macroinvertebrate taxa are mainly recorded from surface environments e.g. lakes, streams, springs. For instance, *Rhynchelmis limosella* is a common European species recorded from the Danube River (Mauch, 1989), and *Dugesia* sp. is a widespread genus in the surface waters of the Mediterranean region (de Vries 1985). *Gammarus uludagi* was described from Uludağ (Bursa, Turkey) by Karaman and Pinkster (1977) and then sampled from streams Kazdağı (Çanakkale, Turkey) by Özbek et al., (2017). Since the identified taxa in the present study were sampled from surface waters in previous studies, they can not be considered troglobiont or stygobite. Similarly, no troglobiont fauna were found in the karstic caves of Dupnisa and Yelköprü located in western Turkey (Balık et al., 2002; Özkan, 2009). On the other hand aquatic troglobiont taxa in caves with permanent hydrological regime were reported from Turkey and fromother regions of the world, (Karaman and Ruffo, 1994; Georgiev et al., 2017; Georgiev, 2012; Özbek et al., 2013; Andersen et al., 2016; Sidorov and Samokhin, 2016; and Culver and Hobbs, 2017.

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Conflict of Interest

The authors declare that there is no conflict of interest.

Author Contributions

D. A. Odabaşı and S. Odabaşı were designed of study. The data collection and interpretation were made by D. A. Odabaşı, S. Odabaşı, O. Deniz, F. Çakır, B. Elipek, N. Arslan, O. Özbek. H. B. Özalp was planned the diving and underwater sampling. The manuscript was written by D. A. Odabaşı, S. Odabaşı, F. Çakır,and O. Deniz. Language correction made by O. Özbek.

Ethics Approval

The material used in this article is invertebrate species therefore ethics committee approval is not required for this study

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RESEARCH ARTICLE

Growth, Mortality and Exploitation Rate of Round Sardinella (*Sardinella aurita*, Valenciennes, 1847) in the New Calabar River, Niger Delta, Nigeria

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Abstract: This study assessed the growth, mortality and exploitation rate of *Sardinella aurita* in the New Calabar River. A total of 513 specimens of *S. aurita* were collected from artisanal fishers and assessed between March 2020 and February 2021.For statistical analysis, FiSAT II software was used. At asymptotic length (L_∞) = 21.73 cm, growth rate (K) = 0.95 yr^{-1}, longevity (*T*max) = 2.68 yrs., theoretical age at birth (t_0) = -0.48 yrs., and growth performance index (Φ′) = 2.65. Length at first capture (Lc_{50} = 15.06 cm) was lower than length at first maturity (Lm_{50} = 21.12 cm). Mortality parameters revealed a total mortality rate (Z) = 3.03 yr^{-1}, a natural mortality rate (M) = 1.42 yr^{-1}, and a fishing mortality rate (F) = 1.61 yr^{-1}. This indicates that *S. aurita* in the study area has a fast growth rate, small attained size, delayed sexual maturation, and high natural mortality. The exploitation rate (E) was 0.53. *S. aurita* was found to be experiencing optimum exploitation. Therefore, to prevent overfishing, sustainable fisheries measures should be adopted, and these include monitoring of fishing efforts and implementation and enforcement of increased mesh size to sustain the fishery of *S. aurita* in the New Calabar river.

Anahtar kelimeler:

Büyüme
Mortalite
Clupeidae
Afrika

New Calabar Nehri’nde (Nijer Deltası, Nijerya) Yuvarlak Sardalyanın (*Sardinella aurita*, Valenciennes, 1847) Büyüme, Ölüm Oranı ve Sömürülme Oranı

Öz: Bu çalışma, New Calabar Nehri'ndeki *Sardinella aurita* türünün büyüme, ölüm oranı ve yararlanma oranını değerlendirdi. Mart 2020 ile Şubat 2021 arasında ticari balıkçılardan toplam 513 *S. aurita* örneği toplandı ve değerlendirildi. İstatistiksel analiz için FiSAT II yazılımı kullanıldı. Asimptotik uzunluk (L_∞) = 21,73 cm, büyüme katsayısı (K) = 0,95 yıl-1, maksimum ömür (Tmax) = 2,68 yıl, teorik doğum öncesi yaş (t_0) = -0,48 yıl ve büyüme performans indeksi (Φ ′) = 2.65 olarak belirlendi. İlk yakalanma boyu (Lc50 = 15.06 cm), ilk eşeysel olgunluk boyundan (Lm50 = 21.12 cm) daha düşüktü. Ölüm parametreleri olan toplam ölüm oranı (Z) = 3.03 yıl-1, doğal ölüm oranı (M) = 1.42 yıl-1, balıkçılık ölüm oranı (F) = 1.61 yıl-1 olarak gerçekleşti. Bu, çalışma alanında *S. aurita* türünün hızlı bir büyüme oranına, küçük boyuta, geç cinsel olgunlağa ve yüksek doğal ölüm oranına sahip olduğunu gösterir. Yararlanma oranı (E) 0,53 idi. *S. aurita* türünün optimum şekilde yararlanıldığı bulundu. Bu nedenle, aşırı avlanmayı önlemek için sürdürülebilir balıkçılık önlemleri benimsenmelidir ve bunlar arasında balıkçılık çabalarının izlenmesi ve New Calabar Nehri’nde *S. aurita* balıkçılığını sürdürülebilir kılmak için artan ağ gözü boyutunun uygulanması ve uygulatılması yer almaktadır.

Introduction

The round Sardinella, *Sardinella aurita* (Pisces, Clupeidae), is a marine pelagic fish that is widely distributed throughout the tropical and subtropical seas of the world, including the entire Mediterranean and the Black Sea (Froese and Pauly 2003). It is a key species inhabiting the ecosystem of the northwest African upwelling region (Bard and Koranteg 1995). *S. aurita* (commonly referred to as sardines and indigenously referred to as Songu) is a ray-finned fish. It belongs to the family Clupeidae. The body is elongated and sub-circular, the belly is rounded. (Riede, 2004). *S. aurita* is a pelagic coastal species that prefers clear saline waters with temperatures below 24 °C (Bianchi et al., 1999). It is a typical schooling and migratory species, rising to the surface at night and scattering inshore and near the surface to the shelf's edge and down to 350 meters, or possibly deeper (Whitehead, 1985).

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S. aurita is a warm-water species that approaches the coast and shoals at the surface during the upwelling season, but retreats below the thermocline in the hot season, down to depths of 200 to 300 meters. It eats mostly zooplankton, particularly copepods and mysid larvae, but sometimes phytoplankton, especially by juveniles. (Whitehead, 1981). It can breed at any time of year, but only at certain times of the year; the breeding pattern is enormously complex, with two main spawning seasons in some areas. Juveniles stay in nursery areas, but when they reach maturity, they join adults in colder offshore waters. (Whitehead, 1985).

The distribution of *S. aurita* extends to the Atlantic Ocean and the West African coast, particularly in the three West African upwelling areas stretching from Mauritania to Guinea, Côte d'Ivoire to Ghana, and Gabon to Angola. (Cury and Fontana, 1988).

Fish and fishing contribute significantly to food and nutrition security in many countries. Nevertheless, fish stocks are declining in many parts of the world. This will have a significant impact on the seafood industry's contribution to achieving the United Nations Sustainable Development Goals. As a result, it is critical to focus on the long-term management of fish stocks. (Tsikliras, 2008). Fish population characteristics are critical inputs in the evaluation and management of fish populations. With world fish populations now being poorly managed, resulting in overexploitation and decline, there is a need for data on critical criteria to assist in guaranteeing proper fisheries management. (Arra et al., 2018). Various research on the sex ratio, growth, mortality, and exploitation of *S. aurita* has been conducted, but none has been conducted in the New Calabar River in Choba. This study is, therefore, essential to provide information to fill the gap in the study area and complement the existing data on management of the species.

Material and Methods

Description of study area

In Choba, Rivers State, Nigeria, the New Calabar River is located between longitude 06°53 53086' E and latitude 04°53 19.020' N. The entire river course is located in the coastal area of the Niger Delta, between longitude 7°60' E and latitude 5°45' N, and drains into the Atlantic Ocean. The yearly rainfall in the New Calabar River region ranges from 2000 to 3000 mm (Abowei, 2000). The New Calabar River is one of the most important water resources in the Niger Delta region of Southern Nigeria; it is located near Port Harcourt, the rapidly rising oil city in Rivers State. Effluent discharge from industries located along the river's banks pollutes the water. Surface run-off from soil erosion, lumberic operations, forestry operations, dredging operations, and domestic sewage inputs are also potential large scale pollution sources (Dienye and Woke, 2015).

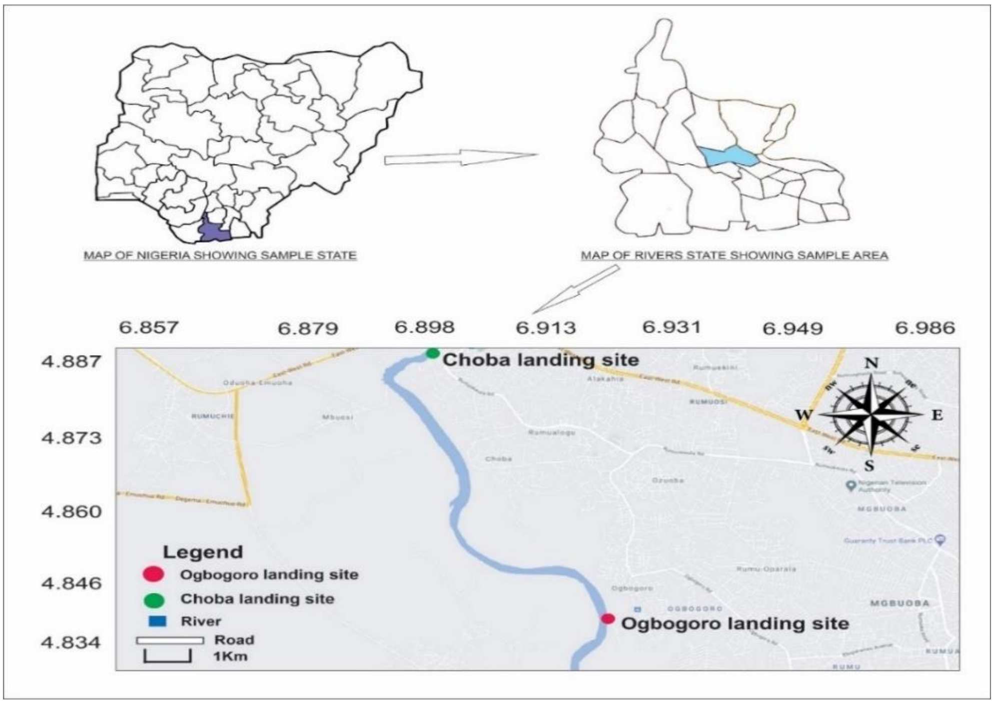

Figure 1. Map of the study area

Data collection

S. aurita was sampled monthly for a period of twelve (12) months, from two stations using cast nets of mesh sizes (1.5–2.5 mm) by the local artisanal fishermen. A total of 513 species were captured. Species identification was carried out using identification keys (Paugy, 2003; Adesulu and Sydenham, 2007).

Sampling stations were chosen due to the high level of fishing activity in these areas (Station One: Choba, Station Two: Rumuoparali). Sampled specimens were preserved on ice for further analysis. The body weights (BW) of the samples were measured to the nearest 0.01 grams with an electronic weighing scale, while the total length (TL), of sampled species was measured to the nearest 0.1 cm with a calibrated 30 cm measuring board.

Length-weight relationship

The length–weight relationships were calculated using the equation:

$W(t)=aL_t^{\ b}$

Where: a is a coefficient relative to body form; b is an exponent indicating isometric growth when equal to 3.0, positive allometry when>3 and negative allometry minorant when<3.

The monthly length frequencies of each sample were grouped into classes of 1 cminterval and were laid out sequentially over one year to estimate the growth (Froese 2006).

Sex-ratio

The sex ratio was determined generally for each sampled station and according to individual size. The sex ratio is the proportion of male or female individuals utilising the gravid gonads in comparison to the overall number (e.g., testis and ovary). The sex ratio was expressed as a percentage of males to females, using the formula by Kartas and Quignard, (1984):

SR=Fx100x(1/(M+F)) (F=female and M=male).

Growth parameters

The parameters for the Von Bertalanffy Growth Function (VBGF) including growth rate (K), asymptotic length ($L\infty$) and the growth performance index (Φ') were estimated using the ELEFAN Simulating Annealing (ELEFAN_SA). Estimation of longevity (Tmax) for the species followed the formula:

$Tmax = 3/K + t_0$ (Anato,1999)

The growth performance index was calculated using the formula:

phi prime test (Φ') $=2\log L_\infty + \log K$ Munro, and Pauly, (1984).

The theoretical age at length zero (t_o) followed the equation:

$Log_{10}(-t_0)=-0.3922-0.2752\log_{10}L_\infty-1.038\log_{10}K$ (Aleev,1952)

Where: Growth rate (K), asymptotic length ($L\infty$) and the growth performance index (ϕ) of the Von Bertanlaffy Growth Function (VBGF) was estimated.

Length at first capture (Lc50)

The ascending left part of the length converted catch curve was used in estimating the probability of length at first capture (Lc50) in addition to the length at both 75 and 95 percent capture, which correlates with the cumulative probability at 75% and 95%, respectively (Pauly,1983).

Length at first maturity (Lm50)

The length at first maturity (Lm50) as:

$Lm50=0.8979\times Log_{10}(L_\infty)-0.0782$ (Arra et al., 2020)

Mortality parameters

The length-converted catch curve was used to calculate the total mortality coefficient (Z). The natural mortality rate (M) was calculated using Pauly's (1980) empirical equation and a mean surface temperature (T) of 25.7°C:

$Log_{10}M = -0.0066 - 0.279\ 1og_{10} L_\infty + 0.6543 \log_{10} K + 0.4634 \log_{10}T$

Total fishing mortality (F) was estimated as:

F = Z - M (Gulland, 1971).

Exploitation rates (Emax, E0.1 and E0.5)

The knife-edge option was used to determine Emax (exploitation rate at maximum yield), Rate of exploitation (E) is the ratio of fishing mortality (F) and total mortality (Z) (Pauly, 1984), and is written as follows:

E = F/Z

Gulland (1971) states that the optimal exploitation for a fish stock occurs when fishing mortality (F) is proportional to the natural mortality:

F optimum = M

Thus, E ranges from 0 to 1. It is optimum at 0.5, under-exploited when it is less than 0.5, and over-exploited when the estimate is above 0.5.

Data analysis

The length frequency data was combined into groups of 1 cm intervals. The FiSAT II (FAO-ICLARM Stock Assessment Tools) program was then used to analyze the data (Gayanilo et al., 2005). The Yield software tool was used to graph the length at each age (Branch et al., 2000).

Results

The length-weight relationship of this study revealed that *S. aurita* had an exponent "b" value of 3.210, which shows a positive allometric growth (Figure 2). The value of the correlation coefficient (r^2) estimated for the species was 0.86971. The size groups of the sex ratio for *S. aurita* in the study area is shown in Table 1. The lengths of sampled fish ranged between 4.1 cm – 24 cm. Of 513 sampled fish, 262 were male and 251 were female, based on a one-centimetre interval corresponding to 51% males and 49% females of the total catch.

The exploitation structure of *S. aurita* in the study area is shown in Figure 3. Maximum exploitation was observed in the range of 8.1–12 cm size group for both the male, pooled and female samples, followed by 12.1 – 16 cm, and the minimum group percentage exploitation was recorded for size group 20.1 – 24 cm.

Figure 4 shows the reconstructed length-frequency distribution superimposed with the growth curves and the length curve for *S. aurita*. Figure 5 shows the length curve for *S. aurita* where the ration of M/K is 1.50.

The estimated growth parameters for *S. aurita* using the ELEFAN II program discovered the best fit for asymptotic length (L_∞) = 21.73 cm, growth rate (K) = 0.95 yr^{-1}, age at birth (t_0) = -0.48 yr^{-1}, longevity (t_{max}) = 9.09 yr^{-1} and the growth performance index (φ'= 2.65) (Table 2).

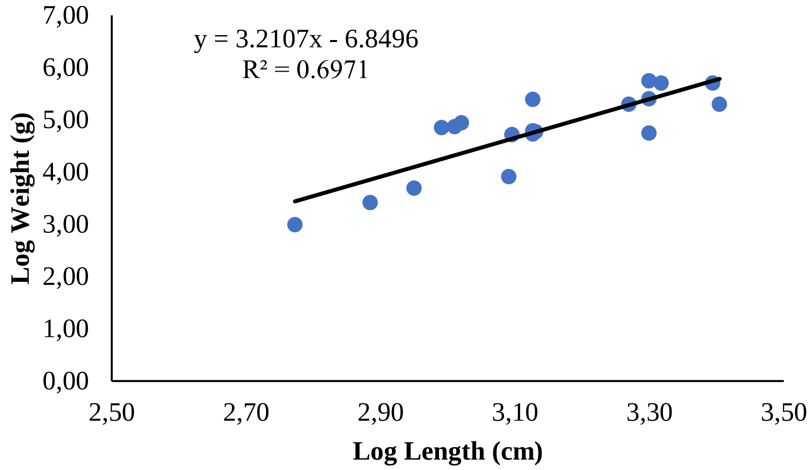

Figure 2. Length-weight relationship of *S. aurita* during the study period

Table 1. Length groups (Sex ratio) of *S. aurita* from New Calabar River

Length groups (cm)	Pooled	No of fish Male	Female	Sex ratio (Male: Female)
4.1 – 8	47	25	22	1:0.88
8.1 – 12	304	174	130	1:0.75
12.1 – 16	157	62	95	1:1.53
16.1 – 20	4	1	3	1:3
20.1 – 24	1	0	1	0:1
Total	513	262	251	51:49

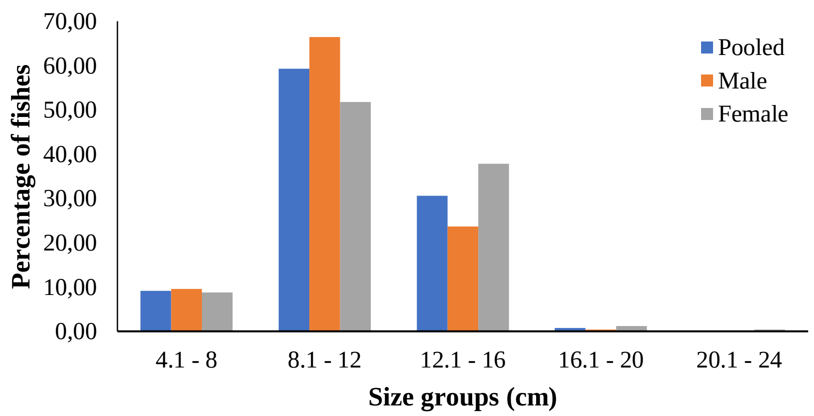

Figure 3. Exploitation structure of *Sardinella aurita* from New Calabar River

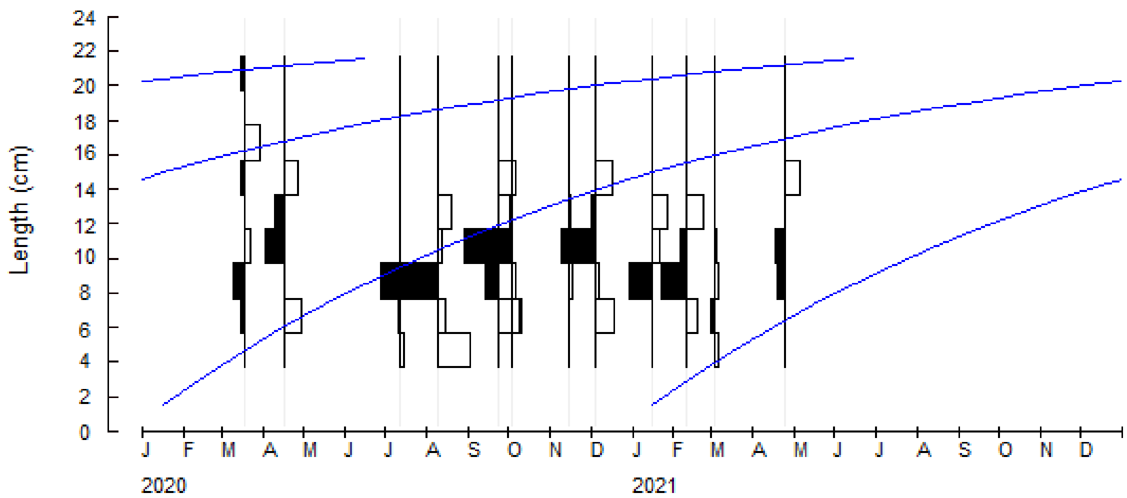

Figure 4. Reconstructed monthly length-frequency distribution

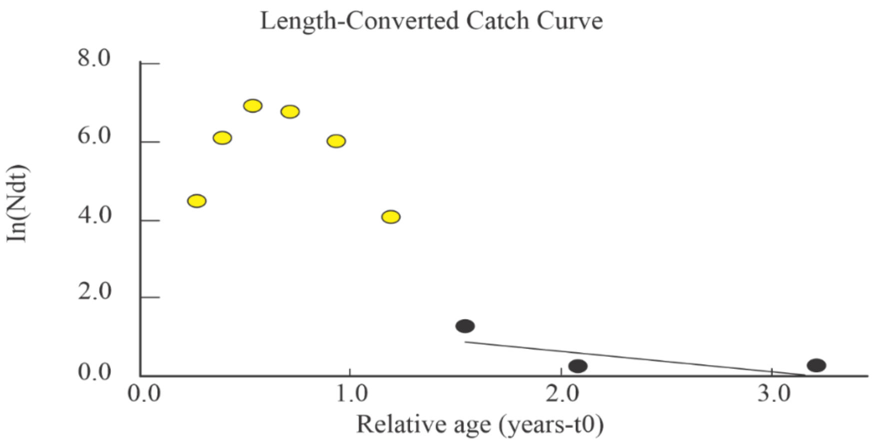

Figure 5. Length-converted catch curve for *S. aurita* in the New Calabar River

Table 2. Some growth parameters of *S. aurita* from New Calabar River

Indicators	Unit	Value
Growth rate (K)	yr^{-1}	0.95
Asymptotic length (L_∞)	cm TL	21.73
Age at birth (t_0)	years	-0.48
Longevity (t_{max})	years	2.68
Growth performance index (phi-prime, φ’)		2.65

The probability of catching *S. aurita* gives a good indicator of the estimated true size of fish captured by certain gear in a given fishing location, as the length at initial capture (Lc50) was 15.06 cm and the length at first maturity (Lm50) was estimated at 21.12 cm. The estimated total mortality rate (z) was 3.03 yr^{-1} and natural mortality was 1.42 yr^{-1}, given a fishing mortality of 1.61 yr^{-1}. The current exploitation rate was estimated as E=0.53 and the M/K ratio found was 1.50 (Table 3).

Table 3. Exploitation rate and mortality of *S. aurita* from New Calabar River

Indicators	Unit	Value
Length at first maturity (Lm50)	cm TL	21.12
Natural mortality rate (M)	yr^{-1}	1.42
Total mortality rate (Z)	yr^{-1}	3.03
Fishing mortality rate (F)	yr^{-1}	1.61
Exploitation rate (E)		0.53
Length at first capture (Lc50)	cm TL	15.06
M/K		1.50
Number of data points (N)		513

Discussion

The value of the correlation coefficient (r^2) estimated for the species shows that the relationship between the length and weight of the fish was highly significant. The length-weight relationship value of the species however, falls within the acceptable range of 2.5 and 3.5, which is typical for tropical fish stocks (Froese, 2006). This is in agreement with the findings of Amina et al., (2016). The differences in sex growth and mortality are useful for an adequate knowledge of demographic structures. The ratio of sex changed significantly when the fish attained maturity, and there were variations in the sex-ratio dependent on the size of the reproductive unit. The sex-ratio favored males (51%) to females (49%), which is in line with the findings of Bensahla-Talet et al. (1988) and Lawson and Doseku (2013) in Majidun Creek, Lagos, Nigeria, but contradicts the findings of Baali et al. (2015), who recorded a higher percentage value for females (63.98%). Sex-ratio varies with respect to size ranges.

Maximum exploitation was observed in the 8.1–12 cm size group, with a higher number of males compared to females. The prevalence of males could also be explained by the migratory nature of this species. In migratory species, females frequently arrive at the spawning site later than males. Males predominate among the early migrants, followed by a numerical disparity between males and females, and a female majority in late migration (Diouf et al., 2010). This could be a factor in the dominance of males in this study as a result of predominance in early migration. Furthermore, differences at various sizes are associated with unequal rates of growth and mortality (Turner et al., 1983). The length at asymptotic (L_∞) (21.73 cm) and growth rates (K) of 0.95 yr^{-1} calculated in this study were relatively different from estimates by other researchers (Al-beak, 2016; Mehanna and Salem, 2011). Nabil et al. (2012) obtained L_∞= 28.37 cm, K= 0.23 year-1 and t_0= 0.98 year. In the Mediterranean Sea, Gaamour et al. (2001) obtained L_∞=31.32 cm; K=0.24 year-1 and t_0=0.87 year in the Tunisian coast. Differences between authors may be due to the number of examined individuals. Such variations in growth coefficients may be due to the estimation protocol, length classes obtained, the geographical locations and the level of fishing pressure (Amponsah et al., 2016a). Also, the variations in estimates of asymptotic lengths may, therefore, be as a result of the maximum observed length, sampling methods, computation methods used and the obtained length-frequency (Sparre and Venema, 1992). The estimated growth rate recorded in this study was higher than the 0.34 yr-1, indicating that *S. aurita* is a fast-growing fish species (Kienzle, 2005). The estimated fast growth rate of *S. aurita* in this study compared to the other related findings may be due to disparities in the ecological characteristics such as habitat, fish adaptive life pattern and location, environmental conditions as a result of regional differences, food abundance or size composition of the stock that directly affect growth rate. The estimation protocol, length classes obtained, geographical locations, and the level of fishing pressure could all be factors for variations in the growth coefficient (Amponsah et al., 2017), as indicated by its 12-year lifespan and a growth performance index outside the normal range of 2.65-3.32, which is reserved for fast-growing fish species (Baijot et al., 1997). *S. aurita's* poor development rate recorded by other researchers could be attributed to the lower nutritional value of the accessible feed (Montchowui et al., 2011).

