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RESEARCH ARTICLE

Growth and survival performance of smooth scallop (*Flexopecten glaber* Linnaeus, 1758) at different depths in the Aegean Sea

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ABSTRACT

This study was conducted between July 2016 and 2017 to determine the growth and survival rates of the smooth scallop *Flexopecten glaber* spats in Urla Karantina Island. The sea water temperature was determined as 21.56±6.33°C, 21.1±6.40°C and 20.87±6.35°C at 2, 4 and 6 m depths, respectively. Salinity values varied between 36 and 38.19 PSU in the region. The highest chlorophyll-*a* value was determined as 8.95 µg l^{-1} in August at 2m depth and 1.65 µg l^{-1} as the lowest at 4 m depth in January. Average values of total particulate matter amount were calculated as 4.41±1.86 mg l^{-1}, 5.09±1.88 mg l^{-1} and 5.47±1.89 mg l^{-1} at 2, 4 and 6m depth, respectively. Scallop spats with an average height of 8.26±1.55 mm were measured at the beginning of the study. The heights of the smooth scallop spats, which were placed at 2m, 4m and 6m depths in the study area, were 42.6±1.11 mm, 41.53±12.85 mm and 41.57±1.64 mm and their weights were measured as 12.71±0.89 g, 12.85±0.53 g and 12.82±1.00 g, respectively. While the survival rate was 53% placed at 2m depth in the study area, the lowest survival rate was found as 37% for the spats grown at 6m depth. The result showed that the mean values of height at the surface depth (2m) were more significant than those at the other depths (4m and 6m). However, there were no statistically significant differences between the depths and specific growth rate (SGR) for height and weight ($p>0.05$). But SGRh and SGRw values at each depth showed statistically significant differences between months ($p<0.05$).

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Introduction

About 40 species of scallops belong to the Pectinidae family, suitable for human consumption and used commercially (Waller, 1991; Minchin, 2003). The smooth scallop (*Flexopecten glaber* Linnaeus, 1758) is an invertebrate bivalve from the Mollusca phylum and is widely spread in the Mediterranean (Poutiers, 1987; Mattei & Pellizzato, 1996; Zenetos, 1996; Tsotsios et al., 2016). This species is one of the high market value bivalve species for the aquaculture industry (Tsotsios et al., 2016). Aquaculture is the fastest growing food production area in the world (FAO, 2020), especially molluscs are an important source of nutritious animal protein. Environmental changes and heavy fishing pressure have led to

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the destruction of fish and scallop populations in many countries (Strand & Vølstad, 1997; Stotz & Mendo, 2001). In some countries, the population of scallop has decreased; because of this, the culture of this species is aimed through stock configuration and conservation programs (Tettelbach et al., 2002; Drummond, 2004).

The bivalve stock supply for production is usually made by collecting spat from nature with polyethylene net bags (Kurtay et al., 2018; Yigitkurt et al., 2020). The culture methods of scallop are the bottom culture, floating cages, sink cages, and suspended methods (Paul et al., 1981; Ventilla, 1982; Roman & Acosta, 1991; Slater, 2005). The preferred culture production method varies according to the location of the cultivation area (Leavitt, 2010).

Bivalve culture in Turkey is limited to the Mediterranean mussel. *F. glaber* has a potential product for aquaculture in Turkey (Vural & Acarli, 2019; Vural & Acarli, 2021) due to its nutritional quality. In addition, this species has high growth and survival performance, early maturation and intensive breeding (Tsotsios et al., 2016).

This study aimed to collect *F. glaber* spats to find the differences between growth and survival rates at different depths and ensure the culture's sustainability by determining the environmental effects on production.

Material and Methods

Study Site

This study was carried out at the coast of Urla Karantina Island in the Aegean Sea which is located at 38°22'44" N and 26°47'12" E (Figure 1).

Figure 1. Study area at Urla Karantina Island

Collector and Suspended Culture System

The scallop spats were obtained between July 2016 and August 2016 with spat collectors designed by connecting 20 collectors prepared using polyethylene net bags with a size of 100×29 cm and a mesh size of 5×4 mm (Figure 2a).

Spats were cultured from August 2016 to July 2017. The suspended culture system was designed with a diameter of 20 cm, a thickness of 5 cm, and a mesh size of 5×5 mm on both sides. The collected spats were placed in three depth culture systems as 90 individuals in each system in 3 repetitions and were cultivated by hanging at different depths (2 m, 4 m, and 6 m) (Figure 2b). According to the growth of the scallop, the mesh size of the net used was increased periodically.

