Kafkas Univ Vet Fak Derg
17 (2): 203-210, 2011
DOI:10.9775/kvfd.2010.2806

**RESEARCH ARTICLE**

# Comparative Growth, Survival and Condition Index of Flat Oyster, *Ostrea edulis* (Linnaeus 1758) in Mersin Bay, Aegean Sea, Turkey

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**Makale Kodu (Article Code): KVFD-2010-2806**

## Summary

Growth and survival of flat oyster, *Ostrea edulis*, juveniles of different sizes (15 mm, 20 mm, 25 mm, 30 mm, 35 mm and 40 mm) from natural spatfall were studied in suspended culture in Mersin Bay Izmir, Turkey from April 2002 to August 2003. Environmental parameters such as temperature, salinity, chlorophyll-a, total particulate matter (TPM), pH were monitored each sampling time. Temperature was between 13.8ºC (December 2002) and 24.5ºC (July and August 2002). Average chlorophyll-a, TPM and pH were 1.7±0.64 µg $l^{-1}$, 0.01311±0.00224 mg $l^{-1}$ and 7.65±0.22, respectively. Shell length increment for each size groups (from small to large) was determined as 49.99, 43.39, 39.10, 33.11, 39.36 and 25.67 mm, respectively. The smallest group was growth faster than others ($P<0.05$). Significant differences in survival rates between size groups occurred (highest: 60% for 15.mm and lowest: 12.8% for 35 mm) ($P<0.05$). Condition index and meat yield which showed many variations throughout the study changed from 2.65% to 5.11% and from 6.65% to 12%, respectively.

***Keywords:*** *Flat Oyster, Ostrea edulis, Growth, Survival, Condition index, Meat yield*

# Yassı İstiridyenin, *Ostrea edulis* (Linnaeus 1758) Mersin Körfezi Ege Denizi Türkiye de Büyüme Yaşama ve Kondisyon İndeksinin Karşılaştırılması

## Özet

Doğadan toplanan farklı boylardaki (15 mm, 20 mm, 25 mm, 30 mm, 35 mm ve 40 mm) yassı istiridyelerin, *Ostrea edulis*, askı kültür tekniği ile büyüme ve yaşama oranı Mersin Körfezi, İzmir, Türkiye de Nisan 2002 Ağustos 2003 tarihleri arasında çalışıldı. Örnekleme süresince aylık olarak sıcaklık, tuzluluk, klorofil-a, total partikül madde (TPM), pH gibi çevresel faktörler takip edildi. Sıcaklık değerleri 13.8ºC (Ekim 2002) ve 24.5ºC (Temmuz ve Ağustos 2002) arasında değişim gösterdi. Ortalama klorofil-a, TPM ve pH değerleri sırası ile 1.7±0.64 µg $l^{-1}$, 0.01311±0.00224 mg $l^{-1}$ ve 7.65±0.22'dır. Her boy grubu için kabuk boyu (küçükten büyüye doğru) artışı sırası ile 49.99, 43.39, 39.10, 33.11, 39.36 ve 25.67 mm olarak belirlendi. En küçük boy grubu diğer boy gruplarına göre daha hızlı büyüdüğü tespit edildi ($P<0.05$). Boy gruplarının yaşama oranları arasında önemli bir fark bulundu (en yüksek: %60 için 15 mm ve en düşük: %12.8 için 35 mm) ($P<0.05$). Çalışma boyunca bir çok değişiklikler gösteren kondisyon indeksi ve et verimi sırası ile %2.65-%5.11 ve from %6.65-%12 arasında değişim gösterdi.