In this study, the length at first capture (Lc_{50}) was recorded as 15.06 cm and the length at first maturity (Lm_{50}) was calculated as 21.12 cm. This study's estimated length at first catch (Lc_{50}) was lower than (Al-Beak's, 2016) estimates and within the range of values recorded by Amponsah et al. (2017). These findings could be attributed to artisanal fishermen's use of small mesh sizes. As a result, fishing gear with small mesh sizes should be prohibited as a management strategy. Furthermore, the relatively higher estimated Lm_{50}/L_∞ ratio indicated that *S. aurita* is a small-sized fished species in the New Calabar river. Environmental factors, long-term fishing pressure and a rapid response to natural selection are all possible causes for this observation. (Tsikliras and Anthonopoulou, 2006).

The index of growth performance (φ') is considered as a useful tool for comparing the growth curves of different populations of the same species and/or of different species belonging to the same family. In this study, the value of the growth performance index was φ'=2.65. This growth index is higher than those obtained by Gaamour et al. (2001) in the Tunisian coast (φ' =2.27), and by Salem et al. (2010) in the Mediterranean coast (φ'=2.27). Differences in growth parameters may be due to genetic structure, temperature, food availability and diseases (Tsikliras et al., 2005).

S. aurita juveniles become susceptible to capture six months after being recruited into the stock, according to the age at first capture (tc_{50}) method, because of the mesh size and type of fishing gear used. The calculated age at first capture (tc) was lower than that calculated by Al-beak (2016) and Mehanna and Salem (2011). Furthermore, the intensity of fishing over time may be a factor that tends to alter the species' length structure in order to prevent future collapse.

Beverton and Holt (1959) demonstrate that a fish's natural mortality coefficient (M) is proportional to its growth coefficient (K) and inversely proportional to its asymptotic length (L) and life span. The natural mortality was 1.42 yr^{-1} while the growth coefficient was 0.95. The M/K ratio in this study was 1.55, which was in agreement with the range of 1–2.5 proposed by Beverton and Holt (1959). Estimated total mortality (Z) at 3.03 yr^{-1} is likened to 2.46-7.07 by Pauly (1994) for several stocks in this study. Barry and Tegner (1989) documented that a M/K ratio < 1 indicates that the population is growth dominated, whereas a M/K ratio > 1 is an indication that the population is mortality dominated. However, when the M/K ratio = 1, then the growth and mortality of the population are in equilibrium. From the present study, the calculated M/K ratio was slightly greater than 1, suggesting that the stock is fishing mortality dominated. King and Etim (2004) highlighted that for a mortality dominated stock, an M/K ratio ≈ 2 denotes a lightly-exploited stock while values greater than 2 show heavy exploitation. With the estimated M/K ratio lower than 2, it shows that *S. aurita* stock in the study area is maximally exploited. The estimated M/K ratio (1.50) was well within the range of 1.5 – 2.5 for fishes, indicating the presence of a good environmental state (Abowei et al., 2009). The exploitation rate ranges from 0 to 1. It is optimum at 0.5, under-exploited when it is less than 0.5, and over-exploited when the estimate is above 0.5. The estimated exploitation rate (E) of 0.53 in this study is within the range of the maximum exploitation rate (E_{max}=0.53), and this shows that the fishery exploitation is at its peak (optimal), but that it may be subject to minor growth fishing pressure. The exploitation ratio found in this study indicates that *S. aurita* is at maximum exploitation and not over-fished (Pauly, 1994). This is predicated on the assumption that natural and fishing mortalities should be equal in an optimally exploited stock, or E=F/Z=0.5 (Gulland, 1971).

Conclusion

The estimated growth rate recorded in this study depicts that *S. aurita* is a fast-growing fish species, and growth overfishing was found to be present due to the harvesting of relatively small-sized species, and also has a high natural mortality to asymptotic length ratio (M/K > 1). The sex-ratio favors males with 51%, particularly for range (8.1–12 cm), with optimum exploitation structure observed within the same group. Additionally, the intersection of the required length at capture and the exploitation rate showed that the species was being exploited at its maximum rate. Therefore, to prevent growth overfishing, sustainable fisheries measures should be adopted, and these include monitoring of fishing efforts and implementation and enforcement of increased mesh size to sustain the fishery of *S. aurita* in the New Calabar river.

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Conflict of Interest

There are no conflicting interests declared by the authors.

Author Contributions

The study was conceived by authors HE and OA, HE prepared the first draft of the publication, and CD conducted the statistical analyses. The final manuscript was read and approved by all the writers.

Ethic Approval

The material used in the article was obtained from the local artisanal fishermen. Ethics committee approval is not required for this study.

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RESEARCH ARTICLE

Recent Record of *Oceania armata* and Near-Past Records of Other Gelatinous Organisms in the Turkish Waters Presumably Derived by Basin-Scale Current

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Basin-scale current

Abstract: The present study reports the occurrence of *Oceania armata* in the Turkish Levantine Sea, and presents evidence to support a hypothesis established to link an increased recent and near-past records of many gelatinous zooplankton species in the Turkish seas, and particularly in the Turkish Levantine Sea to specific Mediterranean basin-scale currents (Atlantic-Ionian Stream and the Mid-Ionian Jet). One worldwide-distributed oceanic cnidarian specimen was collected from the surface water of a location of 36.59002° N and 29.02471° E by a SCUBA diver on January 18, 2019 in the eastern Mediterranean Sea. The hydrozoan specimen was then identified as *O. armata* and recorded for the first time in the Turkish Mediterranean coast and only second time in the Levant coast after about 30 years. This is the second report of the species from the Turkish waters, and the first report was from the Turkish Aegean coast. Recently, new records of the gelatinous species have increased from the Turkish marine coasts; Sea of Marmara, Aegean Sea, and Levantine Sea. Most of them are distributed in the West Mediterranean Sea, but are also present in the Adriatic Sea (East Mediterranean Sea). In the Mediterranean Sea, one branch of the Atlantic current (Atlantic-Ionian Stream) enters the eastern basin via the Mid-Ionian Jet, linked with the southern Adriatic current. Therefore, it is possible that zooplankton could have entered East Mediterranean by the Atlantic current through West Mediterranean.

Anahtar kelimeler:

Yeni kayıt
Hydrozoan
Zooplankton
Türk Levantin Denizi
Basen ölçekli akıntı

Oceania armata Türünün Türk Sularındaki Muhtemel Havza Ölçekli Akıntı Kaynaklı Son Kaydı ve Diğer Jeli Organizmaların Yakın Geçmişteki Kayıtları

Öz: Bu çalışma Türk Levantin Denizi'nde *Oceania armata* bulunurluğu rapor etmek, ve son ve yakın geçmişte Türk denizlerinde, özellikle Türk Levantine Denizinde birçok jeli zooplankton türlerinin artan kayıtları ile Akdeniz havza ölçekli akıntılar (Atlantik-Iyonyan akıntısı ve Orta-Iyonyan jet akıntısı) arasında bağlantı olduğu hipotezini desteklemek amaçı için ön görülmüştür. 18 Ocak 2019 tarihinde ve 36.59002° N and 29.02471° E koordinat noktasının yüzey suyundan SCUBA dalgıçı tarafından dünyada yaygın olan oseanik cnidarian bireyi toplanmıştır. Bu hydrozoan bireyi, *O. armata* olarak tanımlanmış ve Akdeniz'in Türk suları için ilk defa ve Levantin Denizi için 30 yıl aradan sonra kayıt edilmiştir. Bu, Türk suları için ikinci kayıttır ve ilk kayıt Ege Denizi'nin Türk sularından verilmiştir. Son zamanlarda, Türk deniz sularından (Ege Denizi, Marmara Denizi ve Levantin Denizi) jelli organizmaların yeni kayıtları artmaktadır. Bu türlerin birçoğu Batı Akdeniz'de dağılmaktadır ve Doğu Akdeniz'e ait Adriyatik Denizi'nde bulunmaktadır. Akdeniz'de Atlantik akıntısının bir dalı (Atlantik-Iyonyan akıntısı), Adriyatik akıntısı ile bağlantılı olan Orta-Iyonyan jet akıntısı ile doğu havzasına girmektedir. Bu yüzden, Batı Akdeniz boyunca yer alan Atlantik akıntısı ile zooplanktonun Doğu Akdeniz'e girebilme olasılıkları vardır.

Introduction

The Mediterranean Sea hosts a rich and diverse marine life that is comparatively well-studied (Vasilakopoulos et al., 2017). Although it is considered to be a biodiversity hotspot (Coll et al., 2010), it is under increasing threat from pollution, over-exploitation and climate change (Cuttelod et al., 2009). The eastern Mediterranean Sea is well open to the new records of marine organisms, specifically the gelatinous organisms. In the Eastern Mediterranean, biodiversity is also threatened by invasive alien species including the gelatinous organisms (Galil, 2007). These gelatinous alien species span most animal phyla and have created new communities altering the Mediterranean ecosystem (Coll et al., 2010); for instance, a new medusa species, *Chrysaora pseudoocellata* Mutlu,

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Tulay, Olguner & Yılmaz 2020 has recently been established in the eastern Mediterranean Sea (Mutlu et al., 2020; Douek et al., 2020).

The zooplankton, especially gelatinous organisms can be easily drifted by water currents. This may suggest that there could be a relationship between the current direction and occurrence and transportation of the zooplankton in space as atmospheric-oceanographic relation is in progress to shift and change the regime (Vasilakopoulos et al., 2017). Currents are one of the ways to introduction of a zooplankter living in a known marine environment to another suitable area for potential establishment (Mutlu et al., 2020; Mutlu and Özvarol, 2022).

Recently, new introductions of zooplankton, especially gelatinous zooplankton which are common in the West Mediterranean Sea and the Atlantic Ocean have been recorded in the Turkish marine coasts (Table 1).

Table 1. Near-past records of gelatinous zooplankton in the Turkish marine coasts

Taxa	Regions	Citations
One ctenophore	Bosporus exit to Black Sea	Öztürk et al., 2011
Sixteen hydrozoans, One scyphozoan	Sea of Marmara	İşinibilir et al., 2015a, b; 2019
One hydrozoan	Sea of Marmara	Yılmaz et al., 2017
Two scyphozoans, One hydrozoan, One thaliacean	Sea of Marmara	İşinibilir et al., 2022
Two hydrozoans	Aegean Sea	Gülşahin et al., 2013, 2016
One hydrozoan	Northernmost Aegean Sea	İşinibilir et al., 2021
One lobat ctenophore	Turkish water	Gülşahin and Türker, 2017
One new scyphozoan	Levant Sea	Mutlu et al., 2020
One lobat ctenophore	Levant Sea	Gokoglu and Galil, 2020
One cydippid ctenophore	Levant Sea	Mutlu and Özvarol, 2022
Two eumedusoid hydrozoans, One lobat ctenophore	Levant Sea	Mutlu and Karaca, 2022

A hydrozoan medusa, *Oceania armata* Kölliker, 1853 was recorded in the Turkish Aegean coast (Gülşahin et al., 2016). Type locality of *O. armata* is the Mediterranean and additionally the species overspread coasts of Senegal and Gambia, Canary Islands, Cape Verde, Azores, Portugal, Spain; West Indies; Japan, New Zealand, Tasman Sea extending northernmost to Portugal in European waters (Mayer, 1910). Previous Mediterranean occurrences of *O. armata* were reported from the Tyrrhenian Sea and the Adriatic Sea (Madin, 1991). Last records of *Oceania armata* in the eastern Mediterranean waters were reported from the Adriatic Sea (Lučić et al., 2009), Egyptian waters (Dowidar, 1983), Lebanese waters (Goy et al., 1991) and the Aegean Sea as a basin sea of the Mediterranean Sea (Gülşahin et al., 2016).

In the Mediterranean Sea, one branch of the Atlantic current (Atlantic-Ionian Stream) enters the eastern basin via the Mid-Ionian Jet, linked with the southern Adriatic current (Fig. 1 in Poulain et al., 2013). Therefore, it is possible that zooplankton enter the East Mediterranean by the Atlantic currents through West Mediterranean. For instance, in recent sample collections in 2019 June/July, two hydrozoans, *Gastroblasta raffaelei* Lang, 1886 and *Podocorynoides minima* (Trinci, 1903) were observed for the first time for the Turkish Mediterranean coast, and the Levantine Sea (Mutlu and Doğukan, 2022), and a ctenophore species, *Hormiphora plumosa* M. Sars, 1859 as well (Mutlu and Özvarol, 2022). Recently, a copepod species from the Adriatic Sea has been found in the Turkish Mediterranean coast (Güler Sıla Duman, pers. comm., Akdeniz University, unpublished data).

However, *O. armata* has occurred no longer in the Levantine and eastern Mediterranean Sea excluding the Adriatic Sea. The present study was aimed to report occurrence of *O. armata* in the Turkish Mediterranean coast, and to alert either its succession from the Aegean Sea to the eastern Mediterranean Sea, or transportation of the Adriatic species via the Atlantic current entering the eastern basin via the Ionian jet linked with the southern Adriatic current with enhancement of near-past records of the other gelatinous zooplankton.

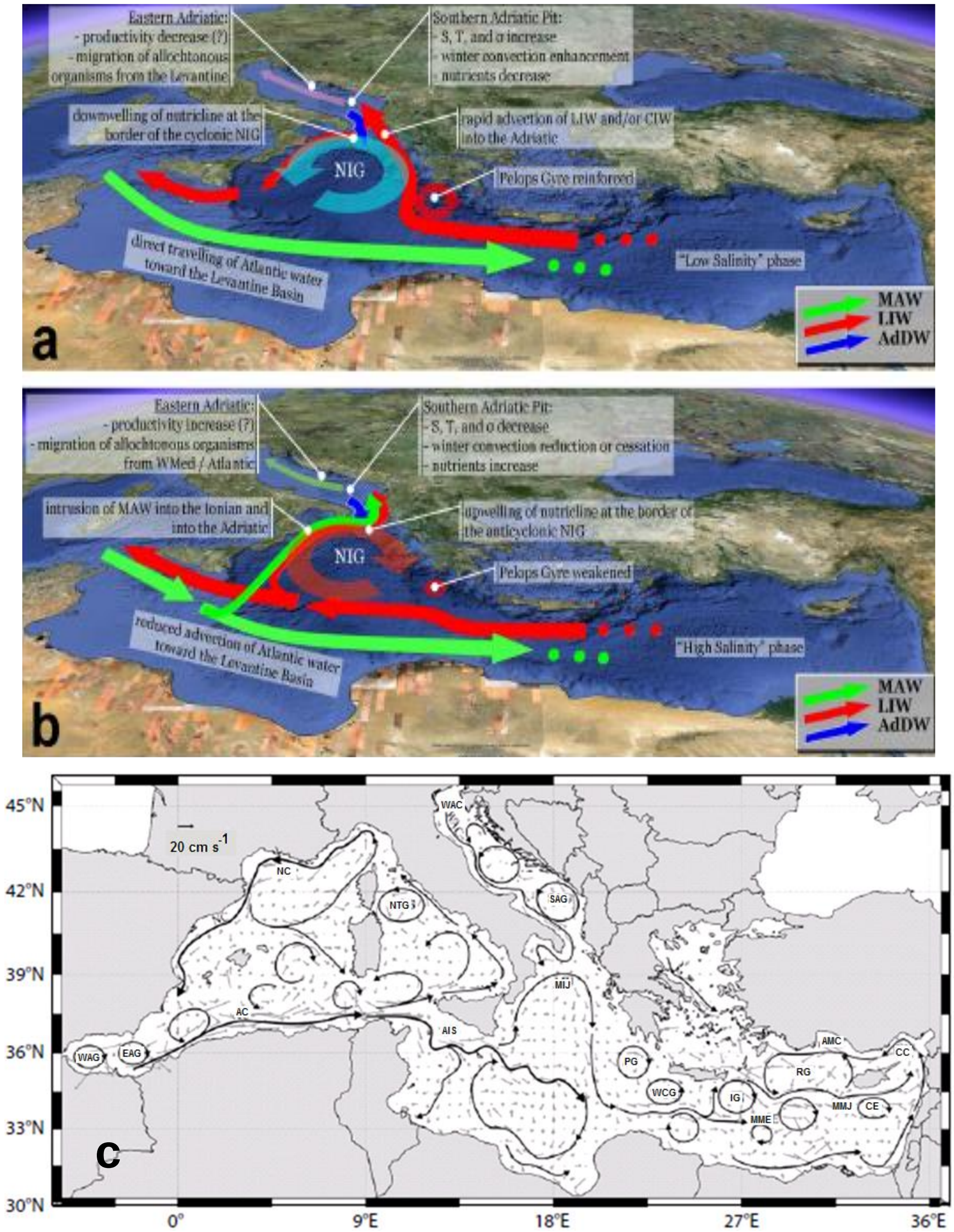

Figure 1. Formation and influence of the cyclonic Northern Ionian Gyre (NIG); (a) anticyclonic NIG (b) derived by the Adriatic–Ionian BiOS interaction (MAW; the Modified Atlantic Water, LIW; Levantine Intermediate Water, and AdDW; Adriatic Dense Water) (from Civitarese et al., 2010), and Mediterranean Sea surface geostrophic circulations and currents (c) measured by the drifters, and then schematized by Poulain et al. (2013)

Material and Methods

During an acoustic survey along the Turkish Mediterranean coast during December 2018-January 2019, a medusa specimen was captured from the surface waters at the location 36.59002° N and 29.02471° E by a SCUBA diver on January 18, 2019 (Fig. 2). The specimen was then preserved in a borax-buffered 3% formaldehyde on board of R/V '*Akdeniz Su*'.

The specimen was identified following the descriptions for the specimen diagnosed by Mayer (1910), Madin (1991) and Schuchert (2004). Bell shape and form, number of marginal tentacles, number and shape of lips, nematocyst warts, and gonad and manubrium locations in subumbrella were taken into consideration for the identification of the specimen. Furthermore, bell height and diameter were measured under a microscope.

During the survey, either physical, chemical and optical environmental parameters were measured on site or water samples were collected for future analysis. Physical parameters measured using a multi-parameter probes (YSI, HiTech) included temperature, pH, and salinity and optical and chemical parameters were Secchi depth, NO_2+NO_3, NH_4, and PO_4, SiO_2, chlorophyll *a* and TSM (Total suspended matter). One liter of the water was filtered through CF/C for each of the nutrients and TSM and through CF/F filters for chl *a*, and then all of filtered water and filters was stored at -20 ºC until measurement.

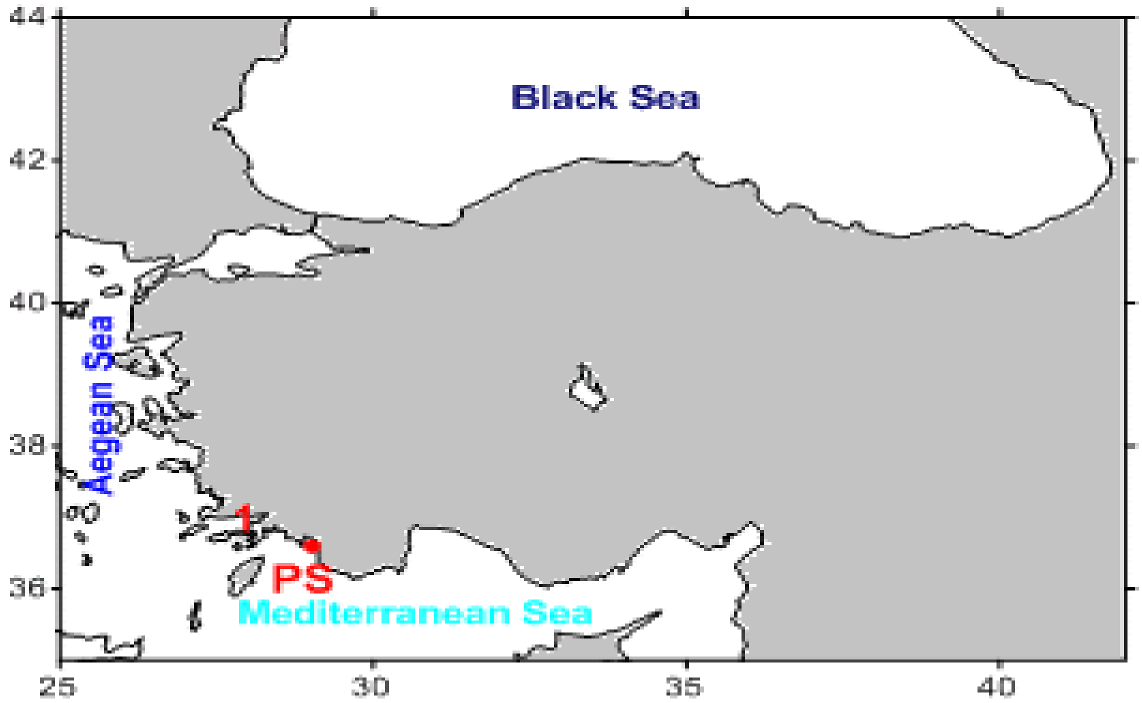

Figure 2. Locations of occurrence of *Oceania armata* along the Turkish Aegean coasts (1; Gelibolu cove in Gökova Gulf (Gülşahin et al. 2016), and in the Turkish Mediterranean Sea PS; present study, red dot)

In the laboratory, the nutrients were measured following the standard procedures: Ammonium (mg NH_4/l), nitrate (mg NO_3/l), nitrite (mg NO_2/l), phosphate (mg PO_4/l), and silicon dioxide (mg SiO_2 /l) were measured using the methods of 4500-NH_4 B, 4500 $N0_3$-E, 4500 $N0_2$-B, 4500-P E, and 4500-SiO 2 Silica, respectively (APHA, 1999). Total suspended solids (material was dried in an oven at 60 ºC for 24 h, and then weighed before the weight of the dried membrane was subtracted from the total dry weight), and chlorophyll *a* (chl-*a*) using a method described by Lorenzen (1967). Secchi disk depth was recorded once at each station.

Results and Discussion

Physical parameters of sea surface waters of the sampling station (PS) were as follows: temperature 18.1 ºC, salinity 38.8 PSU, oxygen 9.56 mg/l, and pH 9.01. Chemical and optical parameters are given in Table 2. Environmental data, especially salinity and nutrient levels indicated effects of the cyclonic and anticyclonic NIG derived by the Adriatic–Ionian BiOS interaction on the northern Levantine Sea (particularly the present study area) as discussed below.

The specimen was identified as *Oceania armata* with the following description: The bell diameter was 5 mm, and the bell height was about 5 mm. Diameter of the bell was identical to bell height measurement. The entire jelly tissue bell was thin. The marginal tentacle count was 84 in total and the tentacles tapering were double-rowed. The bell shape was pyriform, not in a complete hemisphere with flat bell-top. The species had 4 slender radial canals joining manubrium and a simple ring canal. Number of the lips on mouth was 4, they were large and curved extending to the middle of the bell in the subumbrella, and nematocyst warts in knob-shape of sphere fringed the lips on margin of the mouth (Fig. 3).

Genus *Oceania* differs from the genus *Turritopsis* by having stalked nematocyst clusters along the mouth (Schuchert, 2004). Stefano Piraino (pers. comm.) stated differences between genus *Turritopsis* and *Oceania* medusae as follows: "Large *Turritopsis* and *Oceania* medusae resemble each other quite closely. Both have large cells at the proximal end of their radial canals which are continued along the manubrium as four perradial ribs, resembling claws that clasp the manubrium. *Oceania* differs from *Turritopsis* in having stalked nematocyst clusters along it mouth, while they are without a distinct stalk in *Turritopsis*. In addition, the manubrium base of *O. armata* is somewhat constricted. This allows distinguishing even badly preserved material (Kramp, 1965)".

Table 2. Seafloor depth (depth), Secchi disk depth (SDD), temperature (T), salinity (S), pH (pH), dissolved oxygen (Ox), chlorophyll-*a* (chl-*a*), total suspended matter (TSM), and the essential nutrients of the sea surface (prefix S) and near-bottom waters (prefix N) of the stations (PS, Fig. 2) where the gelatinous species was found

Variables	PS
Depth (m)	20
SDD (m)	12
ST (ºC)	17.6
NT (ºC)	17.5
SS (PSU)	38.9
NS (PSU)	38.8
SpH	8.99
NpH	8.98
SOx (mg/l)	9.35
NOx (mg/l)	9.65
SChl-*a* (µg/l)	0.299
STSM (mg/l)	0.058
NTSM (mg/l)	0.071
$SSiO_2$ (µM)	48.81
$NSiO_2$ (µM)	32.06
SNO_2+NO_3 (µM)	1.87
NNO_2+NO_3 (µM)	6.26
SNH_4 (µM)	193.42
NNH_4 (µM)	323.60
SPO_4 (µM)	8.37
NPO_4 (µM)	12.93

Up to now, a specimen of *O. armata* has not been recorded for the Turkish coast of the Levantine Sea, and the Mediterranean Sea (Çinar et al., 2014). *Oceania armata* was recently recorded from the Turkish coastal waters, being previously found along the Turkish coast (Gelibolu cove in Gökova bay) of the Aegean Sea (Gülşahin et al., 2016). The present study showed that succession of *O. armata* was extended to the Turkish Mediterranean coast.