Height and Weight Measurements

The shell height of the scallops was measured from the maximum height between the dorsal (hinge) and ventral edge using a Mitutoyo digital caliper, monthly. The samples were weighed using a digital balance (Sartorius, GW3202-O CE).

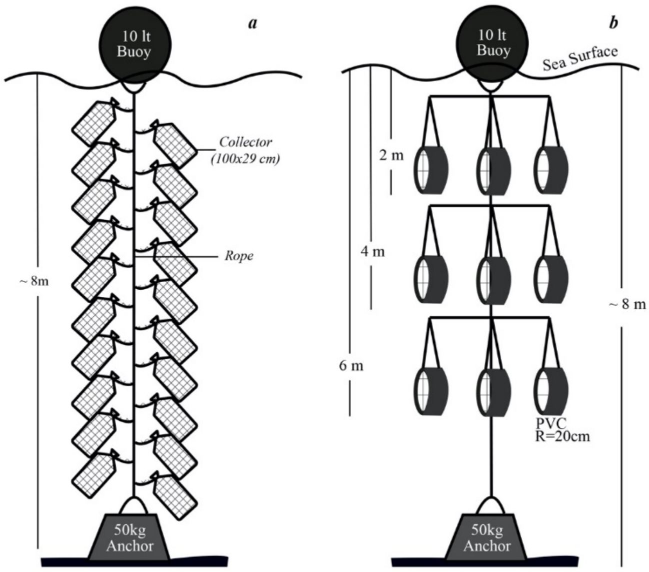

Figure 2. Design of systems: (a) Collector system, (b) Suspended culture system

Environmental parameters

During the study, the water conditions of different depths were monitored and water samples were collected by Niskin water sampler (Model 1010, 5 L). The temperature (°C) was measured monthly with a mercury thermometer, and the temperature of depths was measured with a dive computer (Suunto D4f). The salinity (Practical Salinity Unit - PSU) was analyzed monthly by the Mohr-Knudsen method with water samples taken from different depths (Martin, 1968). The Chlorophyll-*a* and total particulate matter (TPM) values from samples were analyzed according to the method of Strickland & Parsons (1972).

Specific growth rate

The specific growth rates for height (SGRh) and weight (SGRw) were calculated monthly according to the following formulas (Wildish & Saulnier, 1992);

$$SGRh = 100(LnH_t - LnH_0/LnH_0 \times t) \quad (1)$$

H_t is the last height, H_0 is the first height, t is time (30 days).

$$SGRw = 100(LnW_t - LnW_0/LnW_0 \times t) \quad (2)$$

W_t is the final weight, W_0 is the first weight, t is time.

Survival rate

The live individuals were counted in grow-out systems to determine monthly survival. The survival rate was calculated using the equation as below (Lok et al., 2006);

$$Survival\ rate(\%) = 100 - (100 \times \frac{(N_0 - N_t)}{N_0}) \quad (3)$$

N_0 is the number of scallops at the beginning of the experiment and N_t is the number of live scallops at time t.

Statistical Analysis

Descriptive statistics were made using SPSS® statistics program (version 25.0). Kolmogorov-Smirnov test was done for the normality of the distribution of the data. Levene test was done for the homogeneity of variances. Differences between the depths in SGRh and SGRw were determined by a one-way ANOVA test (p>0.05). The survival rate was tested by chi square (χ^2). The relationship between water conditions and growth, SGRh and SGRw were determined by the Pearson correlation coefficient. The relationship between survival rate and water conditions was determined by Spearman's correlation test (Zar, 1984).

Results

The highest seawater temperature was measured as 30.1°C at 2 m depth in August, and the lowest seawater temperature was 12.9°C at 6 m depth in February (Figure 3a). Salinity values in the region varied between 36 and 38.19 PSU (Figure 3b). The maximum chlorophyll-*a* value was observed at 8.95 µg l^{-1} in August at 2 m depth (Figure 3c). The maximum and minimum TPM amounts were measured at 10.12 mg l^{-1} and 1.52 mg l^{-1} at 6 m and 2 m, respectively. Average values of TPM amount were calculated as 4.41±1.86 mg l^{-1}, 5.09±1.88 mg l^{-1}, and 5.47±1.89 mg l^{-1} at 2 m, 4 m, and 6 m depth, respectively.