***Anahtar sözcükler:*** *Yassı istiridye, Ostrea edulis, Büyüme, Yaşama oranı, Kondisyon indeksi, Et verimi*

## INTRODUCTION

Several oyster species are the basis of economically significant Molluscan fisheries and extensive operations throughout the world. One of the most important species is flat oyster, *Ostrea edulis* (Linnaeus 1758), which is produced in France, United Kingdom, Spain and Greece [1]. The European flat oyster, *O. edulis*, is a commercial high

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value species which has increasingly attracted attention in the past years. World oyster production was estimated to be at around 4.8 million metric tons in 2006 with a value of $ 3.2 billion [2]. But oyster production in the wild and cultivated stocks is limited by disease as *Bonamia ostreae* and *Marteilia refringens* throughout much of Europe, e.g. Spain, the Netherlands, France, Denmark and United Kingdom [3,4]. These diseases are a major biological factor limiting oyster growth and survival [5]. However oyster populations the Turkish coastal area are known to have been disease free until now.

Shellfish culture is not a common practice in Turkey and only one species *(Mytilus gallopravincialis)* is farmed today. Oysters are traditionally produced by fishing from wild stocks for human consumption and exportation [6]. However the oyster production's economic importance may also be boosted by aquaculture in Turkey.

In Turkey research has been carried out on reproductive biology [7], larval development [8] and recruitment and cultivation [9-13].

The aim of the present study was to determine the feasibility of growing oysters to marketable size using mesh bags placed on long line system and to determine environment conditions in the culture area for 15 months.

## MATERIAL and METHODS

### *Study Area*

Mersin Bay is located on west cost of Izmir, Turkey (38º12'77" N and 26º25'46" E). It is 3.15 km in length and 1.81 km in width, with the depth at the farm varying between 15-20 m *(Fig. 1)*.

### *Environmental Factors*

Hydrological parameters were measured with mercury thermometer for temperature, hand refractometer for salinity (‰) and pH meter (HANNA HI 8314) for pH, every sampling time. Phytoplanktonic biomass was estimated via chlorophyll-a determinations using a spectrophotometric method [14]. Total particulate matter