Recently, new introductions of zooplankton, especially gelatinous zooplankton which were common in West Mediterranean Sea and the Atlantic Ocean increased in the Turkish marine coasts; the Sea of Marmara in 2019-2021 (İşinibilir et al., 2019, 2022), the northernmost Aegean Sea in 2021 (İşinibilir et al., 2021), the Levantine Sea in 2018-2020 (Mutlu et al., 2020; Gokoglu and Galil, 2020; Mutlu and Özvarol, 2022; Mutlu and Karaca, 2022; Guler Sıla Duman, pers. comm, Akdeniz University). Such increases in recent introductions may be associated with the Bimodal Oscillating System, BiOS (Civitarese et al., 2010). The BiOS has changed the flow direction of the North Ionian Gyre (NIG) from cyclonic to anticyclonic circulation, or vice versa, once every 10 years, depending on the severe winter condition and convection (Civitarese et al., 2010; Poulain et al., 2013). This change in the NIG induced circulation of the Atlantic current based on decadal time scale. The Ionian jet pumped the waster toward the East Mediterranean (Poulain et al., 2013) as the NIG became cyclonic circulation creating upwelling linked with the Southern Adriatic current. Therefore, the decadal NIG stimulated physicochemical hydrograph and ecosystem to change in the eastern Mediterranean Sea (Civitarese et al., 2010). The first NIG induced by the BiOS was noticed in 1988, followed by 1998, and 2008-2009 (Civitarese et al., 2010; Poulain et al., 2013). Occurrence of the recent intensive new introductions of the zooplankton in the Turkish marine coasts during 2018-2020 (İşinibilir et al., 2019, 2021; 2022; Mutlu et al., 2020; Gokoglu and Galil, 2020; Mutlu and Özvarol, 2022; Mutlu and Karaca, 2022) was well coincided with the repetitive mechanism of the BiOS as the NIG turned to the cyclonic circulation every ten years. This could explain a reason of presence of relatively less saline waters, and high-concentrated nutritional waters during the present study (Table 2), and in summer in 2019 (surface water salinity of 37.4-37.6 PSU, and the nutrients; NO_2+NO_3 of 0.30-0.51 µM, NH_4 of 43.9-67.2 µM, and PO_4 of 1.41-3.39 µM) during a study by Mutlu and Karaca (2022). In 2019, summer nutrients could be relatively low as compared to that in winter because of the primary production (chl-*a*, Table 2) occurred in the spring. Summer salinity in the present study area reached up to 39.9-40 PSU in 2010-2011 (Mutlu et al., 2022), and 2014-2015 (de Meo et al., 2018) when the concentrations of the nutrients were relatively low (Mutlu et al., 2022; de Meo et al., 2018) compared to that in 2019 (Mutlu and Karaca, 2022).

A new record of a ctenophore species, *Hormiphora plumosa* which is common in the Tyrrhenian Sea and Adriatic Sea (Madin, 1991; Batistić et al., 2007) has recently been reported for the Levantine Sea from the same location of the present study where *O. armata* occurred simultaneously (Mutlu and Özvarol, 2022). In the Mediterranean Sea, one branch of the Atlantic current enters the eastern basin via the Ionian jet in connection with the southern Adriatic current (Poulain et al., 2013). Thus, it is highly possible that *O. armata* could enter the eastern Mediterranean by the Atlantic currents through the western Mediterranean as postulated for *H. plumosa* by Mutlu and Özvarol (2022).

Civitarese et al. (2010) and Poulain et al. (2013) concluded that flow and circulation direction of the decadal NIG was stimulated by the weather conditions, increasing severity of winter condition recently developed in the global scale of the atmosphere in time. In conclusion, near-past records of the gelatinous and copepod zooplankton were well coincided with decadal regime of the basin-scale water current in the Mediterranean Sea.

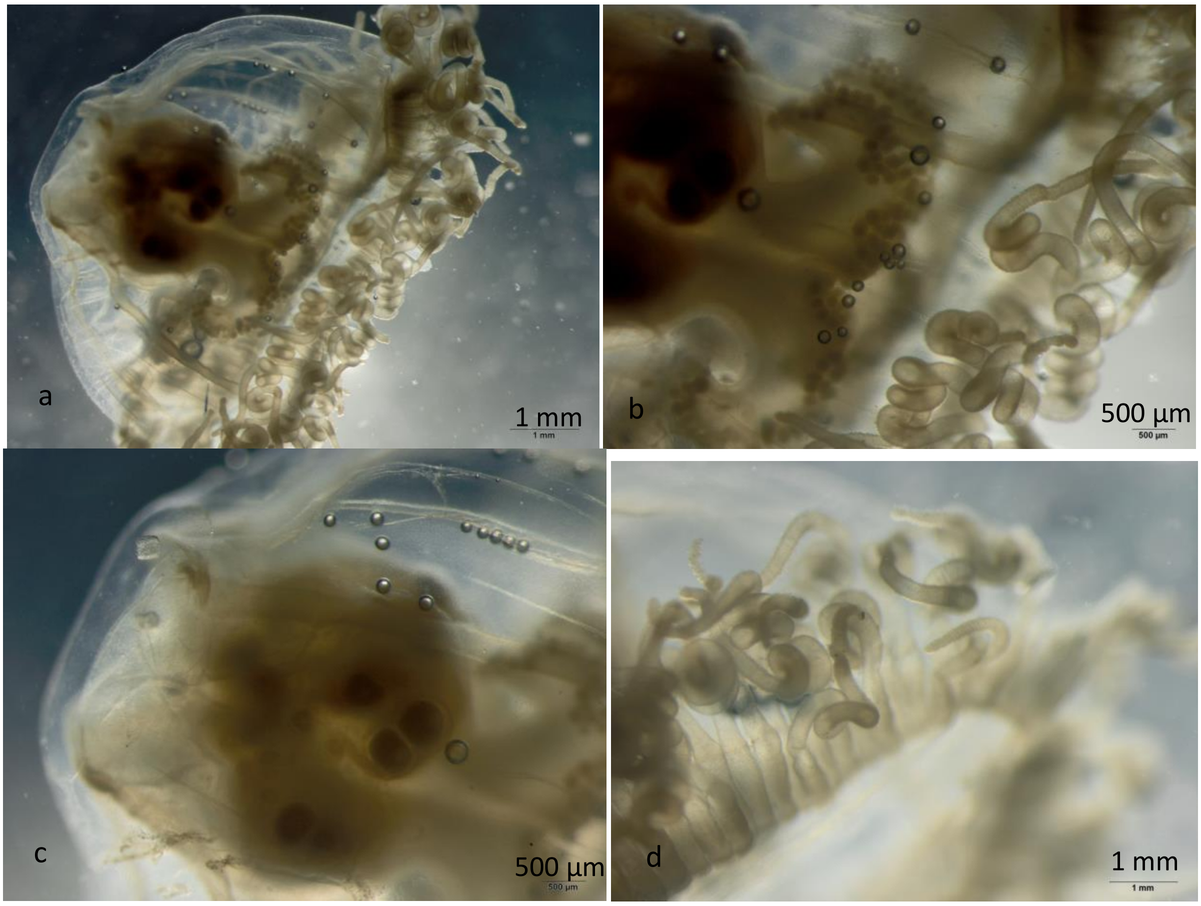

Figure 3. Lateral view of *Oceania armata* specimen preserved in the formalin solution (a), mouth lips fringed by the sphere nematocyst cluster (b), manubrium and gonad (c), and marginal tentacles of the umbrella (d)

Acknowledgements

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Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

All authors contributed to the preparation of the manuscript.

Ethics Approval

Ethics committee approval is not required for this study.

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RESEARCH ARTICLE

Cestode Infection of the Native Brine Shrimp (*Artemia parthenogenetica*) in Çamaltı Saltpan (İzmir/Türkiye)

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Key words:

Aquaculture
Artemia parthenogenetica
Çamaltı saltpan
Flamingolepis liguloides
Live feeds
Parasitism

Abstract: *Artemia* sp. populations in saltworks throughout the world have been gaining importance due to their extensive use in aquaculture and their importance as the main prey organism for aquatic birds in hypersaline ecosystems. The genus *Artemia* sp. is also known as the intermediate host of some cestode species that are associated with flamingos. In this study, *Flamingolepis liguloides* parasitism was determined in *Artemia partenogenetica* for the first time in Turkiye. Infected *A. parthenogenetica* was detected in İzmir Çamaltı saltpans between May-August 2018 and the parasite diagnosis was made. Parasites were detected near the abdomen, thorax and the intestinal tract of *A. parthenogenetica*. The prevalence of parasites was higher in adult Artemia (63.6%). The presence of *F. liguloides* in *A. parthenogenetica* was very high with a frequency of 72.2%. The most abundant and prevalent parasite infection was recorded in July which is the most suitable time of the year with respect to number of flamingos in the area. The results show the prevalence of this parasite infection in *A. parthenogenetica*, which may be important for both the local *Artemia* population in the area and the flamingos breeding in Çamaltı saltpans.

Anahtar kelimeler:

Akuakültür
Artemia parthenogenetica
Çamaltı tuzlası
Flamingolepis liguloides
Canlı yemler
Parazitlik

Çamaltı Tuzlası'nda (İzmir/Türkiye) Yerli Tuzla Karidesinde (*Artemia parthenogenetica*) Görülen Sestod Enfeksiyonu

Öz: Tuzlalardaki *Artemia* sp. popülasyonları, akuakültürde kullanımı ve çok tuzlu ekosistemlerde su kuşlarının besini olmasına göre önem kazanmaktadır. Ayrıca bu besin zincirinde *Artemia*, flamingo kuşları ile ilgili olarak bazı sestod türlerinde ara konakçıdır. On iki ay süren bu çalışmada Türkiye'de ilk kez *Artemia partenogenetica'da Flamingolepis liguloides* parazitliği saptanmıştır. Mayıs-Ağustos 2018 tarihleri arasında İzmir Çamaltı Tuzlasında enfekte olan *A. parthenogenetica* tespit edilmiş ve parazitin teşhisi konmuştur. Parazit, *A. parthenogenetica'* nın karın, göğüs kafesi ve bağırsak kanalı yakınında tespit edilmiştir. Parazitlerin yayılımı çoğunlukla erişkin bireylerde (%63,3) oranında daha yüksektir. Tuzla havuzlarında, *F. liguloides* varlığı %72,2 gibi oldukça yüksek bulunmuştur. En bol ve yaygın parazit enfeksiyonu, ekosistemdeki birey sayısı için yılın en uygun zamanı olan temmuz ayında kaydedilmiştir. Elde edilen sonuçlara göre, flamingo kuşlarının çok önemli bir göç noktası olan bu bölgede *A. parthenogenetica'* da bu parazit enfeksiyonunun yaygınlığı görülmektedir. *A. parthenogenetica*, bu sestodların parazitleştirdiği ara konaktır. Bu sonuç Türkiye'deki birincil tespittir.

Introduction

Many aquatic invertebrate taxa, such as crustacea, branchiopoda, ostracoda and copepoda, can adapt to extreme environmental conditions including high or low temperature and salinities, dry conditions, as well as predation and lack of food by forming dormant stages in dynamic environments such as estuaries and hypersaline ecosystems. (Hand et al., 2016). The genus *Artemia* sp. Leach, 1819 (Branchiopoda, Anostraca) are a complex of sibling species distributed in seven continents with the exception of Antarctica (Vanhaecke et al. 1987; Triantaphyllidis et al., 1998). *Artemia* also known as the brine shrimp is among the most intensely studied aquatic organisms, due to its importance in aquaculture especially in the feeding of larval forms. The brine shrimp genus includes bisexual and parthenogenetic strains of different ploidy (Baxevanis et al., 2006; Gajardo, et al., 2002, 2012). Parthenogenetic *Artemia* populations are widely distributed except in the American continent. Bisexual and parthenogenetic *Artemia* species prefer different microhabitats and are usually temporally separated (Agh et al., 2007), although a handful of populations are mixed (Amat et al., 2007). From an ecological point of view, *Artemia* is a keystone taxon in hypersaline food webs due to its dominance; it is the main prey for aquatic birds

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(Sánchez et al., 2006), the intermediate host for many species of parasites (Georgiev et al., 2005; Rode, Landes, et al., 2013; Rode, Lievens, et al., 2013; Vasileva et al., 2009), and the main consumer of phytoplankton. *Artemia* sp. is particularly suitable for studying phase effects. For instance, it is a good tool for investigating how biological changes in a species translate into "cascading" effects throughout the population and the ecosystem. From this point of view, the first invasion of *Artemia* species by parasitic cestoda were reported from Tunisia (Heldt, 1926), followed by Spain, Italy (Amat et al., 1991a, b), France (Gabrion and MacDonald, 1980; Thiery et al., 1990), and many other countries (Di Cave et al., 1990; Di Cave and Mura, 1990; Mura, 1995). However, there are no data on the abundance of infested *Artemia parthenogenetica* by cestodes from Turkey. In this study, the cestode parasitism of *Flamingolepis liguloides* (Gervais, 1847) in *Artemia parthenogenetica* Barigozzi, 1974 was investigated in order to determine their abundance for the first time in Turkey. It is observed that flamingo populations in the Mediterranean region has increased due to the changing climatic conditions (BirdLife International, 2004) which may help spreading of cestode parasites. This study aimed to form a basis for further research to determine the distribution of this parasitism in Turkey, especially at the migration points of flamingos.

Material and Methods

Study area

The studied native *A. parthenogenetica* is from Çamaltı saltworks (38°30´12.73 "N, 26°54´12.94"E) (Figure 1). Five sampling stations with different salinities were selected and samples were collected for 12 months.

The study area is the Çamaltı saltpans (Figure 2) with an areaof approximately 60 km^2 and a depth of 1-2,5 m. The area gradually overflows with seawater from April to September and continuously over the next few months.

The salinity of the water is high and varies between 40 and 320 ppt. Its avifauna is represented by 289 bird species (Figure 3) (Anonymous, 2019).

Sampling

The *Artemia* samples were collected monthly from a depth of 0.5-2.5 m during January 2018 to December 2018 covering consecutive seasons: winter, spring, summer, and autumn. A 125 µm plankton net was used for collecting *Artemia* samples. All samples were fixed in 70% alcohol. The identification of parasites was performed according to Georgiev et al (2005). The mean number of parasites, prevalence of infection, standard deviation were calculated and a non-parametrical Z-test was performed to compare prevalences between adult and juveniles. The statistical analyses were performed with SPSS software.

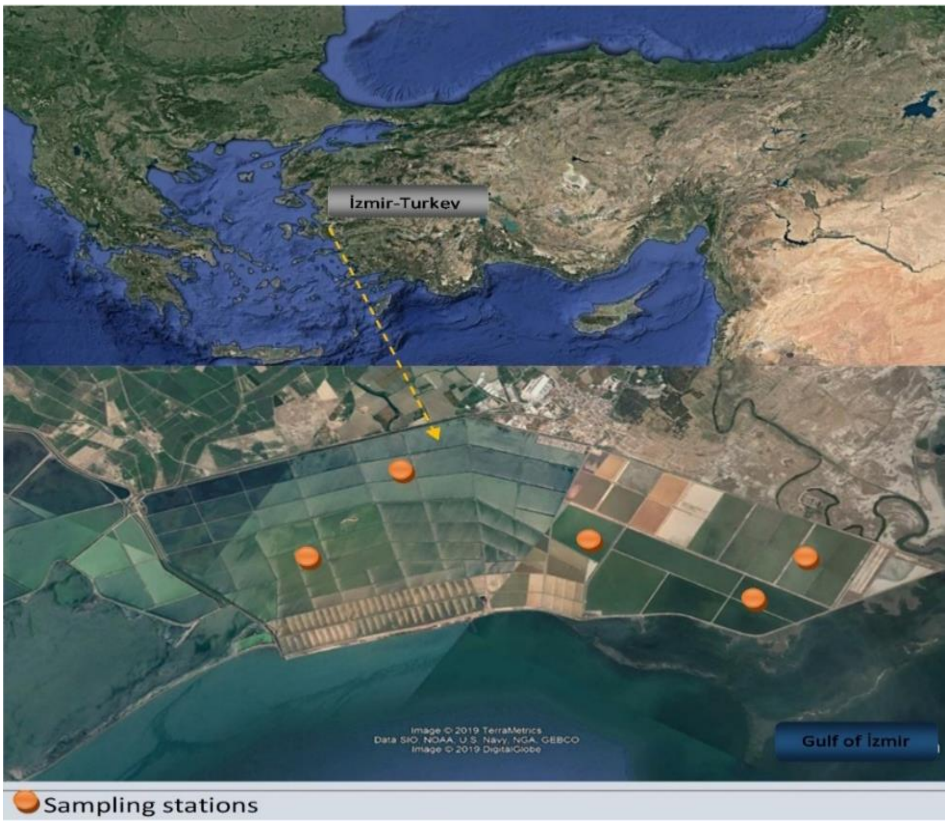

Figure 1. The study area of the Çamaltı saltern ecosystem

Figure 2. The earthen ponds of Çamaltı saltworks

Figure 3. Flamingos in Çamaltı saltworks

Results

In this study, *F. liguloides* parasitism in *A. parthenogenetica* was described for the first time. *F. liguloides* was the only cestode detected in all *A. parthenogenetica* individuals sampled. The parasites were mostly located in the thorax and abdomen, especially near the gut tract, (midgut and hindgut) of brine shrimps (Figure 4).

F. liguloides infection was recorded from both juvenile and adult *A. parthenogenetica* between May-August 2018. The overall infection rate was found very high, with a frequency of 72.2%. Among the 361 infected brine shrimps, 44.8% had only one cysticercoid. Only one individual had 7 cysticercoids. In total, 500 *A. parthenogenetica* were investigated and 139 individuals had no cysticercoid (27.8%) (Table 1).

Figure 4. Infected *A. parthenogenetica* individuals

The prevalences for adults and juveniles were found as 63.6% and 36.4%, respectively (Figure 5).

Monthly proportions of adult and juvenile *A. parthenogenetica* infected with *F. liguloides* were presented in Figure 6 and 7. A maximum of 7 and 4 cysticercoids were determined in adult and juvenile Artemia, respectively.

Monthly parasitic cestode intensity was relatively higher in adult Artemia (63.0% in May, 60.0% in June, 65.0% in July, 65.0% in August) (Table 2).

Table 1. Number of the prevalence of infected and uninfected *A. parthenogenetica*

Descriptions	Infected	Uninfected	Total
Number of *Artemia* samples	361	139	500
Prevalence of infection (%)	72.2	27.8	100
Minimum number of parasites	1	-	-
Maximum number of parasites	7	-	-

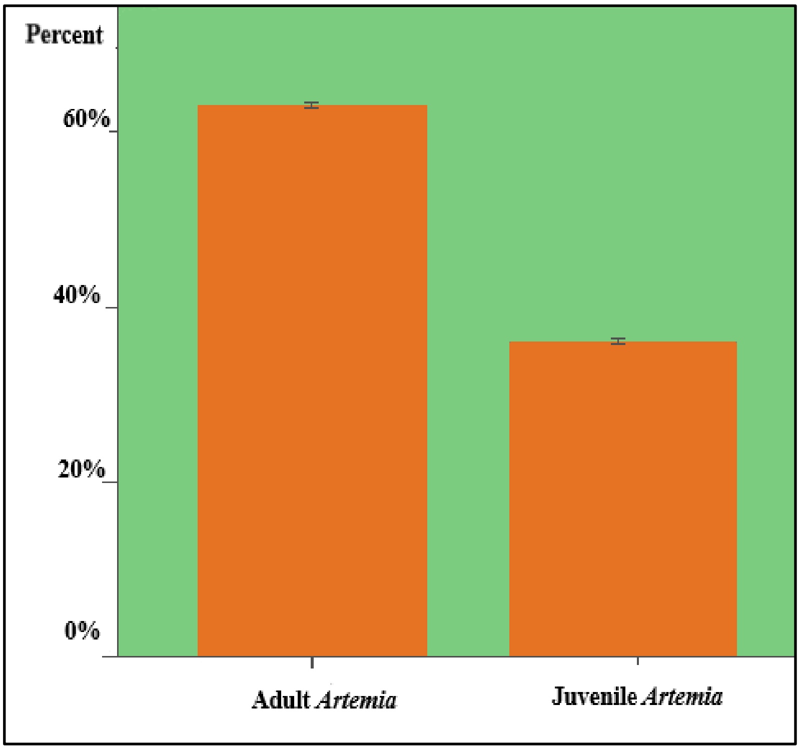

Figure 5. The percentage of *F. liguloides* in adult and juvenile individuals in the whole study

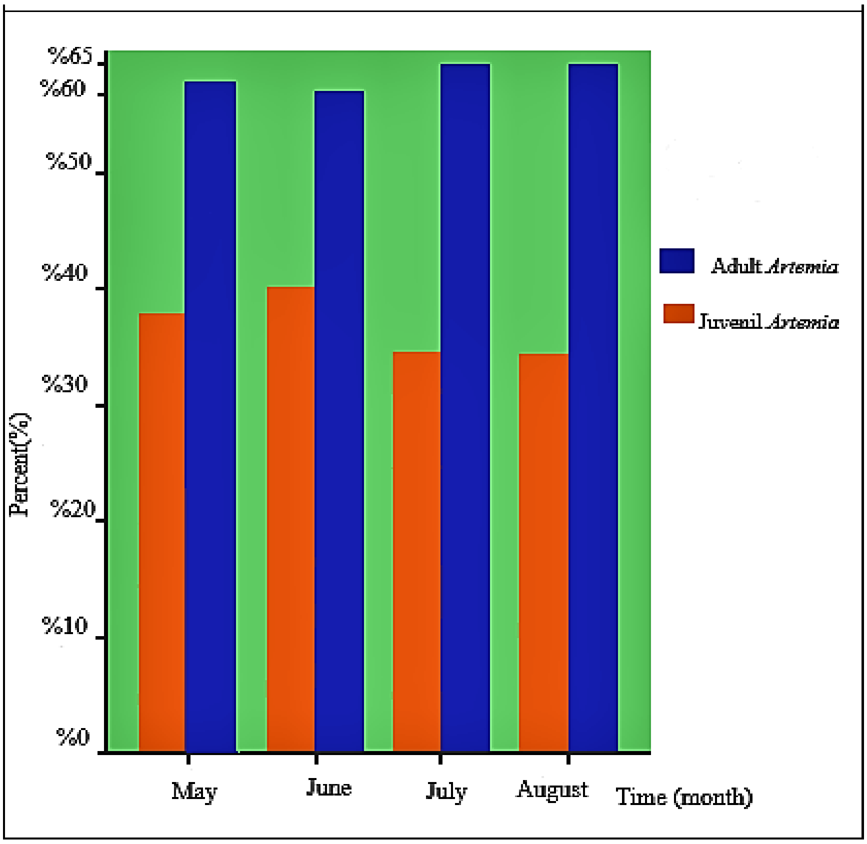

Figure 6. The monthly proportions of *A. parthenogenetica* infected with *F. liguloides* in adult and juvenile Artemia

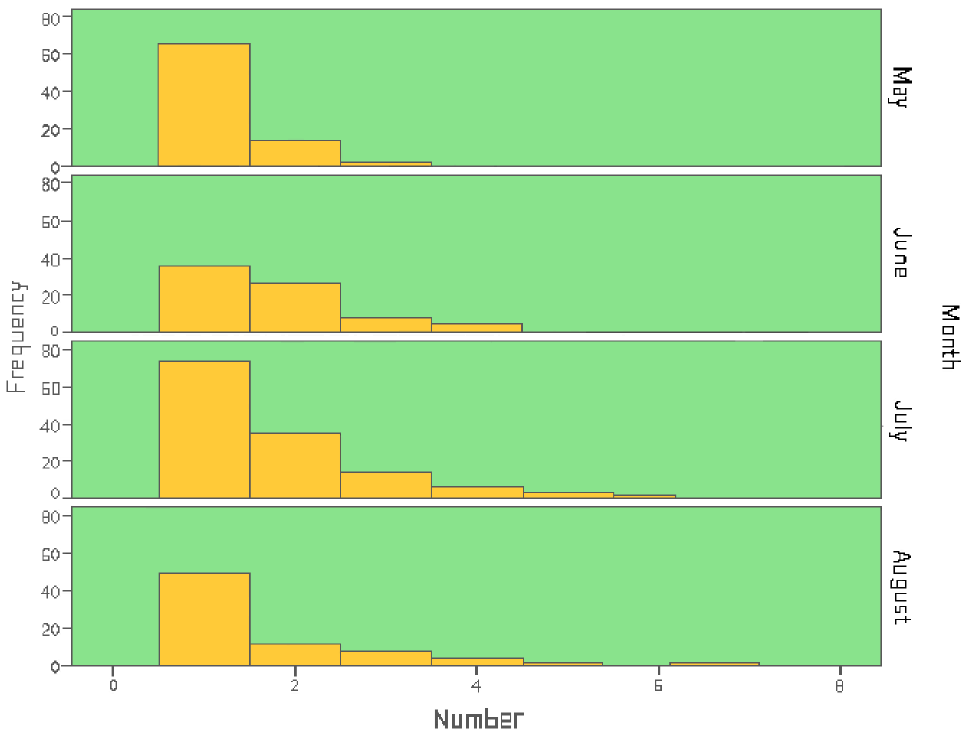

Figure 7. Monthly variations in frequencies of *A. parthenogenetica* infected by *F. liguloides*

Table 2. Parasite infection Month / *A. parthenogenetica* cross-tabulation

Month	Specifications	*A. parthenogenetica*		Total
		Adult	**Juvenile**	
May	Count	63_a	37_a	100
	% within Month	63	37	100
	% within *A. parthenogenetica*	19.8	20.3	20
June	Count	60_a	40_a	100
	% within Month	60	40	100
	% within *A. parthenogenetica*	18.9	22	20
July	Count	130_a	70_a	200
	% within Month	65	35	100
	% within *A. parthenogenetica*	40.9	38.5	40
August	Count	65_a	35_a	100
	% within Month	65	35	100
	% within *A. parthenogenetica*	20.4	19.2	20
Total	Count	318	182	500
	% within Month	63.6	36.4	100
	% within *A. parthenogenetica*	100	100	100

Every subscript letter denotes an *A. parthenogenetic* subset category whose column proportions do not differ significantly from each other at the 0.05 level.

Discussion

Determining the causative factors of an observed disease dynamic is often challenging, particularly with respect to seasonal and variable multi-host systems and other variable parameters. In this study, long-term field data was used to resolve the effects of seasonality and host specificity on prevalence in a simple host-parasite population. Uninfected parasites of *Artemia* individuals are found at the bottom of salt pans whereas those infected with parasites move towards the water surface and move horizontally (Fig. 8).