A total of 270 smooth scallops was collected. The average height and weight of smooth scallop spats which were gathered from the collectors were 8.26±1.55 mm and 0.10±0.02 g, respectively.

At the end of the study, the average heights of the scallop spats placed at 2 m, 4 m, and 6 m depth in the suspended culture systems were measured as 42.6±1.11 mm, 41.53±12.85 mm, and 41.57±1.64 mm, respectively. The average weights of the scallops were measured as 12.71±0.89 g, 12.85±0.53 g, and 12.82±1.00 g, respectively (Figure 4).

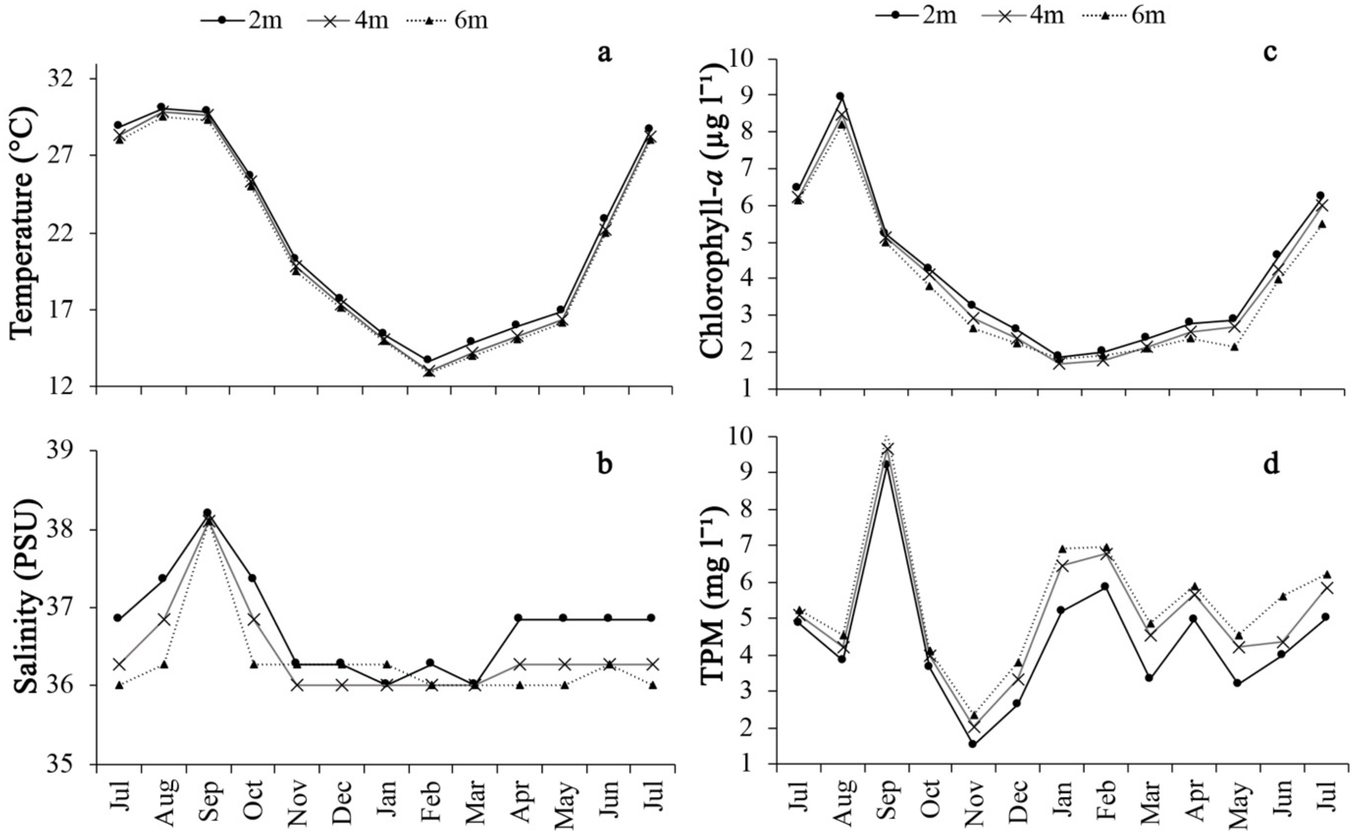

Figure 3. Seawater conditions of the study area (2, 4 and 6 m) (a) Temperature, (b) Salinity, (c) Chlorophyll-*a*, (d) TPM