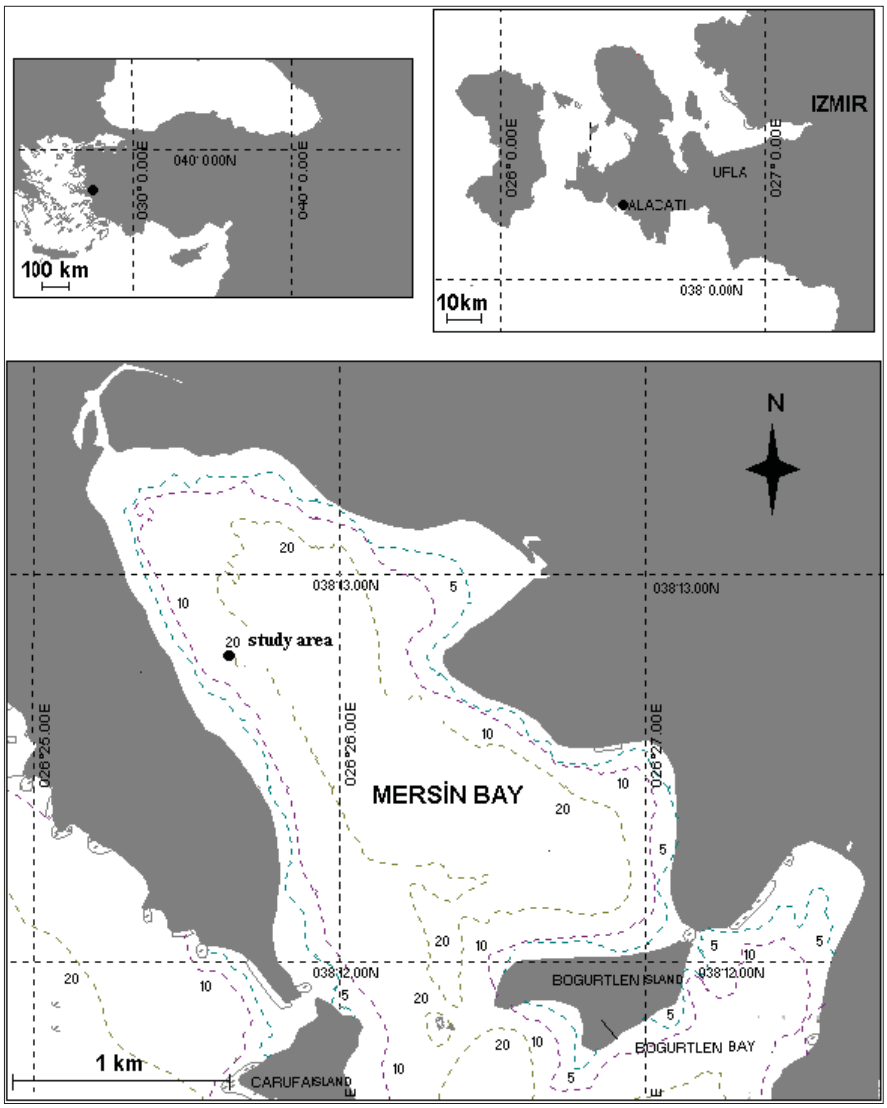



**Fig 1.** Map showing the study area in Mersin Bay (Aegean Sea Turkey)

**Şekil 1.** Mersin Körfezi'nde (Ege Denizi, Türkiye) bulunan çalışma alanını gösteren harita

(TPM) in suspension was monitored monthly [15].

### *Experimental Design*

We started our experiments with *O. edulis* spats that were taken from artificial collectors. The initial mean shell length of oysters for each size group was 15.45±1.16 (group 1), 20.13±1.48 (group 2), 25.35±1.17 (group 3), 29.75±1.08 (group 4), 34.85±1.17 (group 5), 40.19±1.26 (group 6) and the mean total wet weight was 0.68±0.24 g, 1.23±0.46 g, 2.45±0.73 g, 3.37±1 g, 5.34±1.23 g 7.45±1.91, respectively. Spats were placed in oyster mesh bags which were deployed on longline at intervals of 0.5 m. The oysters were monitored for 15 months from April 2002 to August 2003. Each sampling time, oysters were taken out from their bags for measuring morphological parameters, and placed into knew bags to continue experiments.

The morphological parameters (shell length, width and thickness) of oysters were measured using caliper (nearest 1 mm) every month. After oysters were cleaned by scrubbing at each sampling time and the degrees of fouling organisms, total wet weight of all size groups were weighed with an electronic balance (0.01 g, Sartorious, GE 412). Specific growth rate (SGR%) was calculated as:

$$SGR\ (\%) = (\ln L_2 - \ln L_1)/(t_2 - t_1) \times 100$$

Where $L_2$ and $L_1$ represent mean shell length or total wet weight at times $t_2$ and $t_1$ (30 day) [16]. Number of live oysters were recorded in each size groups and percentage survival was calculated by expressing the numbers alive at the beginning of the interval (30 day) as a proportion of the number alive at the end of the interval.

$$\text{Survival rate } (SR\%) = (N_t \times 100)/N_o$$

Where $N_t$ is the number of live oysters after time t and $N_o$ is the number of live oysters at the beginning of the experiment

### *Condition Index and Meat Yield*

Three months before the start of the study, oysters were collected by SCUBA at 1-10 m from Mersin Bay. Oysters were placed in oyster mesh bags and then hung on longline system. Thirty specimens (from 30 mm to 80 mm) were processed for analysis of condition index (CI) and meat yield (MY) monthly between May 2002 and August 2003. The CI was derived after separating meats and shell, and oven drying them to a constant weight at 60°C [17,18]:

$$CI = [\text{dry meat weight (g)}/\text{dry shell weight (g)}] \times 100$$

Meat yield was calculated as follows [18]:

$$\text{Meat Yield } (\%) = [\text{wet meat weight (g)}/\text{total weight(g)}] \times 100$$

An index of between 6.5 and 9 corresponds to "fine" oysters and greater than 9 to "spéciale" oysters.