In the field, prevalence varied between 40 ppt and 320 ppt in all host and parasite combinations. *F. liguloides* was strongly seasonal, being highly prevalent in the summer and absent in the winter (Figure 5, 6, 7). Our findings revealed that cestod seasonality was mainly driven by the seasonality of the host *A. parthenogenetica*; normally *F. liguloides* is unable to persist in host community. As stated by the terminology proposed by Chervy (2002), the cysticercoids of *F. liguloides*, *F. flamingo*, *Wardium stellorae*, *Gynandrotaenia stammeri* belong to the group of the cercocysticercoids, while those of *Eurycestus avoceti*, *Anomotaenia tringae*, and *Anomotaenia* sp. are considered monocysticercoids. The cysticercoid of *Confluaria podicipina* is close to the modification termed "ramicysticer-coid" but its cercomer is not branching. This proposes the necessity of further improvement of the terminology proposed by Chervy (2002). The following 14 cyclophyllidean cestode species were previously known to use brine shrimps of the genus *Artemia* sp. as an intermediate host in their life cycles: Hymenolepididae (11 species): *Confluaria podicipina* (Szymanski, 1905), *Fimbriarioides tadornae* (Maksimova, 1976), *F. liguloides* (Gervais, 1847), *F. caroli* (Parona, 1887), *F. flamingo* (Skrjabin, 1914), *F. tengizi* (Gvosdev and Maksimova, 1968), *Hymenolepis californicus* (Young 1952), *Wardium fusa* (Krabbe, 1869), *W. gvozdevi*, *Branchiopodataenia gvozdevi* (Maksimova, 1988) and *W. stellorae* (Deblock et al., 1960). Dilepididae (2 species): *Eurycestus avoceti* (Gabrion and MacDonald 1980, Maksimova 1991, Robert and Gabrion 1991) and *Anomolepis averini* (Spasskii and Yurpalova, 1967). Progynotaeniidae (1 species): *Gynandrotaenia stammeri* (Fuhrman, 1936) (Gvozde and Maximov, 1968; Chervy, 2002; Vasileva et.al., 2009; Amarouayache et.al., 2009; Gajardo and Beardmore, 2012; Bray, 2014). *F. liguloides* cysticercoids in *Artemia* sp. were reported from the Mediterranean area by Robert and Gabrion in 1991 for the first time but this study is the first report from Turkiye. *Artemia* with its limited predator avoidance such as hypersaline tolerance and daily vertical migrations (Lenz, 1980; Forward and Hettler, 1992; Sanchez et al., 2007) are, in general, easy prey for aquatic birds, aquatic invertebrates and fishes alike. They are a major component of flamingo diet and have a crucial importance as a food source in saltwater habitats (Rolf, 2018). However, parasitic Artemia cestodes increase susceptibility of brine shrimps by reducing their fecundity (Cooper et al., 1984; Britton et al., 1986; Amat et al., 1991a; Verkuil et al., 2003; Sanchez et al., 2006; Sanchez et al., 2007). Overall, 15 cestode species use *Artemia* as an intermediate host which is linked by predation of avian hosts (Georgiev et al., 2005; 2007). The brine shrimp *Artemia* is a non-selective filter feeder (Provasoli and Shiraishi 1959; Dobbeleir et al., 1980; Sanchez et al., 2013), that feeds on microorganisms that are present in the water column including detritus (Savage and Knott, 1998; Sanchez et al., 2013). *Artemia* is infected with the cestode eggs called oncosphere (20 µm) when they ingest the eggs from the water column. The eggs, then, develop into cysticercoid (larva with scolex) in the hemocoel (Robert and Gabrion, 1991; Sanchez et al., 2007; Amarouayache et al., 2009). The parasitic cestodes transmission is completed when infected *Artemia* are ingested by aquatic birds (Sanchez et al., 2013). Once ingested, larval cestodes develop into mature worms in the digestive tract of flamingos and the eggs of the adult parasites are dispersed by defecation (Amarouayache et al., 2009).

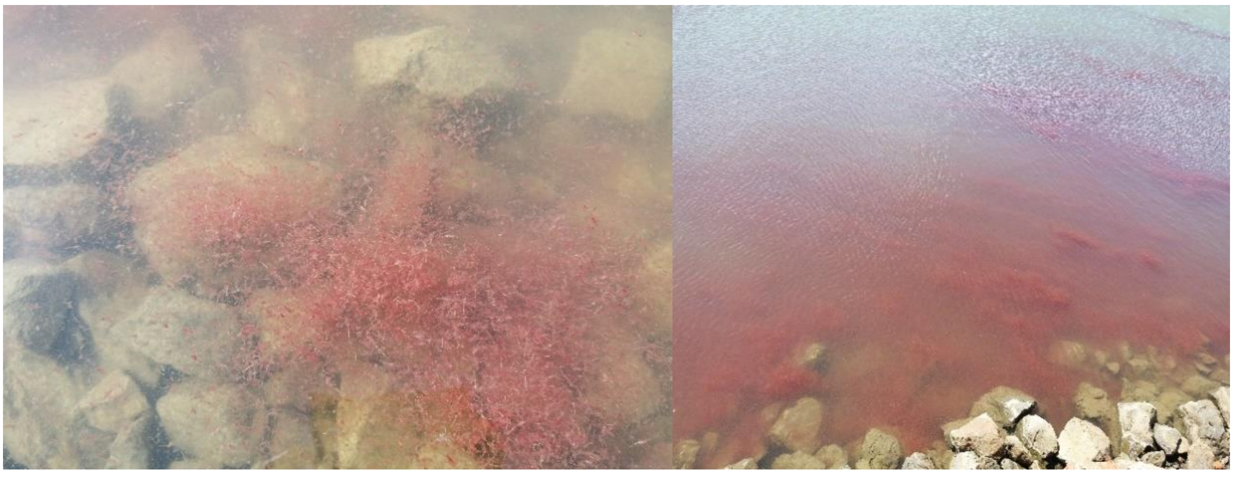

Figure 8. *Artemia* individuals horizontally transmitted in saltern ponds

The saltpans of Çamaltı in İzmir, Turkey has become an important breeding site of flamingos (Figure 3) since 2000. In earlier studies, some biological characterization of this ecosystem and the native *A. parthenogenetica* were determined between January and December in the Çamaltı Region, İzmir which is the biggest marine coastal solar saltwork in Turkey (Koru, 2013; Koru and Deniz, 2017; Koru and Perçin, 2018). A breeding colony of flamingos can be observed in this area between March and August (Balkız et al., 2015). The parasitism of *Artemia* sp. by *F. liguloides* is probably related to the presence of flamingos. Similarly, Amarouayache et al (2009) observed cestode parasitism at the end of the winter (February-March) and in the spring (April-May) coinciding with the presence of flamingos in the study area in Algeria. In earlier studies the intensity of the parasitism was variable; less than 3 cysticercoids per individual in Algeria (Amarouayache et al., 2009), 13 in the populations of Spain (Georgiev et al., 2005) and about 9-11 in France (Thiéry et al., 1990). Sanchez et al (2013) reported multiple cysticercoid infections ranging between 2-4 and a maximum of 14 individuals. In our investigation, a maximum of 7 and 4 cysticercoids were determined in adult and juvenile Artemia, respectively (Figure 4). According to Thiéry et al., (1990), the accumulation of cysticercoids were associated with age and body size. It was reported that brine shrimps could digest 25-30 µm diameter particles at larval instar III-IV stages, and *F. liguloides* eggs with a diameter of 40-50 µm could only be ingested by older stages of brine shrimps (Dobbeleir et al., 1980; Mura 1995). This may explain the difference between the percentage of infected juvenile and adult *A. parthenogenetica* individuals. In this study, the location of the cysticercoids in Artemia was mostly in the thorax and abdomen regions (Figure 4). Similarly, the cysticercoids were reported in the thorax of *Artemia* juveniles, however, they were especially located in the abdomen of adults sampled from the saltworks of Sardinia (Mura, 1995). Thiéry et al., (1990) remarked that the location of the cysticercoids was related to the volume of the hemocoel and the dispersion was relevant to the allometric changes during the growth of *Artemia*. It is important to understand the effects of parasites in biological invasions and the interactions between predators and competitors (Combes, 1996; Torchin and Mitchell, 2004; Prenter et al., 2004; Cespedes et al., 2017). *A. parthenogenetica* spend most of the day in the 25% of the water column near the bottom and occupy the other 75% during the night (Britton et al., 1986; Sanchez et al., 2013) exhibiting strong negative phototaxis and positive diurnal geotaxis (Lenz 1980; Bradley and Forward, 1984; Sanchez et al., 2007). However, infection by cestodes changes the proportion of time that was spent at different depths (Sanchez et al., 2007; Sanchez et al., 2013). Cestode parasites increase buoyancy of infected Artemia and make them swim on the surface of the water facilitating predation by the water birds (Thomas et al., 1997; Helluy and Holmes 2005; Curio 1988; Amarouayache et al., 2009). Infected brine shrimps become photophilous and their surface-swimming behavior can be observed (Sanchez et al., 2007). Sanchez et al (2007) studied the effects of cestode parasitism on the behaviors of *A. parthenogenetica* and reported that 86% of the uninfected *Artemia* showed positive geotaxis whereas 53% of infected *Artemia* showed surface-swimming behavior (negative geotaxis) (Figure 8). This behavior increases the likelihood of predation by the final avian host and makes parasite transmission easier (Sanchez et al., 2007).

In conclusion, in this study, *F. liguloides* infection of the native *A. parthenogenetica* which is the major food source of flamingos in Çamaltı saltworks was established. The prey-predator relationships and the ecological effects should be studied in order to understand the effects of *F. liguloides* parasitism in the region. More research is needed to understand the cycle of parasitism and interactions between the brine shrimp *Artemia* and flamingos in the Çamaltı region.

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Conflict of Interest

The writer in this study declares that there is no relationship based on mutual interests.

Author Contributions

The data collection, methodology, analysis, writing and arrangement of the study were carried out by Edis Koru.

Ethics Approval

The material used in this article is invertebrate species therefore ethics committee approval is not required for this study.

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RESEARCH ARTICLE

Effect of Different Baits on Catch Per Unit Effort (*CPUE*) for Catching Narrow-Clawed Crayfish (*Pontastacus leptodactylus*) with Fyke-Nets and Traps in Çanakkale Atikhisar Reservoir

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Key words:

Crayfish
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Trap
Bait
Catch per unit effort

Abstract: This study was aimed to determine the effects of different bait types on the efficiency of fyke-nets and traps in catching narrow-clawed crayfish (*Pontastacus leptodactylus* (Eschscholtz, 1823)). The study was carried out in Atikhisar reservoir, Çanakkale, between July 2020 and March 2021. In the study, 12 traditional fyke-nets ("D" inlet, 5 rigid rings and a leader net) and 12 traps (double inlet) were used. Fyke-nets and traps were rigged with 34 mm stretched mesh that are commonly used in crayfish fishing in Türkiye. Three different bait types including fish, chicken and bread and a control treatment with no bait were allocated to each gear type. Baits were distributed randomly to each gear before fishing trials. The baits were placed in small bags corresponding to 1% of total trap volume. The results of 24 trials showed 68.8% (1940 crayfish) of the total catch was caught with fyke nets and 31.20% (880 crayfish) with traps. The highest average $CPUE_N$ values for both trap types were observed in those baited with the chicken meat which were 7.89±1.02 n/fyke net/day and 5.07±0.88 n/trap/day.. The mean length of the crayfish caught by the fyke nets was significantly smaller than those caught by the traps (p<0.05). When the mean *CPUE* values based on the number of fishing operations were compared, differences were significant for baits other than the chicken meat (p<0.05). These results showed that catching efficiencies of baited fyke-nets and traps were higher (especially chicken meat) than those of unbaited traps than those without bait.

Anahtar kelimeler:

Kerevit
Pinter
Sepet
Yem
Birim çabaya düşen av

Çanakkale Atikhisar Baraj Gölü'nde Pinter ve Sepetle Kerevit (*Pontastacus leptodactylus* (Eschscholtz, 1823)) Avcılığında Farklı Yemlerin Av Verimine (*CPUE*) Etkisi

Öz: Bu çalışmada, kerevit (*Pontastacus leptodactylus* (Eschscholtz, 1823)) avcılığında, pinter ve sepet takımlarında farklı yemlerin av verimine etkilerinin belirlenmesi amaçlanmıştır. Çalışma, Temmuz 2020 – Mart 2021 tarihleri arasında, Çanakkale Atikhisar Baraj Gölü'nde yürütülmüştür. Çalışmada 12 adet geleneksel pinter ("D" girişli, 5 çembere sahip, tek yönlendirme) ile yine 12 adet sepet takımları (çift girişe sahip) kullanılmıştır. Takımlar Türkiye'de kerevit avcılığında yasal olarak kullanılan 34 mm göz açıklığında ağla donatılmıştır. Her bir av aracı yemli (balık, tavuk, ekmek) ve yemsiz (kontrol grubu) olmak üzere 4 farklı gruba ayrıldı ve her operasyonda rastgele olarak birbirine eklendi. Yemler, tuzakların hacimce %1'ine tekabül edecek şekilde hazırlanmış küçük torbalara yerleştirildi. 24 başarılı avcılık denemesi sonucuna göre toplam avların %68,8'i (1940) pinterler ve %31,20'si (880) sepetler ile gerçekleştirilmiştir. Pinter ve sepet takımlarında en yüksek ortalama $CPUE_N$ değerleri tavuk eti ile yemlenenlerde gerçekleşmiş ve pinter için 7,89±1,02 adet/tuzak/gün, sepet için 5,07±0,88 adet/tuzak/gün bulunmuştur. Kerevitlere ait ortalama boylar, pinter takımları ile yakalananlarda, sepet takımları ile yakalananlara göre daha küçük olarak gerçekleşmiş ve aralarında istatistiki farklar anlamlı bulunmuştur (p<0,05). Pinter ve sepetlerle gerçekleştirilen operasyon sayılarına göre hesaplanan ortalama *CPUE* değerleri arasındaki karşılaştırmalarda farklar tavuk eti ile yemlenenler haricinde diğer yem grupları için anlamlı bulunmuştur (p<0,05). Bu sonuçlar, kerevit avında kullanılan pinter ve tuzakların yakalama etkinliğinde yem (özellikle tavuk eti) kullanımının yemsiz olanlara göre daha etkili olduğunu göstermiştir.

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Giriş

Kerevitler, Crustacea sınıfının, Malacostraca takımına ait, *Astacidae, Parastacidae* ve *Cambaridae* familyalarında 640'ın üzerinde tanımlanmış türü bulunmakta olan, durgun (Lentik) ve akarsu (Lotik) sistemlerinde bulunabilen, omnivor omurgasız canlılardır (Momot vd., 1978; Crandall ve Buhay, 2007; Cılbız vd., 2020). Ekonomik değerinin yüksekliği nedeniyle balıkçılık açısından önemli bir gelir kaynağıdır. Bunun yanında, ekolojik açıdan da hareket ve beslenme aktiviteleri sonucu sediment sirkülasyonu sağlayarak bentik ortamın balıklar için uygun olmasında önemli rol oynamaktadır (Momot vd. 1978, Statzner vd. 2003; Albertson ve Daniels 2018, Cılbız vd. 2020).

Kerevit (*Pontastacus leptodactylus* (Esch., 1823)) türü Türkiye'de Eğirdir, Beyşehir, Akşehir, Eber, Çivril, Apolyont ve Manyas gölleri gibi tatlı sularda doğal olarak yer almakla birlikte, barajlar gibi su kaynaklarına sonradan bırakılmıştır (Erençin ve Köksal, 1977; Çelikkale vd., 1982; Bolat, 2001; Akhan vd. 2014; Kale ve Berber, 2020). Çalışmanın yapılacağı Atikhisar Baraj Gölü kerevit türlerinin sonradan bırakıldığı bir göl olup, Çanakkale ilinin içme amaçlı su temini, tarımsal sulama ve taşkın kontrolü amacı ile 1971-1975 yılları arasında inşa edilmiştir (Koca, 2005). Gölde ticari balıkçılık faaliyetleri 2007 yılına kadar yapılmasına karşın bu tarihten sonra sadece amatör balıkçılığa izin verilmektedir.

Türkiye'de kerevit avcılığına yasal olarak (1 Kasım-30 Haziran tarihleri dışındaki aylar) izin verilen göllerde, genellikle pinter takımları kullanılmaktadır (Anonim, 2020). İç sularında kullanılan pinter takımları genel olarak 5 çember 2 boğaz veya 7 çember ve 3 boğazdan oluşmaktadır. Literatürde pinterlerin donatılmasında D giriş ilk olarak Almanya'da kullanılmış (Nédélec, 1975), Türkiye'de ise ilk Söke bölgesindeki balıkçılar tarafından kullanılmasından dolayı, D girişe sahip pinterler "Söke tipi" olarak isimlendirilmiştir (Hoşsucu, 1998). Türkiye'de kerevit üretimi 2011-2019 yılları arasında 500 ila 600 ton dolayında sabit bir üretim miktarı sürdürülürken 2020 yılında %100 oranında bir üretim artışı sonucu 1200 ton olarak gerçekleştirilmiştir (TUİK, 2021).

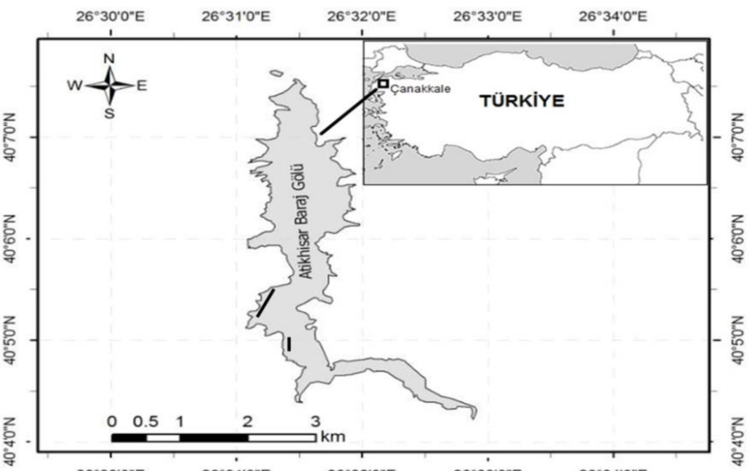
Türkiye kerevit avcılığı ile ilgili daha çok Eğridir ve Keban baraj gölünde çalışmalar yoğunlaşmıştır. Bu çalışmalar, pinter takımlarında farklı yem kullanımı ile av verimi (Balık vd., 2003; Bolat vd., 2011; Demirol vd., 2015; Cilbiz vd., 2021) ve pinter takımlarında kullanılan ağ göz seçiciliği (Bolat vd., 2010; Cilbiz, 2019; Bolat ve Uçgun, 2020) üzerinedir. Marmara bölgesinde kerevit türlerinin bazı populasyon özellikleri konusunda (Güner, 2006; Güner, 2008; Berber ve Balık, 2009) çalışmalar olmasına rağmen, av takımlarına ait av verimi üzerine yapılmış bir çalışmaya rastlanılmamıştır.

Ticari amaçlı su ürünleri avcılığında 1998 yılına kadarki yasal düzenlemelerde kerevit avcılığında sadece ekmek kullanılarak yapılan avcılık yasaklanmışken bu yıldan sonraki düzenlemelerde her türlü yem kullanımının yasak olduğu belirtilmektedir (Anonim, 1999). Bu yasağın konulma gerekçesi "balıkçıların aşırı yem kullanmaları sonucu göllerin su kalitesinde olumsuz etkilenmesi" olarak açıklanmasına rağmen, gerçekleştirilmiş bilimsel bir çalışma bulunmamaktadır. Buna karşılık yemsiz kullanılan pinter takımları ile kerevit avcılığının, yemli kullanılanlara göre daha verimsiz olduğu konusunda çalışmalar bulunmaktadır (Somers ve Stechey, 1986; Romaire, 1995; Balık vd., 2003). Bu nedenle uygulamada olan yasak düzenlemesi balıkçılar tarafından eleştirilmektedir. Bu çalışmada, balıkçıların bu eleştirilerine cevap verebilmek adına kerevit (*P. leptodactylus*) avcılığında, pinter ve sepet gibi farklı av araçlarında yem kullanımının av verimi üzerindeki etkisinin belirlenmesi amaçlanmıştır.

Materyal ve Yöntem

Bu çalışma, ÇOMÜ Hayvan Deneyleri Yerel Etik Kurulundan 03.02.2020 tarih ve 2020/01-08 karar nolu izin belgesi ve Tarım-Orman Bakanlığı, Balıkçılık ve Su Ürün. Genel Müdürlüğü 01.07.2020 tarih ve E.1811532'nolu araştırma izini ile gerçekleştirilmiştir.

Çalışmanın örneklemeleri Temmuz 2020-Mart 2021 tarihleri arasında Çanakkale İli Atikhisar Baraj Gölünde gerçekleştirilmiştir (Şekil 1).

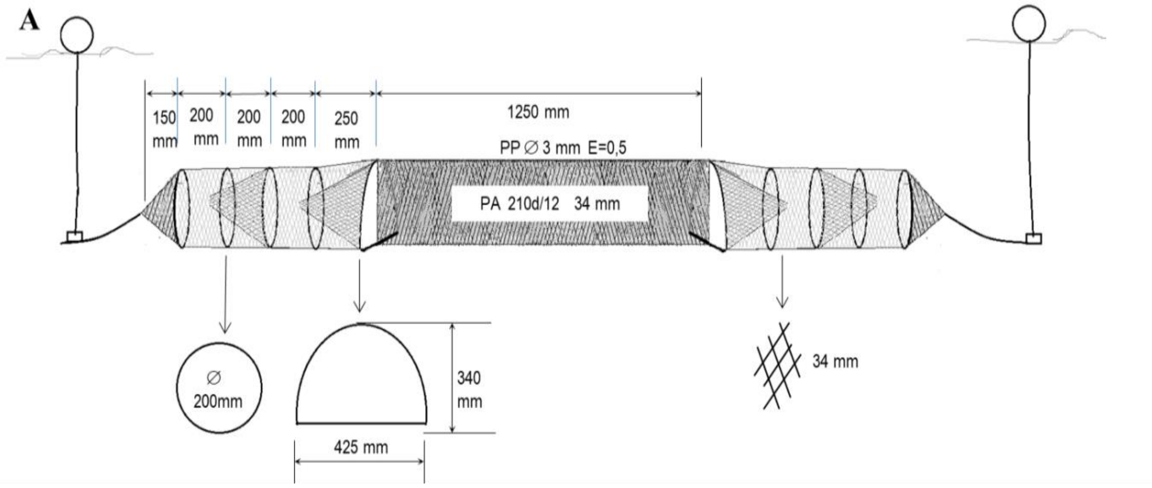


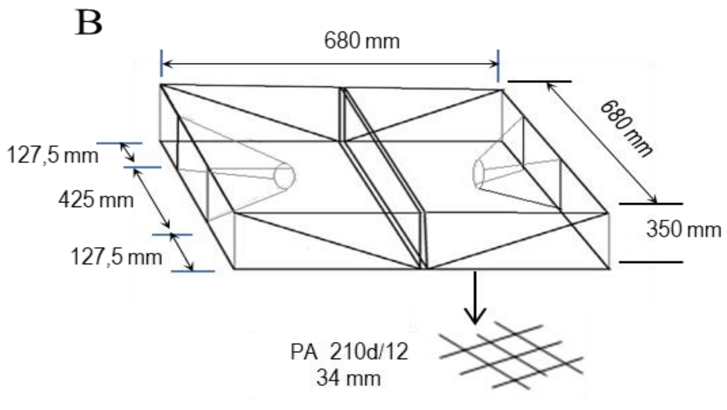
Şekil 1. Atikhisar Baraj Gölü (Çanakkale) örnekleme sahası

Çalışma süresince, gölün yüzey suyu sıcaklığı, çözünmüş oksijen verileri YSI Pro 2030 ve pH verileri ise WTW3110 cihazları kullanılarak örnekleme sahasından toplanmıştır.

Araştırma materyalini 12 adet "D" girişli, 5 çembere sahip, tek germeli pinter ile yine 12 adet çift girişe sahip kolay kurulabilen sepet takımları (Şekil 2) oluşturmuştur. Takımlar kerevit avcılığında yasal olarak kullanılan 34 mm göz açıklığında 210d/12 numara ağlarla donatılmıştır. Her iki takımda da giriş rampaları aynı uzunluk ve açıda olacak şekilde dizayn edilmiştir.

Pinter ve sepetler 3 yemli (balık, tavuk, ekmek) ve 1 yemsiz (kontrol grubu) olmak üzere toplamda 4 tuzak 1 deneme grubunu oluşturmuştur. Tuzaklara konulacak yemlerin miktarının eşit olması ve fazla yem kullanımının önlenmesi amacı ile yemler av araçlarının hacim olarak %1'ine karşılık gelecek şekilde hazırlanan 9 mm göz açıklığındaki küçük torbalar içinde tuzaklara yerleştirilmiştir. Av araçları birbirlerinin av verimini etkilemesinin önüne geçmek amacıyla her bir operasyon için tesadüfi olacak şekilde birbirine bağlanarak bırakılmıştır. Takımlar zemin yapısı düz ve vejetasyonun olmadığı ~5 m derinliğe atılmış 3 gün suda bekletildikten sonra kaldırılmıştır. Yakalanan kerevitlerin boyları tuzaklara göre 0,1 mm hassasiyette ve ağırlıkları da 0,01g hassasiyette olacak şekilde ölçülmüştür. Çalışmada hedef tür kerevit olması nedeniyle ölçülen kerevitlerle birlikte yakalanan diğer türler canlı olarak tekrar suya bırakılmıştır. Ayrıca çalışmada kullanılan av araçları, kerevitlerde görülebilecek hastalıkların yayılmasının önlenmesi düzenlemesine uygun olarak başka bir iç su kaynağında kullanılmamıştır.





Şekil 2. Çalışmada kullanılan tuzak takımları: A) Pinter B) Sepet

Çalışmada farklı yem kullanılan pinter ve sepet takımlarına ait birim çabaya düşen av miktarının (*CPUE*) belirlenmesinde aşağıdaki eşitlikten yararlanılmıştır.