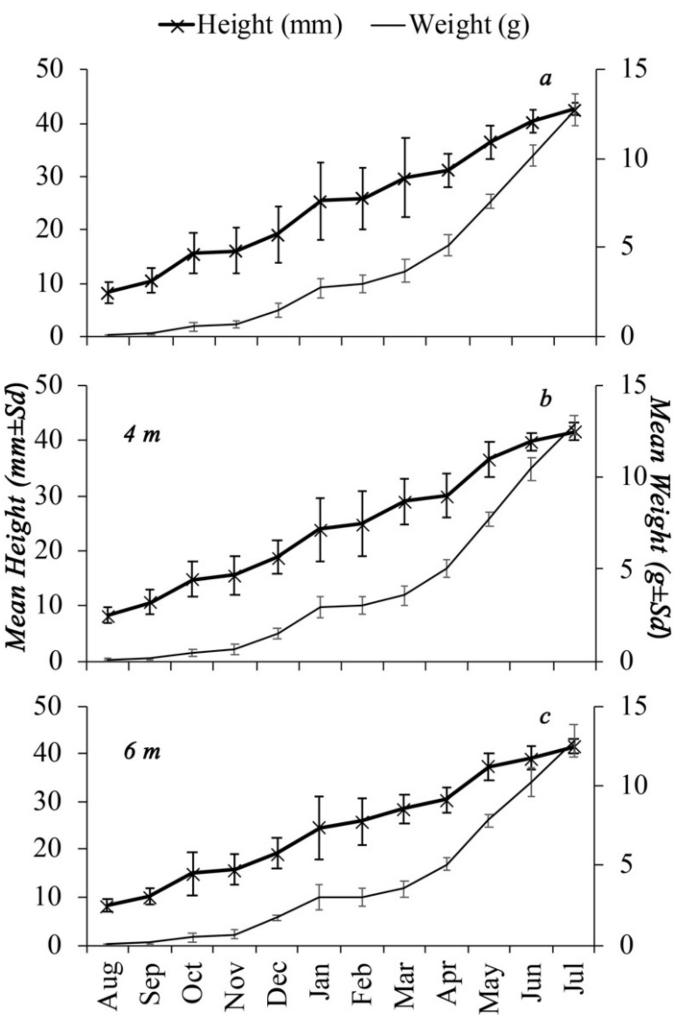

Figure 4. Height -weight change of scallops at different depths (a) 2 m, (b) 4 m, (c) 6 m.

The highest specific growth rate for height and weight of scallops at all depths was observed in October (Figure 5). SGRh at 2 m, 4 m and 6 m depths were determined as 1.62%, 1.33%, and 1.61% and SGRw were found as 9.28%, 7.61% and 6.66% in October, respectively. Daily specific growth rates for height were calculated as 1.156 mm day^{-1} (2 m), 1.112 mm day^{-1} (4 m), and 1.125 mm day^{-1} (6 m) throughout the year. It was determined that there was no statistically difference between specific growth rates depending on height and weight at different depths ($p>0.05$).

The survival rate in scallops was determined as 53.33%, 43.33% and 36.67% at 2 m, 4 m and 6 m, respectively ($p<0.05$) (Figure 6). Significant positive correlations were found between survival rate and temperature parameters with Spearman's correlation for August to February ($r_{2m}=0.961$, $r_{4m}=0.955$, $r_{6m}=0.937$; $p<0.01$).

Discussion

It has been reported that factors such as environmental conditions, predatory organisms, fouling and boring organisms, breeding, and density of individuals in the culture system have affected the growth and survival of bivalves (Yu et al., 2010; Acarlı et al., 2011; Yiğitkurt, 2020). The high growth rate in aquaculture depends on keeping these factors in optimum conditions, especially temperature and salinity are among the environmental factors that largely control the normal development of the scallop (Shumway, 1991; Grecian et al., 2000; Gosling, 2003). In this study, the temperature values varied at all three depths, but the water temperature measured from 2 m depth was higher than other depths. The highest height and weight were measured in individuals at 2 m depth. No correlation was found between specific growth rates and temperature. However, the lowest levels of the size-dependent specific growth rate of scallops were calculated in February at all depths because the lowest temperature was measured in this period. Since scallops are poikilothermic creatures like other bivalves, metabolism and physiological processes generally increase or decrease according to changes in water temperature (Schmidt-Nielsen, 1990). In this study, the water temperature did not reach the lower and upper values that would stop the scallop growth, and it was observed that the growth continued during the periods when the water temperature decreased and increased.