### *Statistical Analyses*

One-way Anova was used to compare the differences in means between size classes for each sampling time. Before this we tested for homogeneity of variance using Levene test. At the end of study, survival rates were tested by Kruskal Wallis. The estimation of the morphometric relationships was made by the adjustment of an exponential curve to the data: $W = aL^b$ where W is the dependent variable whole live weight (g); L is independent variable, shell length (mm); a and b, coefficients determined from empirical data. a = scaling constant (and b = allometric growth parameter (slope). Single regression analyses and *t*-test were used to determine for relationships between growth rate and environmental parameter (temperature, chlorophyll-a and seston), shell length and total weight, CI and MY, CI and growth rate. Monthly CI data were also analyzed with a Kruskal Wallis Test Statistical analysis of data. One-way Anova, Kruskal Wallis and *t*-test were performed using the SPSS program version 13.0 for windows.

## RESULTS

### *Environmental Factors*

Highest temperature was observed between July and August 2002 (24.5°C) followed by a slow decrease until December 2002 (13.8°C). Chlorophyll-a concentration varied significantly between these months. As it can be seen from the figure, very low chlorophyll-a values were observed during winter months (minimum 0.62 µg $l^{-1}$, March 2003), while the maximum values were determined during spring and summer months (maximum 2.45 µg $l^{-1}$, June 2003) *(Fig. 2)*. Particulate organic matter (POM) ranged from a minimum of 9.64 mg/l in February 2003 to a maximum of 19.25 mg $l^{-1}$ in August. The average TPM was determined as 13.11±2.24 mg $l^{-1}$. Salinity and pH ranged 36-36.2‰ and 7.34-8.2, respectively *(Fig. 2)*.

### *Growth*

In *Table 1*, the mean value shell length and total wet weight increments of oyster groups were shown. In most groups, growth for shell length and total wet weight were rapid at the first month and then progressively slowed. After 15 month of culture, the mean increase in shell length was the highest (49.99 mm and 423%) at the group 1 and the lowest at group 6 (27.67 mm and 16%) size group. At the end of experimental period, the final weight for group 1, group 2, group 3, group 4, group 5 and group 6 was 53.72 g, 53.44 g, 50.1 g, 59.66 g and 54 g, respectively. The highest weight increment was observed from group 5 with 54.32 g. Statistical analysis of change in length of oyster groups showed significant difference ($P<0.005$).