CPUE = ∑ Av (adet yada ağırlık) / Birim çaba (E)

E= Tuzak sayısı / balıkçılık günü

olarak kullanılmıştır (Ayaz vd., 2016; Cilbiz vd., 2021). Çalışmada avlanma periyodunda, aynı yem kullanılan takımlarla yakalanan kerevitlerin ortalama boylarının karşılaştırılmasında t testi, kullanılan yemlere göre tuzaklardaki adet bazında örnek sayılarının karşılaştırılmasında da ki-kare testi (%95 güven aralığı ve $p<0,05$ önem düzeyi ile) kullanılmıştır. Avcılık denemelerinde yemlere göre her operasyona ait birey sayılarına göre hesaplanan *CPUE*'lar arasında istatistiksel olarak farkın önemli olup olmadığını belirlemek için ikiden fazla grubun karşılaştırılmasında kullanılan tek yönlü varyans analizi (*ANOVA*) uygulanmıştır. Anova testi sonucunda gruplar arası farkın hangi gruptan kaynaklandığının belirlenmesinde Post-Hoc Tests olarak çoklu deney gruplarından elde edilen ortalamaları bir kontrol grubu ile karşılaştırmalarda kullanılan Dunnet's test tercih edilmiştir. Analiz %95 güven aralığında $p<0,05$ önem düzeyine Bonferroni düzeltmesi (0,05/4 = 0,0125) uygulanmıştır (Dunnet, 1955, Sümbüloğlu ve Sümbüloğlu 2000). İstatistik değerlendirmelerde SPSS 23 ve Ms. Excel programlarından yararlanılmıştır.

Bulgular

Çalışmada av araçlarının kullanıldığı sahalardaki yüzey suyu sıcaklığı en yüksek değeri 27,3ºC ile Temmuz ayında ve en düşük değeri de 8,3 ºC ile Şubat sonunda ölçülmüştür. Çözünmüş oksijen miktarı en yüksek değerini 19,27 mg/L olarak Eylül ayında, en düşük değeri de 7,41 mg/L ile Ekim ayında ölçülmüştür. pH değeri ise Temmuz 2020'de 8,26 olarak en yüksek, Mart 2021 de ise 6,88 olarak en düşük değerde ölçülmüştür.

Çalışmada 2020 yılı Ağustos, Ekim, ve 2021 yılı Ocak ve Şubat aylarında hava koşulları veya takımların düzgün serilememesi gibi nedenlerle çalışılamamış, diğer aylarda toplamda 24 başarılı avcılık operasyonu gerçekleştirilmiştir. Tüm denemelerde kerevit haricinde pinter takımlarında toplam 4 adet (776,37g) İsrail sazanı (*Carassius gibelio* (Bloch, 1782)), sepet takımlarında da 3 adet (253,31g) İsrail sazanı ve 1 adet (26,37g) ak balık (*Leuciscus cephalus* (Linnaeus, 1758)) türü yakalanmış ancak değerlendirme dışı tutulmuştur. Kerevit türüne ait toplam av 2820 adet ve 124024,5 g ağırlığındadır. Kerevitlerin av aracına göre dağılımı, %68,8'i (1940 adet) pinter, %31,20'i (880 adet) sepet şeklinde gerçekleşmiştir. Yakalanan bireylerin minimum ve maksimum toplam boyları sırası ile 41,45 mm ve 172,85 mm, ortalama boyları ise 110,09±0,27 mm'dir. Ağırlık olarak minimum 1,61 g, maksimum 137,71 g ve ortalama 42,74±0,35 g bireyler yakalanmıştır (Tablo 1).

Tablo 1. Pinter ve sepet takımlarında farklı yemler ile örneklenen kerevitlerin birey sayısı (N), *CPUE* , toplam boy ve ağırlığın ortalama ± standart hata(SE) değerleri

Av Aracı	Yem	N (Adet)	$CPUE_N$ Ort±SE	$CPUE_W$ Ort±SE	Total Boy (mm)			Ağırlık (g)		
					Min	Mak	Ort ± SE	Min	Mak	Ort ± SE
Pinter	Balık	534	7,42±1,05	**343,8±72,6**	47,56	163,56	107,87±0,59	7,99	115,95	39,81±0,73
	Ekmek	519	7,21±1,18	293,1±48,5	45,32	151,70	109,01±0,62	7,43	109,23	40,66±0,74
	Tavuk	568	**7,89**±1,02	326,9±42,4	75,57	150,93	109,31±0,56	11,76	113,35	41,44±0,73
	Kontrol	319	4,43±0,53	168,3±19,5	60,81	150,91	106,81±0,80	5,44	112,93	37,98±0,94
	Toplam	**1940**	**6,74±0,70**	**283,0±33,6**	**45,32**	**163,56**	**108,4±0,31**	**5,44**	**115,95**	**40,21±0,38**
Sepet	Balık	224	3,11±0,56	150,4±30,9	55,86	154,46	113,89±1,05	4,75	**137,71**	48,35±1,41
	Ekmek	187	2,60±0,51	112,5±23,8	57,05	154,58	110,99±1,17	4,62	107,41	43,30±1,37
	Tavuk	365	**5,07**±0,88	**271,1±50,9**	62,70	**172,85**	117,46±0,74	6,52	135,42	53,48±1,06
	Kontrol	104	1,44±0,22	56,54±10,7	**41,45**	146,35	105,64±1,97	**1,61**	101,93	39,15±2,11
	Toplam	**880**	**3,06±0,35**	**147,6±19,1**	**41,45**	**172,85**	**113,7±0,36**	**1,61**	**137,71**	**48,32±0,47**
Genel Toplam		**2820**	**4,90±0,39**	**215,3±20,0**	**41,45**	**172,85**	**110,09±0,27**	**1,61**	**137,71**	**42,74±0,35**

Pinter ve sepet takımlarının her ikisinde de yeme göre adet olarak en yüksek hesaplanan ortalama $CPUE_N$ değerleri sırası ile 7,89±1,02 ve 5,07±0,88 adet/tuzak/gün olarak tavukla yemlenenlerde bulunmuştur. Ağırlık olarak ise en yüksek $CPUE_W$ değeri, pinter takımlarında balık ile yemlenenler de (343,8±72,6 g/pinter/gün), sepet takımlarında ise tavuk ile yemlenenlerde (271,1±50,9 g/sepet/gün) hesaplanmıştır (Tablo 1).

Pinter ve Sepet takımları ile yakalanmış olan kerevitlerin yem gruplarına ve örnekleme periyotlarına ait toplam boy dağılımları Tablo 2'de verilmiştir.

Pinter takımlarına ait ortalama boy dağılımları, sepet takımları ile yakalanan ortalama boy dağılımlarına göre daha küçük olarak gerçekleşmiştir ($p<0,05$). Her iki tuzağın sadece kontrol grubunda örneklerinin boy ortalama arasında ve tüm yem gruplarında temmuz ve eylül ayında yakalananların boy ortalamalarında fark bulunmamıştır ($p>0,05$). Ekmekle yemlenenlerde ise sadece Mart ayında yakalananların ortalama boylarında fark gözlenmiştir ($p<0,05$) (Tablo 2). Çalışmada farklı yemler ile yakalanan kerevitlerin örnekleme periyotlarında adet bazında birey sayıları ve *CPUE* değerleri Tablo 3'de verilmiştir.

Tablo 2. Tuzaklarda farklı yemler ile yakalanan kerevitlerin toplam boy (mm) dağılımları

Yem	Tarih	Pinter				Sepet				P
		N	Ort±SE	Min	Mak	N	Ort±SE	Min	Mak	
Balık	Temmuz 20	34	107,21±2,4	80,5	141,3	3	131,7 ± 7,9	116,0	140,32	0,078
	Eylül 20	217	103,6 ± 0,9	66,9	160,0	68	106,8 ± 2,0	55,9	137,49	0,143
	Kasım 20	174	110,8±1,1	47,6	163,6	142	116,1 ± 1,2	84,8	146,315	**0,001**
	Aralık 20	33	114,9 ±1,7	97,5	133,9	8	123,6 ± 2,8	114,5	137,102	**0,021**
	Mart 21	76	110,7 ±1,5	81,9	141,2	3	127,9 ± 13,5	110,3	154,462	0,330
	Toplam	**534**	**107,87±0,59**	**47,6**	**163,6**	**224**	**113,89±1,05**	**55,9**	**154,5**	**0,000**
Ekmek	Temmuz 20	22	104,0 ± 2,9	81,8	127,4	2	105,7 ± 8,2	97,5	113,89	0,869
	Eylül 20	211	103,7 ± 1,0	45,3	143,7	58	108,7 ± 2,7	57,1	151,72	0,089
	Kasım 20	233	113,6 ± 0,9	86,5	151,7	113	112,4 ± 1,3	68,9	154,581	0,413
	Aralık 20	34	114,6 ± 1,5	90,1	131,8	12	112,8 ± 4,4	96,6	141,245	0,710
	Mart 21	19	106,9 ± 3,5	83,3	142,7	2	93,7 ± 0,3	93,4	94,0361	**0,002**
	Toplam	**519**	**109,01±0,62**	**45,32**	**151,7**	**187**	**110,99±1,17**	**57,1**	**154,6**	**0,138**
Tavuk	Temmuz 20	34	104,4 ± 2,2	76,9	140,5	5	102,3 ± 5,1	84,1	114,5	0,726
	Eylül 20	216	104,1 ± 0,8	75,6	144,5	26	102,0 ± 3,6	62,7	132,3	0,570
	Kasım 20	220	114,1 ± 0,9	83,6	150,9	234	119,2 ± 0,8	93,6	160,223	**0,000**
	Aralık 20	22	111,4 ± 2,2	90,2	128,8	26	120,5 ± 1,8	95,2	150,615	**0,003**
	Mart 21	76	111,7 ± 1,5	79,9	148,9	74	117,4 ± 1,8	82,8	172,848	**0,017**
	Toplam	**568**	**109,31±0,56**	**75,57**	**150,93**	**365**	**117,46±0,74**	**62,7**	**172,85**	**0,000**
Kontrol	Temmuz 20	15	104,8 ± 4,3	83,1	141,5	2	99,6 ± 15,0	84,9	114,23	0,782
	Eylül 20	127	102,5 ± 1,2	60,8	143,3	49	98,8 ± 3,2	41,5	137,53	0,294
	Kasım 20	114	111,3 ± 1,2	83,9	138,8	35	108,4 ± 2,5	79,9	142,921	0,301
	Aralık 20	31	111,9 ± 2,8	74,7	150,9	16	120,9 ± 3,7	87,9	146,354	0,061
	Mart 21	32	104,0 ± 2,5	80,8	139,7	2	107,9 ± 5,1	102,8	112,975	0,582
	Toplam	**319**	**106,81±0,80**	**60,81**	**150,91**	**104**	**105,64±1,97**	**41,45**	**146,35**	**0,583**
Toplam	Temmuz 20	105	105,3 ± 1,4	76,9	141,5	12	109,8 ± 5,1	84,1	140,32	0,409
	Eylül 20	771	103,6 ± 0,5	45,3	160,0	201	104,8 ± 1,4	41,5	151,72	0,156
	Kasım 20	741	112,8 ± 0,5	47,6	163,6	524	116,2 ± 0,6	83,5	160,223	**0,001**
	Aralık 20	120	113,4 ± 1,0	74,7	150,9	62	119,5 ± 1,6	87,9	150,615	**0,001**
	Mart 21	203	109,7 ± 1,0	79,9	148,9	81	117,0 ± 1,8	82,8	172,848	**0,000**
Genel Toplam		**1940**	**108,4±0,31**	**45,32**	**163,6**	**880**	**113,7±0,36**	**41,5**	**172,8**	**0,000**

24 başarılı deneme sonunda her yem grubu için toplamda 72 tuzak kullanılmıştır. Örnekleme periyodu boyunca yem gruplarına ait *CPUE* değerlerine göre pinter takımları sepet takımlarından daha verimlidir. Örnekleme periyodlarında gerçekleştirilen operasyon sayılarına göre hesaplanan CPUE değerleri arasında yapılan ki-kare (χ^2) testleri sonucunda tüm yem gruplarında farklar anlamlı bulunmuştur (p<0,05)(Tablo3).

Pinter ve sepetlerde, her operasyonda, kullanılan yemlerle elde edilen bireylerin $CPUE_{pinter}$ *ve* $CPUE_{sepet}$ değerlerinde yemler - kontrol grubu aralarında istatistik karşılaştırma amacı ile uygulanan *Anova* testi sonucunda fark bulunmuştur [*F(3, 92)=6,46, p= .00*]. Tablo 4'de bu farkın hangi yemden kaynaklandığını belirlemek için uygulanan Post-Hoc Test (Dunnett's test) analizi sonucunda her iki av aracı için de tavuk-kontrol grubu karşılaştırmasından kaynaklandığı tespit edilmiştir.

Tablo 3. Tuzaklarda kullanılan yemlere göre örnekleme aylarında birey sayısı ve *CPUE* değerleri

Yem	Tarih	Opr. Sayısı	Tuzak Sayısı	Pinter		Sepet		χ2	p
				N	*CPUEp*	N	*CPUEs*		
	Temmuz 20	1	3	34	11,3	3	1,0		
	Eylül 20	9	27	217	8,0	68	2,5		
Balık	Kasım 20	9	27	174	6,4	142	5,3	75,96	0,000
	Aralık 20	2	6	33	5,5	8	1,3		
	Mart 21	3	9	76	8,4	3	0,3		
	Toplam	**24**	**72**	**534**	**7,4**	**224**	**3,1**	**126,78**	**0,000**
	Temmuz 20	1	3	22	7,3	2	0,7		
	Eylül 20	9	27	211	7,8	58	2,1		
Ekmek	Kasım 20	9	27	233	8,6	113	4,2	17,29	0,002
	Aralık 20	2	6	34	5,7	12	2,0		
	Mart 21	3	9	19	2,1	2	0,2		
	Toplam	**24**	**72**	**519**	**7,2**	**187**	**2,6**	**156,12**	**0,000**
	Temmuz 20	1	3	34	11,3	5	1,7		
	Eylül 20	9	27	216	8,0	26	1,0		
Tavuk	Kasım 20	9	27	220	8,1	234	8,7	133,6	0,000
	Aralık 20	2	6	22	3,7	26	4,3		
	Mart 21	3	9	76	8,4	74	8,2		
	Toplam	**24**	**72**	**568**	**7,9**	**365**	**5,1**	**44,16**	**0,000**
	Temmuz 20	1	3	15	5,0	2	0,7		
	Eylül 20	9	27	127	4,7	49	1,8		
Kontrol	Kasım 20	9	27	114	4,2	35	1,3	17,29	0,023
	Aralık 20	2	6	31	5,2	16	2,7		
	Mart 21	3	9	32	3,6	2	0,2		
	Toplam	**24**	**72**	**319**	**4,4**	**104**	**1,4**	**109,27**	**0,000**
	Temmuz 20	1	3	105	8,8	12	1,0		
	Eylül 20	9	27	771	7,1	201	1,9		
Toplam	Kasım 20	9	27	741	6,9	524	4,9	137,25	0,000
	Aralık 20	2	6	120	5,0	62	2,6		
	Mart 21	3	9	203	5,6	81	2,3		
	Toplam	**24**	**72**	**1940**	**6,7**	**880**	**3,1**	**398,44**	**0,000**

Tablo 4. Pinter ve sepet operasyonlarında yem grupları arası Post Hoc Test analizleri

			Post Hoc Test (Dunnet's Test)	
	Gruplar		**P değeri (t test)**	**Karar (Significant)**
Pinter	Balık	Kontrol	0,0151	Fark Yok
	Ekmek	Kontrol	0,0377	Fark Yok
	Tavuk	**Kontrol**	**0,0044**	**Fark Var**
Sepet	Balık	Kontrol	0,0191	Fark Yok
	Ekmek	Kontrol	0,0454	Fark Yok
	Tavuk	**Kontrol**	**0,0002**	**Fark Var**
Yem	$P_{balık}$	$S_{balık}$	**0,0008**	**Fark Var**
	P_{Ekmek}	S_{ekmek}	**0,0008**	**Fark Var**
	P_{tavuk}	S_{tavuk}	0,0424	Fark Yok
	$P_{kontrol}$	$S_{kontrol}$	**0,0000**	**Fark Var**

(Bonferroni Correction = 0,0125)

Aynı yem grubu kullanılan takımlara ait *CPUE* değerleri arasında farkın belirlenmesinde uygulanan tek yönlü varyans analizi (*ANOVA*) sonucunda da fark belirlenmiştir [$F(3, 876)=17,77$, $p= .00$]. Farkı oluşturan grubun bulunması için uygulanan Post Hoc Test analizi sonucunda, tavuk eti kullanılan takımların *CPUE* değerleri arasında fark olmadığı (p>0,0125), balık ve ekmekle yemlenenler ile her iki kontrol gruplarına ait *CPUE* değerleri arasındaki farkın anlamlı olduğu (p<0,0125) sonucuna ulaşılmıştır (Tablo 4).

Tartışma ve Sonuç

Kerevit türlerinin avcılığında pinter ve sepet gibi tuzak sınıfında yer alan av araçlarının kullanımı oldukça yaygındır. Tuzak avcılığını etkileyen birçok faktörün varlığı Romaire (1995) tarafından genel olarak su ortamının özellikleri (su sıcaklığı, su kalitesi, pH, derinlik vb.), türe ait özellikler (popülasyon yoğunluğu, boyut yapısı, yem ve beslenme rejimi vb.), ve av aracına ait özellikler (tuzak ve gün sayısı, yem tipi ve yem miktarı, tuzak tasarımı ve yakalama stratejisi vb.) olarak sınıflandırılmıştır. Bunun yanında substrat (Flint, 1977; Flint ve Goldman, 1977; Somers ve Stechey, 1986), ay döngüleri (Morgan, 1974; Flint, 1977; Somers ve Stechey, 1986) ve predatör türlerin bulunması (Collins vd., 1983) gibi etkenlerde etkili olmaktadır.

Bu çalışmada ortam özelliklerinin tür için uygunluğunun belirlenmesi amacıyla su özelikleri ölçülmüştür. Çalışma süresince yüzey suyu sıcaklığı ortalaması 15,8±2,27°C, pH ortalaması 7,73±0,13 ve çözünmüş oksijen ortalaması 11,78±1,48mg/L olarak belirlenmiştir. Bu su kalite parametreleri, Köksal (1988) tarafından kerevit türünün büyüme ve gelişmesi için kabul edilebilir sınırlar içinde yer almıştır. Kerevit türü için sudaki çözünmüş oksijen miktarının 3 mg/L altına düştüğü durumlarda davranışlarda anormallikler görüldüğü ve hareketin yavaşladığını belirtilmiştir (Aksu ve Harlıoğlu, 2003; Huner, 1988). Su ortamındaki çözünmüş oksijen miktarının belirli bir süre boyunca 3 mg/L'nin altında kalması kerevitlerde fizyolojik strese neden olmakta ve beslenme aktivitelerini etkileyerek yakalanmalarını azaltabilmektedir (Araujo ve Romaire, 1989; Bolat vd., 2011). Çalışmamızda oksijen miktarı en düşük 7,41 mg/L olarak ölçülmüştür. Tüm bu su özelliklerinin türün dağılımı ve gelişimini olumsuz bir etki göstermediği ve dolayısı ile denemelerde avcılığın gerçekleşmesinde de olumsuz bir etkisinin olmadığı görülmüştür.

Kerevit türlerinin genelde güneş batımından sonra, hem hayvansal hem de bitkisel olarak beslendikleri bilinmektedir (Diler, 2013). Yetiştiriciliği ile ilgili yapılan çalışmalarda, besin olarak genelde taze olanları tercih etmekte oldukları ve her türlü et, ticari balık yemleri ile bitki tohumları, patates, havuç, kurutulmuş ot gibi besinleri kullandıkları belirtilmiştir (Alderman ve Wickins, 1990; Yüksel, 2007). Bunun yanında tuzakla avcılıkta yem olarak balık, tavuk, evcil hayvan maması ve karaciğer maması gibi et türevli yemlerin taze olmalarının yakalamada daha etkili olacağı belirtilmiştir (Bean ve Huner, 1978; Somers ve Stechey, 1986). Bu nedenle çalışmamızda kerevit türlerinin besin olarak tüketebileceği balık, ve tavuk yem olarak tercih edilmiş ve etler taze olarak kullanılmıştır. Balık vd. (2003) tarafından Eğridir gölünde yapılan çalışmada pinter avcılığında yem olarak ekmek, patates, elma ve balık (Prusya sazanı *Carassius auratus gibelio* (Bloch, 1782)) kullanmış ve diğer çalışmaların aksine ekmeğin kerevit avcılığında daha etkili olduğunu ve diğer yemlerle boş olanlar arasında fark olmadığını belirtmiştir. Bolat vd. (2011) tarafından yine Eğridir Gölü'nde yapılan diğer bir çalışmada ise Prusya sazanı ile yemlenen ve yemsiz pinter takımları karşılaştırmasında, yemsiz pinterlerin daha etkili olduğundan bahsetmiş olsa da, balıkçılar ve diğer bazı yazarlar tarafından, kerevitlerin yemsiz olarak kullanılacak pinter takımlarındaki verimin daha az olacağı konusunda ortak bir görüş vardır (Somers ve Stechey, 1986; Romaire, 1995; Balık, vd., 2003). Bizim çalışmamızda da pinter takımlarında yakalanan birey sayıları yemsiz olarak kullanılan kontrol grubuna göre, tavuk eti ile yemlenenler 1,78 kat, balık ile yemlenenler 1,67 kat ve ekmek ile yemlenenler 1,63 kat daha fazla yakalamıştır. Sepet takımlarında ise kontrol grubuna göre, tavuk eti ile yemlenenler 3,50 kat, balıkla yemlenenler 2,15 kat ve ekmekle yemlenenler 1,79 kat daha fazla birey yakalamıştır (Tablo 1).

Tuzaklarda yem olarak tavuk kullanılan takımlarda yakalanan kerevitlerin ortalama boyları diğer yemlere göre daha büyük bireyler oluşturmuş (Tablo 2) ve Somers ve Stechey (1986) ve Balık vd. (2003) tarafından yapılan çalışmalarla uyum sağlanmıştır. Ancak Bolat vd. (2011) balık ile yemlenen ve yemsiz tuzak karşılaştırmasında yemsiz tuzakların daha büyük bireyleri yakaladığını sonucunu bulması, akla, daha önce de belirttiğimiz tuzakla yakalamayı etkileyen faktörlerden bazılarından kaynaklı olabileceğini, getirmektedir. Örneğin, av aracının donam özelliği etkili olabilmektedir. Özellikle av araçlarının giriş bölümündeki rampaların donatılma açıları küçük bireylerin tırmanmalarını olumsuz yönde etkilemesi gözlenebilmektedir. Bu çalışmada, rampadan kaynaklı etkinin azaltılması için her iki av aracının giriş bölümündeki rampalar aynı açıya sahip olacak şekilde donatılmış ve av verimi üzerine yemin etkili olması üzerinde durulmuştur.

Pinter ve sepet takımları arasında donam yapılarındaki farklılık pinter takımlarında yönlendirme bölümünün yer almasıdır. Bu sayede av pinter ağzına yönlendirilir ve yakalamayı daha etkili kılar. Tür barınma ya da beslenme amacıyla tuzaklar içine girebilmektedir (Cilbiz vd. 2021). Çalışmada Tablo 3'te gözlenen sonuçlara göre de pinter takımlarının tüm yem gruplarına ait *CPUE* değerleri sepet takımlarındakilerden daha fazladır. Sepet takımlarında ise yönlendirme ağının olmamasına rağmen, yem kullanılanların, yem kullanılmayan kontrol grubuna göre daha fazla *CPUE* değerlerine sahip olması (Tablo 3), kerevitin barınma içgüdüsünden ziyade, yeme yöneliminin daha etkili olması sonucu yakalandığını düşündürmektedir.

Kerevitlerin hangi yemi tercih ettikleri ile ilgili yapılan karşılaştırmalarda her iki av aracı için de tavuk-kontrol grubu karşılaştırmasından kaynaklandığı tespit edilmiştir (p<0.0125) (Tablo 4). Bu sonuçlar kerevitlerin tuzaklara yakalanmalarında yem kullanımının ve özellikle tavuk eti ile yemlemenin daha etkili olduğunu göstermiştir.

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RESEARCH ARTICLE

Length-Weight Relationships of *Fistularia commersonii* Rüppell 1835 from the Northeastern Mediterranean Sea, Türkiye

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Abstract: In this study, the length-weight data for bluespotted cornetfish, *Fistularia commersonii* in the Iskenderun Bay (NE Mediterranean Sea, Türkiye) was reported. *F. commersonii* specimens were caught from Iskenderun Bay between September 2018 and March 2019. The total length and total weight of both sexes varied from 23.0-108.1 cm and 4.0-599.58 g. The length-weight relationship was determined as $W= 0.0005xL^{2.963}$ (R^2= 0.969) with negative allometric growth for both sexes. The values of the exponent b of the length-weight relationships (LWRs) were 2.993 for females and 2.925 for males. This present study provides the first comprehensive gender-based description of the length-weight relationships of *F. commersonii* from the northeastern Mediterranean Sea, Türkiye

Anahtar kelimeler:

Fistularidae
Boy
Ağırlık
Regresyon parameterleri
Iskenderun Körfezi
Akdeniz

Kuzeydoğu Akdeniz'den (Türkiye) *Fistularia commersonii* Rüppell 1835'nin Boy-Ağırlık İlişkileri

Öz: Bu çalışmada, İskenderun Körfezi'ndeki (KD Akdeniz, Türkiye) külah balığı, *Fistularia commersonii* Rüppell 1835 için uzunluk-ağırlık verileri rapor edilmektedir. İskenderun Körfezi'nden yakalanan *F. commersonii* örnekleri üzerinde Eylül 2018 ve Mart 2019 tarihleri arasında bir çalışma yapılmıştır. Her iki cinsiyetin toplam uzunluğu ve toplam ağırlığı 23.0-108.1 cm ve 4.0-599.58 g arasında değişmiştir. Boy-ağırlık ilişkisi, her iki cinsiyet için negatif allometrik büyüme $W= 0.0005xL^{2.963}$ (R^2= 0.969) olarak belirlenmiştir. Boy-ağırlık ilişkilerinin (LWR'ler) b üssünün değerleri, dişiler için 2.993 ve erkekler için 2.925'tir. Bu çalışma, Türkiye'nin Kuzeydoğu Akdeniz bölgesinden *F. commersonii*'nin boy-ağırlık ilişkilerinin cinsiyetlerine göre ilk kapsamlı tanımını sunmaktadır.