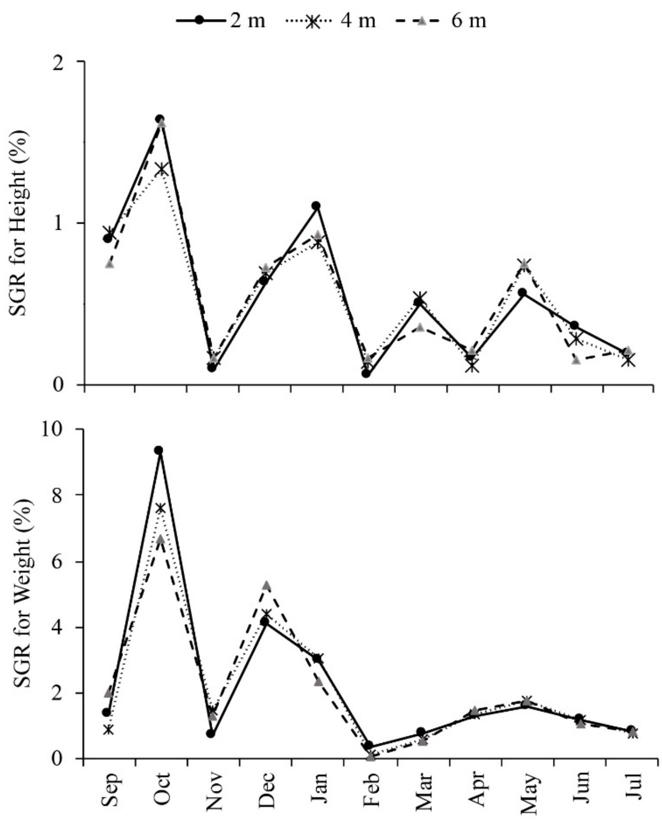

Figure 5. Specific growth rates for height (%) (a) and weight (%) of *Flexopecten glaber*.

The food sources of the scallops are phytoplankton, detritus, bacteria, and other organic substances that it filters from the water (Bricelj & Shumway, 1991, Beninger & Decottignies 2005). While high nutrient availability is assumed to increase both tissue and gonad growth, nutrient deficiency basically directs metabolic energy to maintain reproductive activity (Delgado & Perez-Camacho, 2005; Yigitkurt, 2021). In this study, seasonal chlorophyll-*a* peaked throughout the water column in July and August. Chlorophyll-*a* started to decrease in September. It was lowest between January and February. No relationship was found between chlorophyll-*a* and SGRh and SGRw. However, SGRh and SGRw values were also lowest in the months when the nutrient level was at its lowest. Chlorophyll-*a* values that were measured in the study area provided the necessary nutrients for scallop growth throughout the year, and nutrient abundance changed in parallel with the increase and decrease in water temperatures, indirectly affecting SGRh and SGRw.

Atmospheric cycles, wave movements, extreme weather changes and high rainfall in shallow sea areas significantly affect TPM levels (Orpin et al., 2004). Szostek et al. (2013) reported that resuspension of sediments would affect the growth, feeding and survival rates of scallops. There was little difference between concentrations at the depths. The seasonal variation in TPM was very erratic. Peaks occurred in September. The lowest TPM values at all depths were determined in November. SGRh and SGRw values were at low levels in November, but no correlation was found between TPM and SGRh and SGRw values.

Louro et al. (2005) stated that the scallops *Pecten maximus* that are 3 mm placed in suspended culture systems, reached 17 mm at the end of 85 days, the spats placed in the system as 4 mm size, grew up to more than 17 mm at the end of 57 days. At the same time, the survival rate was 70%. In a study in Ria de Arosa (Galicia, Northwest Spain) that lasted 259 days (October-July), it was reported that *Aequipecten opercularis*, one of the scallop species, increased from 22 mm to 58 mm with a specific growth rate of 0.11 mm day^{-1} (Roman et al., 1999). In a study conducted in the North Adriatic Sea, it was reported that *F. glaber*, which was placed in the system with a size of approximately 18 mm during the culture period, reached 35 mm height at the end of 390 days with a specific growth rate of 0.08 mm day^{-1} (Marčeta et al., 2016). In this study, the 8 mm *F. glaber* spats were grown at different depths for 12 months (360 days), and the best growth was found as 42.6±1.11 mm at a depth of 2 m with a daily specific growth rate of 1.156 mm day^{-1}. Comparing the findings of this study with other studies, the daily specific growth rate is higher in the present study. There was no statistically significant difference in specific growth rates between depths ($p>0.05$), but there was a statistically significant difference between the specific growth rate by months ($p<0.05$). Due to the small size of the individuals used in the experiment, we encountered high specific growth rates at the beginning of the study, and these rates continued to decrease in the following months of the study.

Causes such as wave motion, contamination, nutrient limitation, stock density have been reported as factors that increase the mortality rate (Grecian et al., 2000). In addition, Duggan (1973) reported that deaths increased as the shells of the scallops cut the soft tissue of the other scallop with the wave movements in the culture systems and called this "stabbing". It has been determined that the increase in mortality rates and the increase in the height of the scallops in the growing systems and

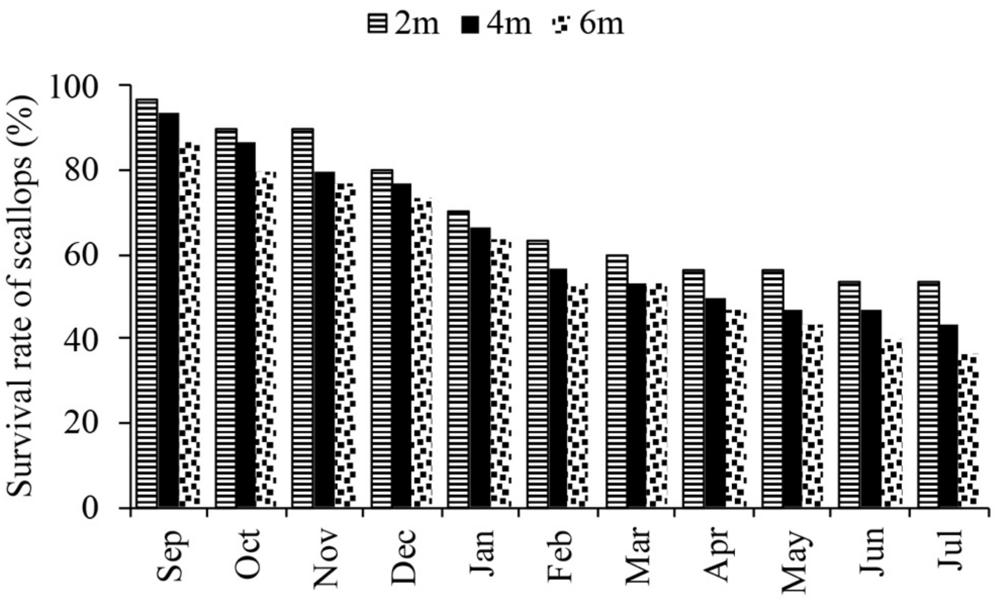

Figure 6. Survival rates of *Flexopecten glaber* (%) at different depths (2 m, 4 m and 6 m)

the narrowing of the area they are in cause harm to each other. At the end of this study, the mortality rates at 2 m, 4 m and 6 m depths were determined as 46.67%, 56.67%, and 63.33%, respectively. A strong positive correlation was found between mortality rate and height growth (r_{2m}=0.941, r_{4m}=0.956, r_{6m}=0.982). In culture systems, as the individual height increased, the mesh size was changed, but the culture system dimensions were kept constant, which increased the mortality rate. It has been reported that growth slows down, and high mortality rates are seen in growth systems near the bottom due to high TPM concentrations (Duggan, 1973; Emerson et al., 1994). This study also observed that the mortality rate increased in growth systems close to the bottom, and TPM rates were higher at 6m depth, which can be explained by the high TPM values.

Conclusion

In conclusion, the growth of scallops in suspended culture systems has been carried out for the first time in the region. In this study, the culture of *F. glaber*, one of the scallops known as potential species for culture in İzmir Urla Karantina Island and its surroundings, has been deemed appropriate due to the survival rate of approximately 50%. Even so, determining new potential areas for culture operations of this species is important in terms of higher survival rate and growth performance. Thus, this species' culture will contribute to the country's economy and create a new employment area and a new alternative product for export. For this species, it is recommended to investigate sexual maturity times and sizes in future studies.

Compliance With Ethical Standards

Conflict of Interest

The author declares that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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