Introduction

Members of the family Fistularidae are represented by the genus *Fistularia* Linnaeus, 1758 with four valid species described in the literature so far; *Fistularia commersonii* (Rüppell, 1838), *Fistularia corneta* (Gilbert and Starks, 1904), *Fistularia petimba* (Lacepède, 1803), and *Fistularia tabacaria* (Linnaeus, 1758) (Fritzsche, 1976). *F. commersonii* and *F. petimba* species have been reported in the Mediterranean waters (CIESM, 2022) and the Red Sea (Fischer & Bianchi, 1984).

The blue-spotted cornetfish *F. commersonii* is a reef-associated fish species and occurs between depth ranges of 0 - 132 m (Mundy, 2005) and is commonly found in sandy bottoms and near seagrass meadows (Fritzsche, 1976; Watson & Sandknop, 1996; Bilecenoglu et al., 2002; Pais et al., 2007). It mainly feeds on many small fishes, various squids, and shrimps (Hiatt & Strasburg, 1960; Khalaf & Disi, 1997; Saad & Sabour, 2010).

Living organisms that migrate to the Mediterranean via the Red Sea are called "Lesepsian species". *F. commersonii* is known as a lessepsian sprinter species (Stern et al., 2017) with a fast-spreading and wide geographical distribution (Karachle et al., 2004). This lessepsian splinter species was first recorded from the coasts of Israel (Eastern Mediterranean) (Golani, 2000, Golani et al., 2007, Golani, 2010).

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The length-weight relationship is a critical parameter in fish biology (Erguden et al., 2017; Erguden et al., 2018; Erguden et al., 2020) and is used to recognize the ecology and life cycle of fish species when morphological comparison of populations from different geographical areas are made (Petrakis & Stergiou, 1995). The length-weight relationship parameters can also provide information on the stock condition and growth studies. In addition, the length-weight relationship is commonly used to convert growth-in-length equations for the prediction of weight-at-age and apply in stock assessment models (Pauly, 1993), to calculate condition indices (Anderson & Neumann, 1996).

In the Mediterranean Sea, previous compherensive studies of the bluespotted cornetfish which were carried out were focused on the population structure of the species (Bariche, & Kajajian, 2012), maximum length and biological data (Edelist, 2014; Castriota et al., 2014; Mouine-Oueslatia et al., 2017), diet (Bariche, 2007; Bariche et al., 2009; Kalogirou et al., 2007), reproduction (Bariche et al., 2013, morphometry (Raghep, In press), new record (Golani, 2000, Bilecenoglu et al., 2002; Corsini et al., 2002; Azzurro et al., 2004; Ben Souissi et al., 2004; Fiorentino et al., 2004; Pipitone et al., 2004; Azzurro, 2006; Micarelli et al., 2006; Sanchez-Tocino, 2007; Dulcic et al., 2008; Kara & Oudjane, 2008; Psodomakis et al., 2009; Rafrafi-Nouira et al., 2011; Meloni & Piras, 2013) and distribution (Gokoglu et al., 2002; Corsini et al., 2002; Ligas et al., 2007; Pais et al., 2007; Joksimović et al., 2008; Occhipinti-Ambrogi & Galil, 2008; Garibaldi & Orsi Relini, 2008; Hemida & Capapé C. 2009; Elbaraasi & Elsalini, 2009; Bodilis et al., 2011; Deidun & Germanà, 2011; Azzurro et al., 2013; Türker Çakır et al., 2014; Bănaru & Harmelin-Vivien, 2018).

Although only a few studies have been conducted on *F. commersonii* length-weight relationships (Taskavak & Bilecenoglu, 2001; Erguden et al., 2009) and maximum length (Torcu Koc et al., 2019) in the Mediterranean coasts of Turkey, none of the results of the reported length-weight data were evaluated with respect to gender. The present study, comprehensively reports the length-weight relationships (LWRs) of male and female *F. commersonii* foe rhe first time in the eastern Mediterranean, Türkiye.

Material and Methods

A total of 146 fish specimens were collected from a commercial trawler at 10-30 m depths between September 2018 and March 2019 from 4 different fishing localities (Samandag, Arsuz, Pirinclik, Dörtyol) in the Iskenderun Bay, Turkey (Figure 1). The collected specimens were identified onboard and then preserved in an ice box. In the laboratory, each fish was measured for total length (TL) to the nearest 0.1 cm and weighed to the nearest 0.01 g. Fish specimens were identified based on Fritzche (1976) and Golani (2000) and also validated following FishBase (Froese & Pauly, 2022).

Figure 1. Sampling areas in the Iskenderun Bay

The length-weight relationships were established using linear regression analysis with the equation W= axL^b (*W*: fish weight, *TL*: fish total length, *a*: intercept parameter, and *b*: slope parameter). Logarithmic expression was used for the data. TW and TL were converted: lnTW =ln(a) + bln(TL) (Bagenal & Tesch, 1978; Avşar, 2016).

The determination coefficient (r^2) was used as an indicator of the quality of the linear regression. A significant difference of b values from 3, which represent isometric growth, was tested using a t-test (Pauly 1993). Analysis of variance (ANOVA) was used to test the difference of the b values of the length-weight relationship between sexes (Zar, 1999). All data were statistically analyzed by using Microsoft Excel 2018 and IBM SPSS statistics (Version 23.0, Armonk NY: IBM Corp.) package programs.

Results

In this study, a total of 146 (86 females and 60 males) *F. commersonii* specimens which were caught from Iskenderun Bay were examined. The population of *F. commersonii* of comprised of 58.9% of females and 41.1% of males. The sex ratio for female and male individuals (M:F) was 1.00:1.43. The difference between male to female ratio was not statistically significant at 0.05, (p>0.05).

The total length of all individuals ranged from 23.00 to 108.10 cm TL and weighed between 4.00 g. and 599.58 g. Males and females ranged from 23.00 to 98.50 cm TL and 29.00 to 108.10 cm TL. The maximum TL and weight recorded as 108.10 cm and 599.58 g, respectively belonged to a female individual of *F. commersonii*. The descriptive statistics and estimated parameters of the length-weight relationship are given in Table 1. The ANOVA test indicated the differences length-weight relationships between females and males were not statistically significant ($P > 0.001$). Length-weight relationships are given in Table 2 for females, males and both sexes, including sample size (n), equation parameters a and b, the 95% confidence limits for both parameters and the coefficient of determination (r^2).

Table 1. Mean and standard deviation, maximum, minimum for length (L) and weight (W) parameters of each sex of *Fistularia commersonii*

Sex	n	Total Length (Min-Max)	Total Length Mean±SE	Total Weight (Min-Max)	Total Weight Mean±SE
Female	86	29.00-108.10	64.00±2.11	7.00-599.58	140.56±15.27
Male	60	23.00-98.50	63.67±2.11	4.00-39 6.30	131.21±14.40
Both sexes	146	23.00-108.10	63.86±1.62	4.00-599.58	136.72±10.68

n: Sample size; Min: minimum; Max: maximum

Table 2. Length-weight relationships of *Fistularia commersonii* from Iskenderun Bay, Turkey

n	Sex	a	b	r^2	SE of b	95% CI of b	P	Growth Type
86	Female	0.00040	2.993	0.965	0.062	2.870-3.117	<0.05	Allometric (-)
60	Male	0.00050	2.925	0.974	0.063	2.799-3.050	<0.05	Allometric (-)
146	Both sexes	0.00050	2.963	0.969	0.044	2.875-3.050	<0.05	Allometric (-)

n: Sample size; a: Intercept of the relationship; b: Slope of the relationship; S.E: Standart error, r^2: Coefficient of determination

Overall, the b value for both of female (b = 2.993) and male (b = 2.925) population were calculated as negative allometric growth (b < 3.00) (Figure 2). The length-weight relationships of *F. commersonii* for female, male and both sexes, were described as W= $0.0041xL^{2.993}$ (R^2= 0.965), W= $0.0005xL^{2.925}$ (R^2= 0.974) and W= $0.0005xL^{2.963}$ (R^2= 0.969) respectively (Figure 2). The length-weight regressions were significant ($P < 0.001$) for all sexes, with all r^2 values greater than 0.96.

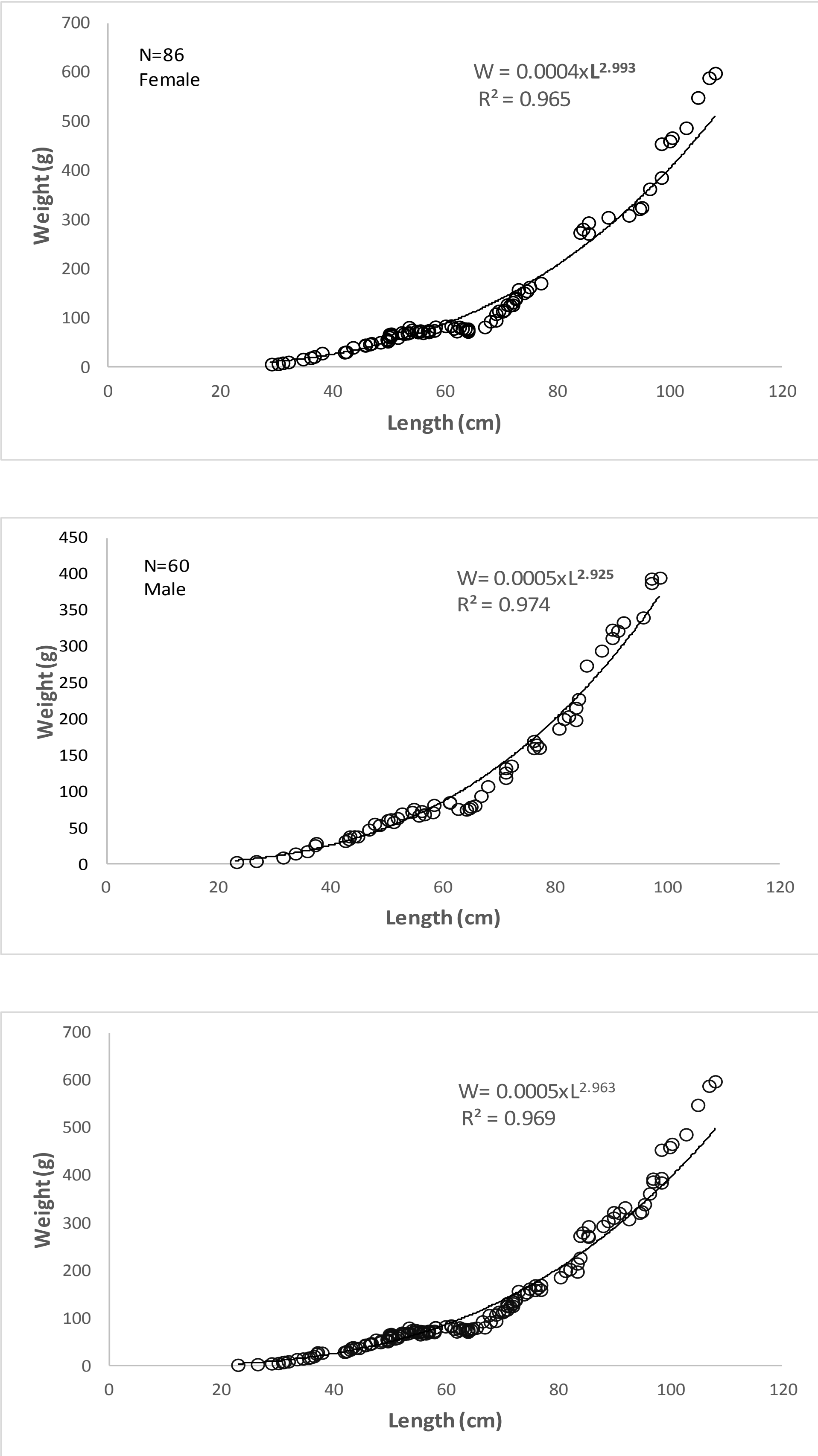

Figure 2. Length-weight relationship of female, male and both sexes for *Fistularia commersonii* from the Iskenderun Bay (Eastern Mediterraenan Sea)

Discussion

Overall, sex ratio (male: female = 1.00:1.43) was slight different from the accepted ratio of 1:1 ($\chi 2 = 5.21$, $p > 0.05$) with the dominance of females in the population which is similar to Bariche & Kajajian (2012) who found the sex ratio as 1:1.51 from the eastern Mediterranean waters. The sex ratio may vary from species to species, even differing from one population to another within the same species, and may also show temporal variations within the same population (Nikolsky, 1980). Small differences in the sex ratio may also be due to the sample size.

The total lengths for both sexes ranged between 23.0-108.0 cm (63.86 ± 1.42) and the total weight ranged between 4.0-599.58 g (136.72±10.68). Females were found to grow slightly larger than the males. Larger samples with higher length and weight values were reported in other studies. For example, Torcu Koc et al. (2019) reported max length (116.5 cm TL) and weight data (1291.88 g) for *F. commersonii* collected from Iskenderun Bay (Mediterranean Sea, Turkey) (Table 3). Similarly, Dulcic et al. (2008) declared a maximum length of 115.0 cm TL and a maximum weight of 1210.0 g for *F. commersonii* from the Adriatic Sea, Croatia. In the previous studies in Table 3; Golani (2000) reported the standard length as 26.8-51.6 cm for *F. commersonii* from the Mediterranean Sea (Israel). While Corsini et al. (2002) stated that the minimum and maximum values of standard lengths of the samples collected from Rhodes Island (Adana, Turkey) ranged between 14.1-73.4 cm, Kalogirou et al. (2007) reported the standard length as 5.0-108.0 cm for *F. commersonii* collected from SE Aegean Sea (Greece). However, Saad & Sabour (2010) reported the total length as 29.0-108.0 cm for *F. commersonii* collected from the Syrian coast (Syria). Deidun and Germana (2011) stated that the minimum and the maximum values of total length for *F. commersonii* collected from Maltese Islands (Malta), ranged between 30.0-110.0 cm. Bariche & Kajajian (2012) reported the total length as 19.2-113.1 cm from the Tunisian coast (Tunisia). Bilge et al. (2014) reported the total length as 31.4-63.2 cm for *F. commersonii* collected from the Southern Aegean Sea (Turkey). In addition, investigation on the populations of the *F. commersonii* living in the Central Mediterranean Sea and South of Sicily showed that the minimum and the maximum values of total length ranged between 66.0-115.0 cm and 66.0-115.0 respectively (Castriota et al., 2014; Vitale et al., 2016). The nearest one to the length values presented in our study stated that the minimum and the maximum values of the total length as 24.1-107.5 for *F. commersonii* collected from West of Alexandria, (Egypt) Raghep (2002). Comparison of previously published maximum length-weight data for *F. commersonii* from different Mediterranean areas is given in Table 3.Size differences are related to sex, fishing gear, season and habitat and are also considerably affected by factors such as reproductive activity, nutrition and environmental factors (Le Cren, 1951; Froese, 2006).

The b value of the length-weight relationships varies between 2.5 to 3.5 (Froese 2006). A value of *b* indicates that fish grows symmetrically or isometrically and allometrically in which *b* is different from 3. In this study, b values were calculated as 2.993, 2.925, and 2.963 for females, males and both sexes which indicated negative allometric (-) growths, respectively. Comparison of the b values from different regions showed that these values vary from negative to positive allometric growths (Table 4).

The b values found in the present study were generally in agreement with similar results for the Mediterranean waters of Turkey (Table 4). Erguden et al. (2009) reported the b value as 2.540 for *F. commersonii* from Southeastern Mediterranean. Bilge et al. (2014) reported the b value as 2.727 from Southern Aegean Sea, Turkey. On the contrary, the previous studies of positive (+) allometric growth of *F. commersonii* have been reported by Kalogirou et al. (2007) and Castriota et al. (2014). In their studies, b values for both sexes of *F. commersonii* were calculated as b= 3.377 in the SE Aegean Sea and 3.372 from the Mediterranean Sea. Similar findings from the Mediterranean waters were reported; Bariche and Kajajian (2012) and Vitale et al. (2016) reported b values as 3.406 and 3.619 respectively, for *F. commersonii*. These differences of b value may stem from differences in ecological factors (Wootton, 1998). According to Le Cren (1951), b value may fluctuate in a particular species due to gender, food availability, preservation method, gonadal maturation, and physiological condition.

Length-weight relationships in fishes are affected by several factors including habitat, area, seasonal effect, general fish condition, gonad maturity, sex, diet and stomach fullness, health and preservation techniques (Tesch, 1971; Bagenal & Tesch, 1978). Consequently, the present length and weight relationships reported in this study may be usefult for fishery biologists to compare general health status, morphological characteristics and the growth pattern of *Fistularia commersonii* populations from different locations and habitats and can be used as a guideline for this species in the future.

Table 3. Comparison of maximum length-weight data for *F. commersonii* from different localities in the Mediterranean Sea

References	Max Length (cm)	Length Type	Weight (g)	Locality/Country
Golani (2000)	51.6	SL	82.5	Mediterranean Sea, Israel
Bilecenoglu et al. (2002)	72.8	TL	-	Antalya Bay, Turkey
Gökoglu et al. (2002)	77.5	TL	350.0	Antalya Bay, Turkey
Gökoglu et al. (2002)	64.0	TL	180.0	Gökova Bay, Turkey
Corsini et al. (2002)	73.4	TL	-	Rhodes Island, Greece
Karachle et al. (2004)	92.0	TL	448.1	North Western Aegean Sea, Greece
Ben Soussi et al. (2004)	98.7	TL	-	Gabes Gulf, Tunisia
Fiorentino et al. (2004)	90.4	TL	345.0	Strait of Sicily, Italy
Azurro et al. (2004)	104.5	TL	-	Strait of Sicily, Italy
Pipitone et al. (2004)	84.5	SL	-	NW Sicily, Italy
Micarelli et al. (2006)	78.9	TL	-	North Tyrrhenian Sea, Italy
Sanchez-Tocino (2007)	104	TL		Iberian Peninsula
Garibaldi & Orsi Relini (2008)	92.6	TL	450.0	Ligurian Sea
Dulcic et al. (2008)	115.0	TL	1210.0	Adriatic Sea, Croatia
Psomadakis et al. (2008)	84.7	-	-	Latium coasts, Italy
Joksimovic et al. (2009)	71.5	TL	-	Montenegrin Coast
Bariche et al. (2009)	112.0	TL	-	Lebanon
Hemida & Capape (2009)	83.5	TL	-	Algerian coast
Kara & Oudjane (2009)	86.3	TL	405.0	Algerian Coast, Algeria
Psomadakis et al. (2009)	101.3	TL	-	Aegean Sea, Greece
Ergüden et al. (2009)	65.0	TL	98.20	Eastern Mediterranean, Iskenderun Bay, Turkey
Deidun & Germanà (2011)	102	TL	450.0	Maltese Waters, Maltese
Bodilis et al. (2011)	100	TL	-	French Coast, France
Bariche et al. (2013)	113.0	TL	-	Mediterranean Sea
Meloni & Piras (2013)	92.0	TL	170.0	South Western Mediterranean Sea, Sardinia, Italy
Edelist (2014)	99.5	TL	926.0	Israel
Türker-Çakır et al. (2014)	53.9	TL	68.8	Edremit Bay, Turkey
Mouine-Oueslatia et al. (2017)	80.0	TL	930.2	Gulf of Tunis, Tunisia
Bănaru & Harmelin-Vivien (2018)	99.0	TL	347.2	Bay of Marseille, France
Elbaraasi & Elsalini (2009)	95.0	TL	395.0	Benghazi, Libya Coast
Torcu Koc et al. (2019)	116.5	TL	1291.88	Iskenderun Bay, Turkey
This study	108.1	TL	599.58	N.E Mediterranean, Turkey

n: Sample size; TL: Total length; SL; Standard length

Table 4. Comparison of length-weight relationships parameters for *F. commersonii* from different regions

Author(s)	Area	n	Length Type (cm)	Sex	Length Min-Max (cm)	a	b	r^2
Fritzsche (1976)	Pacific Ocean	29	SL	-	17.8-86.5	-	-	-
Pauly et al. (1998)	Manila, Philippines	2	TL	-	78.0-104	0.00056	3.000	-
Golani (2000)	Mediterranean Sea, Israel	3	SL	-	26.8-51.6	-	-	-
Corsini et al. (2002)	Rhodes Island, Greece	37	SL	F+M	14.1-73.4	-	-	-
Kalogirou et al. (2007)	SE Aegean Sea, Greeece	245	SL	F+M	5.0-108.0	0.000147	3.377	0.994
Ergüden et al. (2009)	Southeastern Mediterranean, Turkey	12	TL	F+M	58.0-65.0	0.01120	2.540	0.981
Saad & Sabour (2010)	Syrian Coast	40	TL	F+M	29.0-108	-	-	-
Deidun and Germana (2011)	Maltese Island	21	TL	F+M	30.0-110.0	-	-	-
Rafrafi-Nouira et al. (2011)	Tunisian coast	14	TL	F+M	94.3-107.4	-	-	-
Bariche & Kajajian (2012)	Mediterranean Sea	1073	TL	F+M	19.2-113.1	0.01066	3.406	0.989
Bilge et al. (2014)	Southern Aegean Sea, Turkey	48	TL	F+M	31.4 - 63.2	0.01180	2.727	0.992
Castriota et al. (2014)	Central Mediterranean Sea	60	TL	F+M	66.0-115.0	0.00010	3.372	0.857
Vitale et al. (2016)	South of Sicily	23	TL	F+M	69.0-104.0	0.0000009	3.619	-
Raghep (2022)	West of Alexandria, Egypt	338	TL	F+M	24.1-107.5	-	-	-
This study	N.E Mediterranean, Turkey	146	TL	F+M	23.0-108.1	0.0005	2.963	0.969

n: Sample size; TL: Total length; SL; Standard length; F: Female; M: Male; a: Intercept of the relationship; b: Slope of the relationship; r^2: Coefficient of determination

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Conflict of Interest

Authors declare no conflict of interest pertaining to the publication of this manuscript.

Author Contributions

Deniz Ergüden (DE): Designed the study, Data curation, Validation, Investigation, Formal analysis, Writing - original draft, final editing. Mevlut Gürlek (MG): Validation, Supervision, Investigation, review & editing. Cemal Turan (CT): Data curation, Validation, Supervision, Investigation, Formal analysis, Writing - original draft, Writing - review & editing. All authors discussed the results and contributed to the final version of the paper.

Ethics Approval

The materials used in the article were collected from the commercial trawler. Ethics committee approval is not required for this study. The study was carried out with the research permit (date: 29.09.2017 and number: E.2412565) of the Ministry of Agriculture and Forestry, General Directorate of Fisheries and Aquaculture.

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RESEARCH ARTICLE

The Exotic Species and Their Catch Per Unit Effort (CPUE) from Gillnet Fisheries in the Southern Aegean Coasts (Türkiye)

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Abstract: This study presents some exotic fish diversity and catch per unit effort values of exotic fish from gillnet fishery along the southern Aegean Sea. Lessepsian puffer fish (*Lagocephalus sceleratus*), lionfish (*Pterois miles*), squirrelfish (*Sargocentron rubrum*), rabbitfish (*Siganus* sp.) and a blue crab (*Portunus segnis*) were caught in the Aegean Sea. Rabbitfish and blue crab sell in the fish markets. Seasonally, the average CPUE of exotic fish was calculated to be 0.7 ± 0.3 kg.1000 m^{-1} in autumn in catch. This value indicated that it was 72 times lesser than the total seasonal CPUE.

Anahtar kelimeler:

Egzotik balık
İstilacı tür
CPUE
Küçük ölçekli balıkçılık
Ege Denizi

Güney Ege Kıyıları (Türkiye) Uzatma Ağları Balıkçılığında Egzotik Türler ve Birim Çaba Başına Düşen Av (CPUE) Miktarları

Öz: Bu çalışma, Güney Ege Kıyıları boyunca uzatma ağları balıkçılığından bazı egzotik balık çeşitliliğini ortaya koymakta ve egzotik balıkların birim çaba başına düşen av değerlerini sunmaktadır. Araştırmada Ege Denizi'nde Lesepsiyen balon balığı (*Lagocephalus sceleatus*), aslan balığı (*Pterois miles*),sincap balığı (*Sargocentron rubrum*), sokar balıkları (*Siganus* sp.) ve bir mavi yengeç (*Portunus segnis*) yakalandı. Sokar balıkları ve mavi yengeç balık pazarlarında satılmaktadır. Mevsimsel olarak, ortalama egzotik balık CPUE'si, en yüksek sonbaharda 0,7 ± 0,3 kg.1000 m^{-1} olarak hesaplanmıştır. Bu değer, toplam mevsimsel CPUE'den 72 kat daha az olduğunu göstermiştir.

Giriş

Son yıllarda artan küresel ısınmaya bağlı olarak Akdeniz, tropikalizasyon sürecine girmiş olup (Bianchi ve Morri, 2003); özellikle Süveyş Kanalı yoluyla Hint-Pasifik kökenli balıkların; Cebelitarık Boğazı yoluyla ise Atlantik kökenli balıkların ve gemi balast suları yoluyla da her iki kanaldan Akdeniz'e geçip yaşama şansı bulan türlerin sayısında önemli artışlar yaşanmaktadır. Çınar ve Bilecenoğlu (2015), Akdeniz'in yabancı tür çeşitliliği açısından oldukça zengin noktalardan biri olarak kabul edildiğini ve bölgeden bugüne kadar 1000'e yakın yabancı türün bildirildiğini ifade etmişlerdir. Rapor edilen son listede, 2020 itibariyle Türkiye denizlerinde toplam 539 yabancı türün bulunduğu, bunların 404'ünün yerleşik olduğu, 105 türün işgalci olduğu bildirilmektedir (Çınar vd., 2021).

Balıklar, Akdeniz de yaşayan tüm deniz canlıları arasında yaklaşık 650 tür ile en yoğun bulunan gruplardan biridir (Coll vd., 2010). Bunun yanı sıra Temmuz 2015'te Süveyş Kanalı'na yeni bir kanalın inşasıyla kanal büyük ölçüde genişletilmiş ve bu genişleme girişiminin, Akdeniz'de önemli, geri dönüşü olmayan ekolojik ve ekonomik sonuçlara yol açabilecek daha fazla Lesepsiyen türlerin girişini kolaylaştıracağı öngörülmüştür. Makrofit, omurgasız ve balık olarak ise bugüne kadar, 89'u beş veya daha fazla ülkede kaydedilen toplam 443 türün Süveyş Kanalı üzerinden Akdeniz'e girdiği bilinmektedir (Galil vd., 2015).

Egzotik türlerin ilk kolonizasyon alanlarından biri ve önemlisi coğrafik konumu nedeniyle Türkiye kıyılarıdır. Çınar vd. (2021) tarafından gerçekleştirilen son kontrol listesinde, Türkiye kıyıları boyunca dağılmış yerli olmayan balık türlerinin kayıt sayısının 80'i bulduğu rapor edilmiştir. Bu türlerin 73'ü Akdeniz, 44'ü Ege, 6'si Marmara ve 3'ü Karadeniz'de dağılım göstermektedir.

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Bunlardan bazıları (örneğin, ceylan balığı, paşa barbunu, sokar balıkları, vb.) ekonomik olarak balıkçılığa katkı yaparken, bazıları (balon balıkları, aslan balıkları, vb.) ekolojik, ekonomik ve sosyal problemler ortaya çıkarabilmektedir. Bu durumdan, günümüzde Ege Denizi'nin en kuzey kıyıları dahi etkilenmektedir. Ege Denizi özelinde istilacı türlerin varlığı bilinmekle beraber, yeterli izleme yapılamadığından tür sayılarındaki değişimler, stok boyutları ve balıkçılıkla etkileşimi tam olarak bilinmemektedir. İstilacı türler sosyal, ekonomik ve hatta insan sağlığı açısından hayati öneme sahip olduğu için her ülke bu türlerin alımı-satımı ve tüketimi hakkında yasal düzenlemelere gitmektedir. Ülkemizde 4/1 Numaralı Ticari Amaçlı Su Ürünleri Avcılığının Düzenlenmesi Hakkında Tebliğde (Madde 17- 4) balon balıklarının avlanması, satılması ve tüketilmesi yasaklanmıştır (Anon. 2016). Daha sonra balon balığının avcılığı izne bağlı olarak imha amaçlı serbest bırakılmıştır (Tebliğ No: 2020/9). Yine son yıllarda Türkiye'nin Akdeniz kıyılarından giriş yapan, hızla batıya ve Ege Denizi'ne doğru nüfuzunu arttıran aslan balıklarının (*Pterois miles*) oldukça zehirli olduğu bilinmektedir. Bu tür denizlerimiz için endişe veren bir tür olarak izlemeye alınmıştır.

Yabancı yayılımcı türlerin Ege Denizi özelinde izlemeye alınması bölgemiz balıkçılığı ve turizmi açısından oldukça önemlidir. Türkiye özellikle Kızıldeniz yoluyla giriş yapan bu türlerin ilk durak noktasını oluşturmakta, ilk etkilenen ülkelerin başında gelmektedir. Kısaca Türkiye Akdeniz için bir erken uyarı noktasıdır. Bu türlerin zararlı olanlarının (balon balıkları, aslan balıkları, vb.) tür ve yoğunluk tespitini yapmak, türler üzerine kamuyu bilgilendirmek ve balıkçılık idarecilerine acil önlem uyarıları ve önerileri geliştirmek, ayrıca balıkçıların bu balıkları avlarken, avlandıktan sonra dokunurken nasıl davranması gerektiği ve satışını yapıp, yememeleri konusunda bilinçlendirilmeleri oldukça önemli hususlardır.

Bu çalışmanın amacı, Akdeniz'e çeşitli yollarla giren, yabancı-istilacı balık türlerinin Ege Denizi'nde uzatma ağları balıkçılığı ile yakalananların bir tür listesini ortaya çıkarmak, bu türlerin birim çaba başına av miktarlarını tespit etmektir.

Materyal ve Yöntem

Bu çalışmada, Ekim 2017 – Aralık 2019 tarihleri arasında Ege Denizi'nin güney kıyılarında çeşitli balıkçı barınakları ve teknelerde gözlemler yoluyla elde edilmiş veriler değerlendirilmiştir. Özellikle Ege Denizi'nin güneyinde yer alan Fethiye Körfezi'nden başlayarak, Bodrum ve Güllük Körfezi'nde çalışmalar yapılarak, ana balıkçı barınaklarında uzatma ağı balıkçılığı gerçekleştiren balıkçılardan gözlem yoluyla av kayıtları tutulmuştur. Bu amaçla Fethiye'den 1, Turgutreis'ten 2, Gündoğan'dan 19, Torba'dan 2, Türkbükü'nden 25, Apostol Adası civarından 66, Didim'den 18, Akbük'ten 33, Kazıklı'dan 7 ve Salih Adası civarından 6 olmak üzere toplam 179 av kaydı formlara işlenmiştir.

Çalışmanın yürütüldüğü Ege Denizi'nin güney kıyı barınaklarından Söke, Göltürkbükü, Gündoğan, Turgutreis, Gümüşlük, Yalıkavak, Akyarlar, Boğaziçi, Güllük, Akyaka, Fethiye toplam 49 kıyı balıkçısıyla görüşülerek kullandıkları teknelerin bazı özellikleri kayıt formlarına işlenmiştir.

Av kayıtlarından elde edilen veriler mevsimsel olarak ve yıllara göre havuzlanmış ve birim çaba başına av (CPUE) ile egzotik türlerin birim çaba başına av miktarları uzatma ağları için günlük kg.1000 m^{-1} ağ olarak hesaplanmıştır.

Verilerin normal dağılım içerisinde yer almaması sebebiyle elde edilen sonuçlar arasındaki farkın istatiksel olarak önem düzeyi parametrik olmayan Kruskal-Wallis testi ile ortaya konmuştur. Tüm analiz ve grafik hazırlama işlemlerinde R programlama dili altında gerçekleştirilmiş (R Core Team, 2020) ve Tidyverse paketi (Wickham vd. 2019) kullanılmıştır.

Bulgular

Çalışmanın yürütüldüğü Ege Denizi'nin güney kıyı barınaklarındaki balıkçılar ile gerçekleştirilen görüşmelerde kullanılan teknelerin bazı özelliklerine dair bilgiler Tablo 1'de özetlenmiştir.

Tablo 1'de verilen değerlerden sadece bir tekne (Söke) motorsuz olarak kullanılmaktadır. Tekneler ya tek kişi tarafından kullanılmakta ya da 3 kişiye kadar tayfa bulundurmaktadır. Teknelerin tamamı ahşap materyalden yapılmıştır. Teknede bulunan av araçları uzatma ağı, paragat ve oltadır. Teknelerde sadece uzatma ağı kullananların oranı %37, paragat kullananların oranı %21, hem uzatma ağı hem de paragat kullananların oranı %35, bunlara ilaveten olta kullananların oranı ise %4 ve uzatma ağı yanında sadece olta kullananların oranı ise %2 civarındadır.

Balıkçıların kullandıkları av araçlarıyla genellikle kupes, akya, mercan, çipura, karagöz, mırmır, mürekkepbalığı, kalamar, ahtapot, lahos, kılıç, barbun, tekir, fangri, sinarit, turna gibi balıkları hedefledikleri belirlenmiştir. Balıkçılar avları sırasında egzotik türlerden sırasıyla en çok balon balığı *(Lagocephalus sceleratus* %96), sokar (*Siganus* spp. %16), aslan balığı (*Pterois miles* %16), sincap veya Hindistan balığı (*Sargocentron rubrum* %2) ve mavi yengeçe (*Portunus segnis* %2) rastladıkları tespit edilmiştir (Şekil 1). Bunların yanı sıra fok (*Monachus monachus* %16) ve deniz kaplumbağasının (*Caretta caretta* %14) da balıkçıların ağlarına kazayla takılmakta olduğu belirlenmiştir.

Çalışmada ticari balıkçıların uzatma ağlarıyla gerçekleştirdiği operasyonlarda birim çaba başına av CPUE değerleri 0 ile 525 kg.1000 m^{-1} arasında değişirken, ortalama 38,6 ±4,17 kg.1000 m^{-1} olarak tespit edilmiştir.

Uzatma ağlarıyla ticari balıkçıların gerçekleştirdiği avcılıkta mevsimsel avın ortalama CPUE'si sonbaharda en düşük ilkbaharda en yüksek düzeyde hesaplanmıştır (Tablo 2; Şekil 2). CPUE değerleri ile mevsimler arasındaki fark istatistiki olarak önemli bulunmuştur ($p<0,05$).

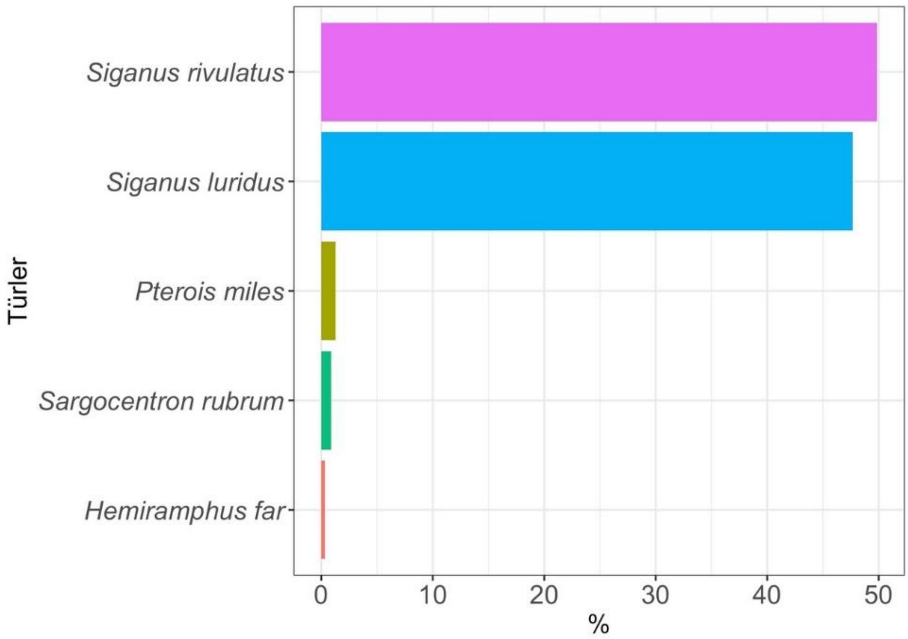
Tablo 1. Örneklenen tekne özellikleri (n: örneklenen tekne sayısı, LOA: tekne tam boyu, HP: motor gücü, GT: teknenin gros tonajı, Ort.: ortalama, S.E.: standart hata)

	LOA (m)	HP	GT	Teknenin yaşı	Tayfa sayısı
Minimum	6,3	9	0,8	3	0
Maksimum	14,0	340	14,0	60	3
Ort. ± S.E.	8,3 ± 0,24	78,6 ± 13	4,2 ± 0,6	21,4 ± 2,1	0,9 ± 0,1
n	48	47	28	48	49

Uzatma ağlarında yabancı tür miktarları tek tek kaydedilmiş olup, ağırlık bazında en yüksek av oranı beyaz sokar (*Siganus rivulatus*) balığına aittir. Onu siyah sokar (*Siganus luridus*) ve aslan balığı (*Pterois miles*) takip etmektedir (Şekil 1). Aslında uzatma ağlarıyla avcılıkta egzotik balıklara rastlanmama oranı oldukça yüksektir. Bu nedenle tüm tablolarda minimum CPUE'lerde '0' değeri bulunmaktadır. Bunların oranı (yani tüm operasyonlarda hiç çıkmama oranları) mevsimlere göre sonbaharda %78, kışın %91, ilkbaharda %97'dir. Yıllara göre ise 2017'de %75, 2018'de %93 ve 2019'da %92'dir. Av sahalarına göre ise adalar civarında %95, Bodrum kıyılarında %80, Kafes civarında %100 ve komşu körfezlerde %77 oranıyla hesaplanmıştır.

Tablo 2. Mevsimlere göre uzatma ağlarının CPUE (kg.1000 m^{-1}) değerleri (n: örnekleme sayısı, S.E.: standart hata, Min.: minimum, Maks.: maksimum)

Mevsim	n	Min	Maks	ort ± S.E.
Sonbahar	18	0,00	40,00	6,60± 2,76
Kış	87	0,00	208,30	35,28± 4,51
İlkbahar	74	0,57	525,00	50,29± 8,26

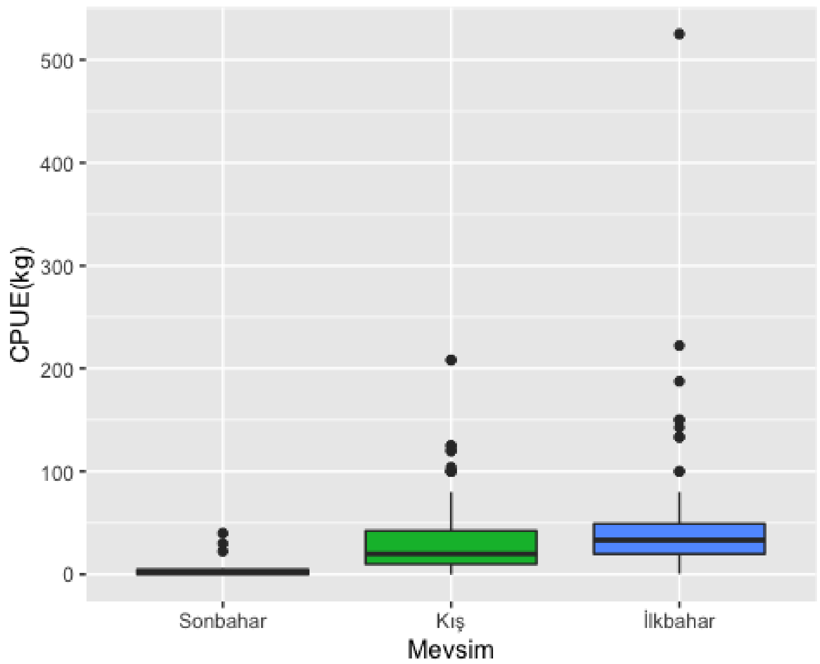


Şekil 1. Ege Denizi'nin güney kıyılarında uzatma ağlarıyla yapılan avda egzotik balık av oranları

Uzatma ağlarıyla yapılan avcılıkta mevsimlere göre egzotik av CPUE'si en düşük İlkbaharda en yüksek Sonbaharda tespit edilmiştir (Tablo 3; Şekil 3). CPUE değerleri ile mevsimler arasındaki istatistiki olarak fark önemsiz bulunmuştur ($p>0,05$).

Yıllara göre CPUE ortalama miktarı en az 2019 yılında, en çok 2017 yılında hesaplanmıştır (Tablo 4; Şekil 4). CPUE değerleri ile yıllar arasındaki fark istatistiki olarak önemli değildir ($p>0,05$).

Av sahalarına [adalar (Apostol, Toprakada, Papaz adası, Salih adası), Bodrum kıyıları, ağ kafes civarı, komşu körfezler (Didim önleri, Akbük, Kazıklı, Gökova, Fethiye)] göre egzotik tür CPUE ortalama miktarı en az ağ kafesler civarı, en fazla ise komşu körfezlerde hesaplanmıştır (Tablo 5; Şekil 5). CPUE değerleri ile av sahaları arasındaki fark istatistiki olarak önemli bulunmuştur ($p<0,05$).



Şekil 2. Mevsimlere göre uzatma ağlarının CPUE (kg.1000 m^{-1}) değerleri

Tablo 3. Mevsimlere göre uzatma ağlarının egzotik av CPUE (kg.1000 m^{-1}) değerleri

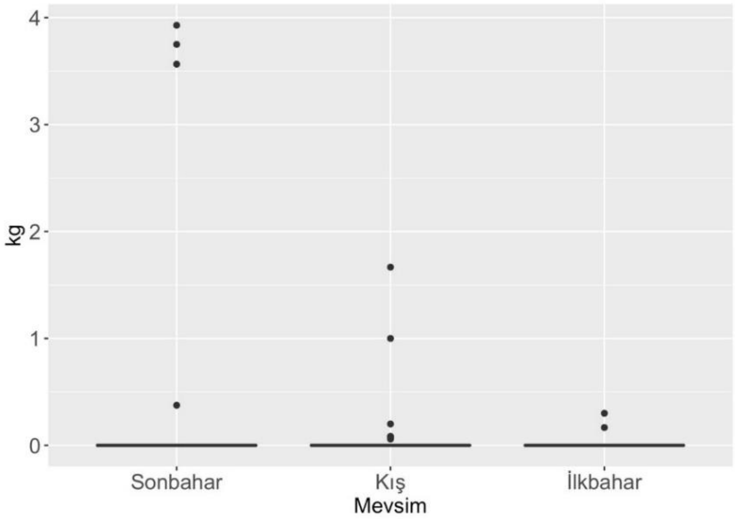
Mevsim	n	Min	Maks	Ort ± S.E.
Sonbahar	18	0	3,93	0,65 ± 0,34
Kış	87	0	1,67	0,04 ± 0,02
İlkbahar	74	0	0,30	0,01 ± 0,00

Tablo 4. Yıllara göre uzatma ağlarının egzotik av CPUE (kg.1000 m^{-1}) değerleri

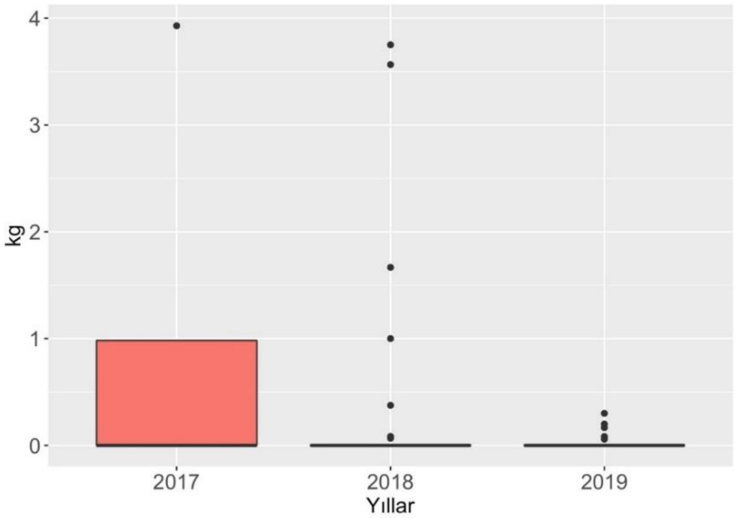
Yıl	n	Min	Maks	Ort ± S.E.
2017	4	0	3,93	0,98 ± 0,98
2018	113	0	3,75	0,09 ± 0,05
2019	62	0	0,30	0,01 ± 0,01

Tablo 5. Av sahalarına göre uzatma ağlarının egzotik av CPUE (kg.1000 m^{-1}) değerleri

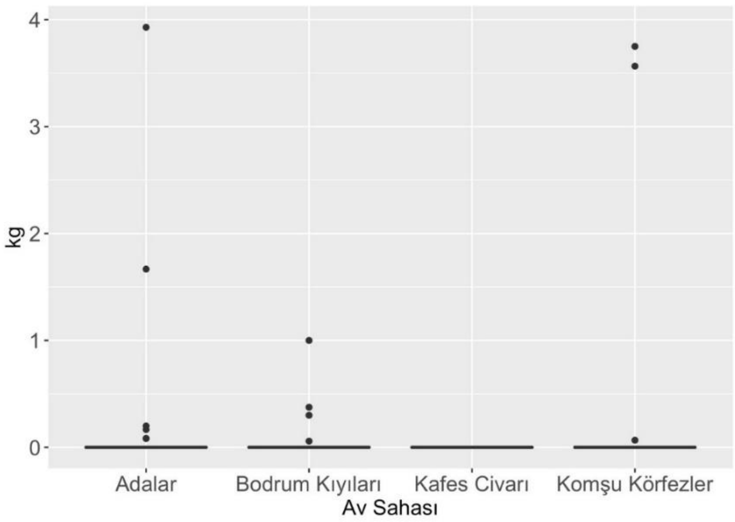
Av sahaları	n	Min	Maks	Ort ± S.E.
Adalar	136	0	3,93	0,05 ± 0,03
Bodrum Kıyıları	20	0	1,00	0,09 ± 0,05
Ağ Kafes Civarı	10	0	0,00	0,00 ± 0,00
Komşu Körfezler	13	0	3,75	0,57 ± 0,38



Şekil 3. Mevsimlere göre uzatma ağlarında egzotik av CPUE (kg.1000 m^{-1}) değerleri



Şekil 4. Yıllara göre uzatma ağlarında egzotik av CPUE (kg.1000 m^{-1}) değerleri



Şekil 5. Av sahalarına göre uzatma ağlarında egzotik av CPUE (kg.1000 m^{-1}) değerleri

Tartışma ve Sonuç

Bodrum Yarımadası balıkçılığının esasını oluşturan uzatma ağı-paragat balıkçılığı toplam üretimin ancak %7-8'ini oluşturmaktadır (Kara ve Gurbet, 1998). Buna ilaveten, bölgede deniz kafes balıkçılık faaliyetlerinin oldukça yüksek oranda üretim yaptığı da bilinmektedir. Bu sahalar çok fazla doğal balık topladığı için kıyı balıkçıları açısından kafes civarında avlanmak onlara yüksek av garantisi sağlamaktadır. Özellikle sade kupes ağlarıyla avcılık bu alanda en çok yapılan avcılıktır (Akyol vd., 2017). Bu çalışmada da örneklenen uzatma ağlarının %80'ini sade kupes ağları oluşturmuştur. Diğer uzatma ağları ise dil, barbun, voli, fanyalı uzatma ağları vb.'dir.

Çalışmada karşılaşılan ve kıyılarda avlanan türler (*Boops boops, Mullus barbatus, M. surmuletus, Diplodus annularis, D. vulgaris, D. sargus, Siganus luridus, S. rivulatus, Dentex dentex, Zeus faber, Trachurus trachurus, Pagellus erythrinus, P. bogaraveo, P. acarne, Scomber colias, S. scombrus, Dicentrarchus labrax, Sparus aurata, Solea solea, Spicara maena, Sardinella aurita, Mugil spp., Octopus vulgaris, Sepia officinalis,* vb.) Ege Denizi'nin tipik türleridir. Burada özellikle sparidler, carangidler, mugilidler ve mullidler asıl hedeflenen türlerdir. Kafes civarının hedef türü ise kupestir. Bölgede küçük ölçekli balıkçılıkta önceki bir çalışmada 30 civarında tür ekonomik olarak hedeflenmiş olup, bunlar arasında lahoz, orfoz, kefal, barbun, çipura, mercan, sinarit, ıskarmoz gibi balıklar ön plana çıktığı bildirilmiştir (Akyol vd., 2016).

Son yıllarda artan sıcaklık ve küresel ısınma sebebiyle Akdeniz'e çok sayıda giriş yapan egzotik, yabancı ve yayılmacı türler de bölgede hâkimiyet kurmaya başlamıştır (Çınar vd., 2021). Bunlar arasında özellikle balon balıkları, sokar, sincap ve aslan balıklarına bu çalışmada rastlanmıştır. Bu tür balıklardan özellikle balon balıkları balıkçılara en çok tahribat veren türlerin başını çekmektedir. Zira bu balıklar zehirli olduğu için yenmesi ve karaya çıkarılması yasak olmakla birlikte balıkçıların av araçlarına da ciddi maddi kayıplar verdirmektedir. Bu kayıplar özellikle paragatlarda kendini göstermekte, paragata yakalanmış balığı ya da paragat yemini yemeğe kalkan balon balıkları, köstek ve iğneleriyle birlikte yutmaktadır. Bununla ilgili bildirilen en çok 1000 iğnenin yarısına varan kesme tahribatı, maddi kayıp (yem ve misina-iğne) yanında ciddi bir işçilik kaybı da yaratmaktadır (Türkbükü, Gölköy, Gökçebel Su Ürün. Koop. Başk. Seyit Ali Özcan, kişisel görüşme).

Balon balıklarının İzmir ve Hatay kıyılarında kıyı balıkçılarına yarattığı zarar üzerine yapılan bir çalışmaya göre, 261 balıkçıyla yapılan anket sonuçları balıkçıların %78'inin balon balıkları nedeniyle ekonomik kayıp yaşadıklarını, yine balıkçıların %89'unun balon balıklarının avlarını azalttığını, %82'sinin ise bunların denizel biyo-çeşitliliği olumsuz etkilediğine inandığını ortaya koymuştur (Ünal vd., 2015). Bazı çalışmalar (Ünal vd., 2015; Ünal ve Göncüoğlu-Bodur, 2017) bu türün sosyo-ekonomik etkilerine odaklanan balıkçılığın teşvik edilmesi ve balıkçılar üzerindeki etkisinin azaltılması için ödül sistemi önermektedir. Tarım ve Orman Bakanlığı Su ürünleri Genel Müdürlüğü bu konuyu gündemine almış olup, Ocak 2020 yılından başlayarak 2023 sonuna kadar bir milyon kuyruk başına 5 TL'lik bir bedel ödeyerek balon balıklarının stoklarının azaltılması için bunların avlatılmasına yönelik geri satın alma programını uygulamaya koymuştur (Resmi Gazete, Sayı: 31322; Anon. 2020).

Bu çalışmada, balıkçıların %60'ının bu egzotik türlere rastladıkları belirlenmiştir. Aslında bu türler daha ziyade Türkiye'nin güney kıyılarında (Akdeniz) yoğun olarak bulunmalarına rağmen, artan ısınmayla birlikte artık Ege Denizi'nin kuzeyine doğru yönelmiştir. Yine yoğunlukları fazla olmamakla birlikte sayılarının yıldan yıla Güllük Körfezi'nde arttığı da tespit edilmiştir. Gerçekten de bu balıklardan en zararlı ikisi, balon balığı (*Lagocephalus sceleratus*) ve aslan balığı (*Pterois miles*) artık kuzey Ege sularında görünmeye başlamış (Özgül, 2020), hatta balon balıkları Marmara (Irmak ve Altınağaç, 2015) ve Karadeniz'de (Bilecenoğlu ve Öztürk, 2018) de ortaya çıkmıştır.

Ege Denizi'nde bu istilacı ve yabancı türlerin yoğunluğu *Siganus* (sokkan balıkları) türleri hariç henüz şimdilik çok fazla artmamıştır (kişisel gözlem). Bu çalışmada egzotik türlerin CPUE değerleri en yüksek ortalamayla (0,7 ±0,3 kg.1000 m^{-1}) Sonbaharda, 2017 yılında (1,0 ±1,0 kg.1000 m^{-1}) ve komşu körfezlerde (0,6 ±0,4 kg.1000 m^{-1}) görülmüştür. Oysa uzatma ağlarının tüm balıklar toplamında en yüksek CPUE verileri İlkbaharda (50,3 ±8,3 kg.1000 m^{-1}) elde edilmiştir. Buradan da anlaşılmaktadır ki, mevsimler bakımından egzotik türler yaklaşık 72 kat daha azdır. Buradan görece olarak özellikle Güllük Körfezi ve kuzeyi dikkate alındığında balıkçıların da belirttiği gibi bölgede egzotik türler henüz dikkat çekici oranda değildirler.

Sonuç olarak, yapılan birçok çalışmada Akdeniz'in bir tropikalleşme sürecine girdiğini göstermektedir (Bianchi ve Morri, 2003; WWF, 2021). 1869 yılında açılan Süveyş Kanalı tropik sularla bağlantıyı sağlarken, Akdeniz'e yoğun bir egzotik tür girişi olmuş, yine Cebelitarık Boğazı yoluyla yine Atlantik kökenli balıklar girişlerine devam etmiş ve etmektedir. Bunun yanı sıra deniz ve akvaryum ticaretinden kaynaklanan egzotik tür girişleri de devam etmektedir. Bu girişlerin ekolojik, ekonomik, sosyal ve kültürel etkileri vardır ve bu türlerin kısa sürede tanımlanması, izlenmesi, gerekirse azaltılmasına yönelik tedbirler gündemde var olmaya devam edecektir. Bu amaçla uluslararası izleme ağları, medya, vatandaş bilimi (Citizen Science) projeleri, gönüllü izleme programları ile akademik camia sıkı iletişim içerisinde olmalı ve tüm yeni girişlerden anlık haberdar edilmelidir. Bu sayede, türlerin istilacı olanları üzerine erken önlem geliştirip, bu türlerin popülasyonlarının artışı kısmen de olsa durdurulabilir.

Teşekkür

Bu çalışma Ege Üniversitesi Bilimsel Araştırma Koordinatörlüğü (Proje No: 2017-SAUM-001) tarafından desteklenmiştir. Çalışmada bizi teknelerine kabul eden ve araştırmamıza destek veren Egeli balıkçılara şükranlarımızı sunarız.

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SHORT COMMUNICATION

The Occurrence of *Phronima sedentaria* Forskål, 1775 (Crustacea: Amphipoda) in the Gulf of Antalya (Eastern Mediterranean, Türkiye)

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Antalya Bay

Abstract: This study reports the occurrence of *Phronima sedentaria* in the Eastern Mediterranean. The new pram shrimps were collected from the Gulf of Antalya, located on the Levantine coast of Turkey. Examination and definition of the sampled specimen in the area reported as the first occurrence.

Anahtar kelimeler:

Pram karidesi
Hyperid amphipod
Levantin Denizi
Antalya Körfezi

Antalya Körfezi'nde (Doğu Akdeniz, Türkiye) *Phronima sedentaria* Forskål, 1775 (Crustacea: Amphipoda)Türünün Kaydı

Öz: Bu çalışma *Phronima sedentaria* türünün Akdeniz'in doğusundaki bulunurluğunu temsil etmektedir. "Pram shrimp" olarak da adlandırılan bu Amphipod türü Türkiye'nin Levant Denizi kıyısında yer alan Antalya Körfezi'nden örneklenmiştir. Bu alanda örneklenen türün incelenmesi ve tanımlanması sonucunda, ilk kayıt olarak rapor edilmektedir.

Introduction

The family Phronimidae currently includes two genera; *Phronima* Latreille, 1802 and *Phronimella* Claus, 1871. The genus *Phronima* includes 10 accepted species (Shih, 1991; Vinogradov et al., 1996).

The pram shrimp *Phronima sedentaria* (Forskål, 1775) is a pelagic hyperiid amphipod often found living inside transparent pelagic tunicates such as salps and pyrosomes; *P. sedentaria* parasitizes and fashions these tunicates into gelatinous, barrel-like abodes where it shelters and rears it's young (Quigley et al., 2015). The species is one of the most well-known and common hyperiid amphipods dwellings within plankton (Diebel, 1988) and is distributed throughout the tropical and temperate oceans, including the Mediterranean Sea (Zeidler and De Broyer, 2009).

Here, we report the capture locations of *P. sedentaria* specimens in Antalya Bay, located off Turkey in the eastern Mediterranean, in association with an unidentified salp species; this represents the first report of such specimens in the study area. There was no information about the species' distribution in the Turkish seas.

Material and Methods

This study was conducted after receiving legal permission (Date: 07.04.2016, No: 1320) from the Republic of Turkey, Ministry of Agriculture and Forestry General Directorate of Fisheries and Aquaculture.

The specimens were collected on the bathyal ground of the Antalya Bay in April and July 2019 (Figure 1) within the framework of a monthly sampling program conducted by the research vessel "Akdeniz Su." The sampling design was developed for fishery surveys, with no intention of specifically sampling *P. sedentaria*. A bottom trawl net with a mouth opening of 1.5 m was used for sampling. The hauling speed was about 2.4 knots, and the hauling duration was 1 h. All hauls were conducted during daylight.

"Pram shrimp" specimens and their sexes were identified based on the *Hyperiid Amphipods of the World Oceans* guide (Vinogradov et al., 1996). The total length (TL) was measured with a digital caliper to the nearest 0.01 mm. The specimens were preserved in 70% ethanol and stored in the Faculty of Fisheries laboratory, Akdeniz University.

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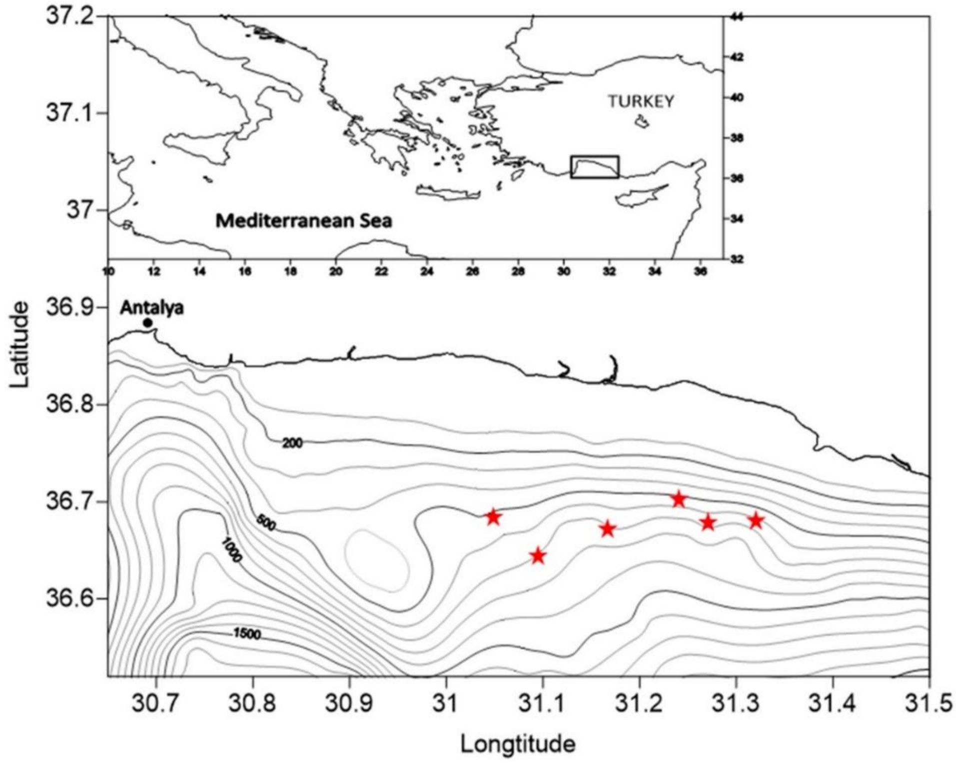

Figure 1. The sampling stations of the specimens in the Antalya Gulf

Results

Specimen characterization

The specimens were identifiedas *Phronima sedentaria* (Forskål, 1775) of the genus *Phronima* Latreille, 1802 and family Phronimidae Rafinesque, 1815. Twelve female individuals (TLs 32–40 mm) were collected from six stations at depths between 530 m (N36º42.610', E31º10.040') and 650 m (N36º41.500', E31º09.380'). Notably, many juveniles (> 200) were collected, along with two adult females (40 mm TL) and an empty unidentified salp in the second haul at a depth of 540 m. In the fifth haul, six female individuals (TLs 32 -39 mm) and seven empty unidentified salps were sampled (Table 1).

Table 1. Specimens of the pram shrimp *P. sedentaria* collected in Antalya Bay, Turkey

Date	Hauls	Stratum (m)	TL (mm)	Sex	Specimen	Unidentified salp
27.04.2019	1	500-599	36	F	1	-
	2	500-599	40	F	1 with 200^+ juveniles	1
	3	600-699	37	F	1	2
	4	600-699	-	-	-	2
	5	600-699	32-39	F	6	7
21.07.2019	6	600-699	38-40	F	2 with 200^+ juveniles	2

Species classification

The characteristics of the specimens agreed well with the descriptions of *P. sedentaria* (Figure 2a–b) presented by Vinogradov *et al.* (1996). The length of the fifth segments of pereopod *V* of the females were much greater than their widths (Figure 2c). The rami of the uropods of the females were approximately equal in length (Figure 2d). The specimens could be easily distinguished from all other species in the genus based on many distinctive features.

Figure 2. A, B: Lateral views of the specimen; C: female *V* pereopod close-up view; D: abdomen, pleopods and uropods

Discussion

Previous studies (Christodoulou et al., 2013; Vinogradov et al., 1996) reported the presence of P. sedentaria based on Stephensen (1924) without giving details or specifying the location of collected specimens. Veini and Kiortsis (1974) sampled a few *P. sedentaria* individuals in Greek waters also without giving the details of the specimens. Four preserved specimens of *P. sedentaria* were reported in Global Biodiversity Information Facility (see details; GBIF.org) in Spain and France; date unknown and in Italy; 1930. However, it's been noted that all locations and dates are invalid but only occurrence in Greece (2009) seems to be valid (Tecchio and Ramirez-Llodra, 2018). Furthermore, only two species from the genus *Phronima* (*Phronima stebbingi* and *Phronima atlantica*) were reported in the Aegean by Bakir *et al.* (2014).

This paper represents the first report of captured living specimen *P. sedentaria* in the Turkish waters of eastern Mediterranean.

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Conflict of Interest

The authors declare that there are no conflicts of interest.

Author Contributions

M. Tunca Olguner; performed data collection, identify the specimen, laboratory studies, design and wrote the manuscript. M. Cengiz Deval; verification of the specimen, provided help in editing, design and correction. All authors discussed the results and contributed to the final manuscript.

Ethics Approval

Ethics committee approval is not required for this study. This study was conducted after receiving legal permission (Date: 07.04.2016, No: 1320) from the Republic of Turkey, Ministry of Agriculture and Forestry General Directorate of Fisheries and Aquaculture.

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SHORT COMMUNICATION

First Record of the Epizoic *Octolasmis angulata* (Cirripedia) on *Maja squinado* (Herbst, 1788) (Majoidea, Crustacea) from Çanakkale, Türkiye

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Barnacle
Çanakkale

Abstract: Some morphometric and biological characteristics of a European spider crab, *Maja squinado* (Herbst, 1788) caught off Aksaz region, (Biga, Çanakkale, Türkiye) were investigated. In addition, an epizoic species infesting this *M. squinado* specimen has been identified. The crab specimen was caught by a commercial fisherman using trammel nets. Carapace length, carapace width and weight of the crab were 15.9 cm, 14.5 cm, and 1109 g respectively. The specimen was an ovigerous female with a calculated fecundity of $3.48 x 10^4$ eggs. Eggs were in stage 4^{th} of development and covered the whole carapace region. Additionaly, it was observed that the specimen was infested with the epixoic barnacle *Octolasmis angulata* (Aurivillius, 1894). A total of 46 *O. angulata* individuals were observed; 32 from the gill lamellae, and 14 from the carapace. This study reports the existence of the epizoic *O. angulata* on *Maja squinado* for the first time in Türkiye.

Anahtar kelimeler:

Örümcek yengeç
Epizoik
Barnacle
Çanakkale

Maja squinado (Herbst, 1788) (Majoidea, Crustacea) Üzerinde Epizoik *Octolasmis angulata* (Cirripedia) Türünün Çanakkale, Türkiye'den İlk Kaydı

Öz: Çanakkale Aksaz kıyılarında gerçekleştirdiğimiz çalışmada, *Maja squinado* (Herbst, 1788)'nun bazı morfometrik ve biyolojik özellikleri ile *M. squinado* üzerinde konakçı olarak yaşayan epizoik tür incelenmiştir. Ticari balıkçılar tarafından fanyalı uzatma ağları yakalanan yengecin karapas uzunluğu 15.9 cm, karapaks genişliği 14.5 cm ve ağırlığı 1109 g olarak ölçülmüştür. Yengeç dişi olup üzerinde yumurta taşıdığı tespit edilmiştir. Yengecin abdomen bölgesinde toplam $348 x 10^4$ yumurta olduğu hesaplanmıştır. Yengecin yumurtalarının 4. evrede olduğu ve tüm abdomen bölgesini kapladığı belirlenmiştir. Ayrıca yengeç bireyinin üzerinde konakçı epizoik *Octolasmis angulata* (Aurivillius, 1894) taşıdığı görülmüştür. Yengecin solungaç lamellerinden 32 adet ve karapaks altından 14 adet olmak üzere toplamda 46 adet *O. angulata* örneklenmiştir. Bu çalışma ile *M. squinado* türü üzerinde epizoik tür *O. angulata,* ülkemiz denizlerinden ilk kez kaydedilmiştir.

Introduction

Crustaceans have a significant contribution to world fisheries production (Karadurmuş and Aydın, 2016). The European spider crab *Maja squinado* (Majoidea, Decapoda, Crustacea) is a species of great commercial importance distributed in the northwest Atlantic and Mediterranean at depths of up to 90 m (Kergariou, 1976; Bernardez, 2005). However, environmental degradation and inappropriate fisheries management have resulted in declining stocks of this species (Born et al., 2004). This species is exploited by several countries; in the north-eastern Atlantic, intensive spider crab fisheries are operated by the United Kingdom, Ireland, France, the Channel Islands, Spain, Portugal, Morocco, and in the Mediterranean, Turkey (Brosnan, 1981). *M. squinado* was caught commercially in Turkey until 2006 (Harlıoğlu et al., 2018), but this species has been a rare occurence recently. In Turkey, information on *M. squinado* has been limited to biodiversity studies (Kocatas et al., 2005; Harlıoğlu et al., 2018; Çiftçi et al., 2019).

Epibiosis involves mutualistic and commensal relationships with the most critical factor for colonization being the availability of a suitable substratum (Ross, 1983; Parapar et al., 1997). Epizoic species like stalked barnacles of the genus Octolasmis Gray, 1825 (Poecilasmatidae) are sessile invertebrates frequently found attached to the branchial chairs of crabs (Jeffries and Voris, 1996; Chan et

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al. 2009; Ihwan et al., 2014). When Octolasmis inhabit branchial chambers of the crabs, they occupy space on the surface of the gills normally available for oxygen exchange and can therefore, severely impair host respiration (Hudson and Lester, 1994).

Since the underlying reasons for the decline of *M. squinado* stocks are not known, information on the biology of this species and its interaction with the environment may help to shed some light on their abundance in this area. In this study, the epizoic species *Octolasmis angul*ata infesting *M. squinado* was recorded for the first time in Turkey.

Material and Methods

The specimen of *M. squinado* was caught incidentally from a depth of 70 m by commercial fishermen using trammel nets on the southern coasts of the Marmara Sea on April 27, 2021 (Coordinates of sampling area: 40° 29' N - 27° 13' E). The specimen was identified according to Ng and Richer de Forges (2015) (Figure 1).

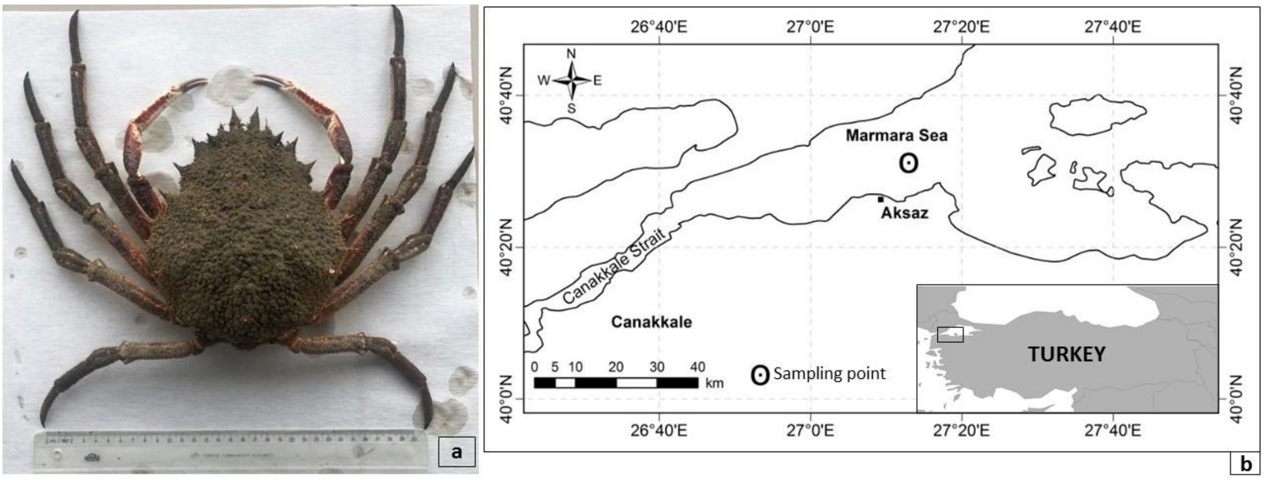

Figure 1. a: The sampled ovigerous female of *M. squinado* b: Sampling location of *M. squinado* in the present study.

The specimen was transferred to the laboratory in a cooler and the morphometric characteristics were measured with a digital caliper according to Neumann 1996. Total weight and gonad weight were measured using a digital scale. Development and color changes of gonads were determined macroscopically according to Carmona-Suárez (2003). Maturity stages of the eggs were identified according to the 4-staged maturity scale as follows: Stage I: almost absent, very small, transparent; Stage II: milky white, thin, soft; Stage III: light orange, covers a great part of the internal organs; Stage IV: orange-red, covers entire abdomen region. Fecundity was determined based on a 0.05 g sub-sample with 3 replicates taken from the egg mass and counting the number of eggs under a stereomicroscope. The minimum, maximum, and average egg sizes were also calculated by measuring the diameters of 70 sub-samples. *M. squinado* specimen was then dissected and epizoic barnacles were carefully removed. Species identification was carried out according to Jefferies et al., 2005 and Chan et al. 2009, and the number of epizoics was recorded.

Results

Morphological measurements of *M. squinado* caught in trammel nets from Çanakkale Aksaz Region are given in Table 1. The carapace length of *M. squinado* was 15.9 cm and the carapace width was 14.5 cm. The abdominal length of the crab was 9.6 cm and the abdomen width was 7.7 cm. The total weight of of the crab was 1109 g.

The eggs of the ovigerous female crab were red in color and in the 4^{th} stage of development. The total egg mass of this crab was recorded as 104.68 g. The total number of eggs was calculated as $348x10^4$. The diameter of the crab eggs ranged between 0.6039 - 0,7951 mm, , with a mean diameter of 0.7200 ± 0.038 mm.

O. angulata was identified as the epizoic species on the crab's gill lamellae and carapace margins. A total of 46 *O. angulata* were found on the crab; 32 from the gill lamellae and 14 from the carapace. Photographs of *O. angulata* are presented in Figure 2.

Discussion

This study provides information on the morphological characteristics of the spider crab *M. squinado* in Çanakkale. Our findings were compared with those of other studies. In a study conducted on the Tunisian coast, the mean CL was found to range between 22.5 and 87 mm and a mean CL of 52 mm was measured in adult females (Baklouti et al., 2015). Authors in this study, stated that there were ovigerous females in April-May but the gonads reached peak maturation in December-March. In a different study conducted on northwest Spain, an individual with eggs were found in December (Bernardez et al., 2003). In the present study, an ovigerous female was caught in April and similar results were obtained in other studies.

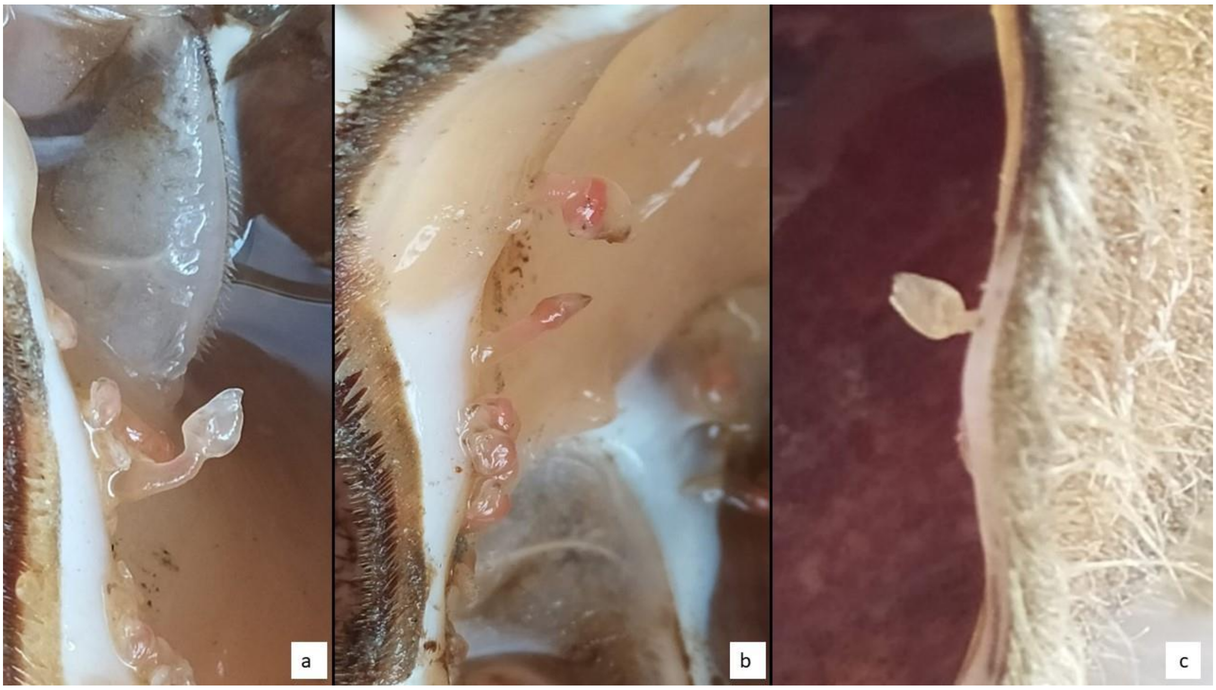

Figure 2. Location of epizoic species *O. angulata* on *M. squinado* (a, b: Gills filament; c: Under the carapace)

Host species and availability vary according to the characteristics of the organism, the type of host, and maturity stages (Dudgeon 1980; Maldonado & Uriz 1992; Woods & McLay 1994; Woods & Page 1999; Cruz-Rivera 2001; Berke & Woodin 2008; Hultgren & Stachowicz 2008; Martinelli et al., 2011). A range of organisms including algae, sponges, hydroids, bryozoans, amphipods, cirripedes, polychaetes, etc. have been recorded on crabs (Sato & Wada 2000) and their intensity of infestation appear to differ chemically/mechanically. In addition to the phenomenon of epibiosis on their exoskeleton, *M.* crabs display a distinctive masking behavior that creates a complex camouflage system to ward off predators. *Octolasmis* sp. has been reported in different studies on the gills of different crustaceans such as Palinuridae, Scyllaridae, and Portunidae, especially *O. angulata*, inhibiting the respiratory process, thus preventing oxygen uptake by these crustacean hosts (Irvansyah et al., 2012; Jeffries et al., 1996; Schejter & Spivak, 2005; Ihwan et al., 2014; Hassan et al., 2019). This study shows features similar to other studies and the individuals of *O. angulata* show a dense distribution, especially in the gill lamellae of the crab.

Earlier studies on biodiversity have confirmed the presence of *M. squinado* in the Çanakkale Strait and the Sea of Marmara. In this study, morphometric characteristics of an ovigerous female and its infestation by the epizoic species *O. angulata* are reported for the first time.

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Conflict of Interest

There is no conflict of interest between the authors.

Author Contributions

All authors contributed equally to the paper.

Ethics Approval

The material used in this article is invertebrate species therefore ethics committee approval is not required for this study.

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- D. Nak, E. Kuruoglu and Y. Nak, planned and designed the research. Z. M. Ekıcı, D. Koca, T. Avcılar, M. E. Sahın and A. H. Shahzad provided help in the clinic process. M. O. Ozyıgıt and Z. Avcı Kupelı made histopathological examinations. All authors discussed the results and contributed to the final manuscript.
- D. Çayan and E. Unur conceived the ideas of the study and writing manuscript; D. Çayan, M. Nisari, D. Patat and E. Dağlı performed data collection and analysis; H. Akalın performed gene expression stages.

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- Baran, B. (2010). Scaphopod species (Mollusca) of the Turkish Levantine and Aegean seas. *Turkish Journal of Zoology*, *38*(2), 190-209. doi:10.3906/zoo-0902-12
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