At the beginning of the experiment, specific growth

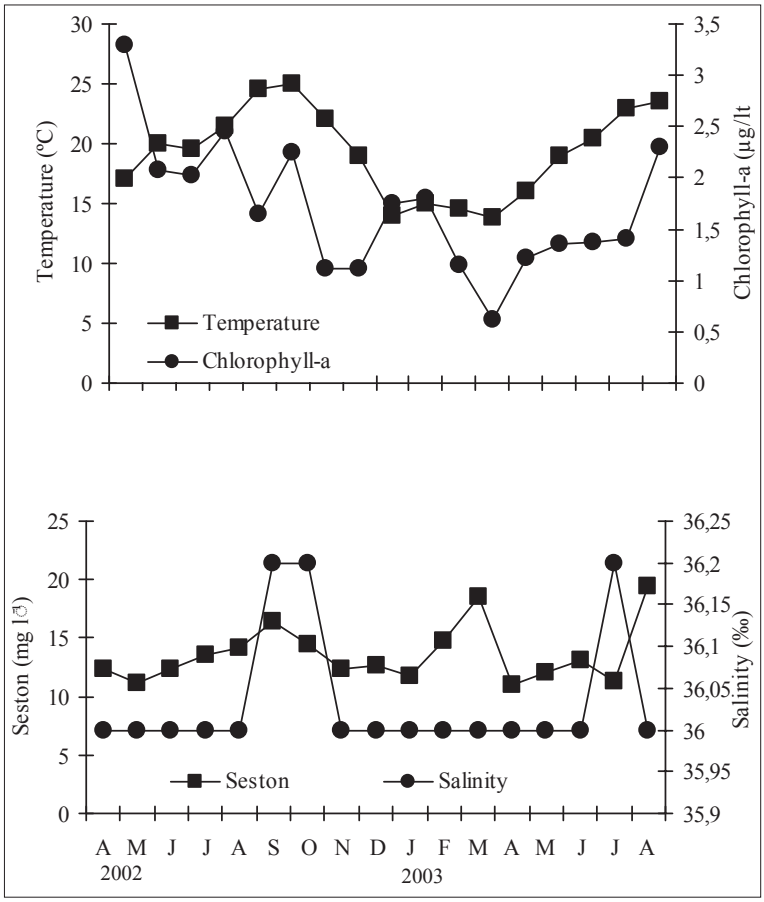



**Fig 2.** Variations in temperature, chlorophyll-a, seston and salinity value between April 2002 and August 2003

**Şekil 2.** Nisan 2002 Ağustos 2003 tarihleri arasındaki sıcaklık, klorofil-a, seston ve tuzluluk değerlerindeki değişim

***Table 1.*** *Monthly values of mean and standard deviation of growth in shell length and total wet weight of oyster size groups*
***Tablo 1.*** *İstiridye boy gruplarının kabuk boyu ve total yaş ağırlığındaki artışın aylık ortalaması ve standart sapması*

| Month | Group 1 | | Group 2 | | Group 3 | | Group 4 | | Group 5 | | Group 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Length | Weight | Length | Weight | Length | Weight | Length | Weight | Length | Weight | Length | Weight |
| March-02 | 15.46±1.16 | 0.68±0.24 | 20.13±1.48 | 1.23±0.46 | 25.30±1.17 | 2.45±0.73 | 29.73±1.08 | 3.37±1.09 | 34.85±1.17 | 5.34±1.23 | 40.19±1.26 | 7.45±1.91 |
| May | 23.41±2.70 | 1.89±0.46 | 24.03±3.59 | 2.14±0.75 | 32.44±4.81 | 4.03±1.16 | 35.84±3.97 | 5.31±1.82 | 38.68±4.15 | 7.54±1.44 | 43.39±3.60 | 10.86±2.39 |
| June | 29.07±3.88 | 3.67±1.29 | 29.45±4.93 | 3.97±1.55 | 37.07±5.38 | 6.43±2.12 | 41.2±6.19 | 8.61±3.64 | 43.25±4.55 | 11.06±2.56 | 45.43±4.40 | 13.36±3.02 |
| July | 35.44±4.40 | 6.29±2.11 | 34.52±6.02 | 5.98±2.69 | 41.52±3.52 | 9.89±1.93 | 45.65±5.85 | 12.18±4.45 | 44.9±5.64 | 14.29±4.47 | 48.65±4.50 | 17.30±4.12 |
| August | 39.92±5.44 | 10.09±3.09 | 36.33±5.90 | 9.25±3.56 | 42.40±3.79 | 13.88±3.12 | 45.22±6.45 | 16.00±5.81 | 46.1±6.33 | 27.25±12.53 | 49.59±5.96 | 23.37±6.26 |
| September | 41.66±5.97 | 20.42±3.38. | 40.85±6.33 | 13.02±4.49 | 45.94±4.96 | 17.87±4.75 | 48.8±6.65 | 19.19±6.92 | 45.83±6.53 | 28.58±12.85 | 51.33±6.30 | 24.45±6.93 |
| October | 43.39±6.50 | 18.39±5.87 | 45.37±6.77 | 16.79±5.43 | 49.49±6.13 | 21.86±6.39 | 52.38±6.86 | 22.39±8.04 | 53.56±6.74 | 29.92±13.18 | 53.081±6.65 | 25.53±7.61 |
| November | 49.82±7.33 | 22.45±7.93 | 51.13±6.01 | 23.25±7.75 | 51.47±7.17 | 22.32±7.79 | 54.83±8.65 | 24.13±9.41 | 57.41±6.32 | 31.88±11.54 | 61.37±7.15 | 37.31±12.39 |
| December | 51.00±9.30 | 27.08±10.95 | 52.01±6.92 | 26.21±9.42 | 57.03±5.30 | 29.46±8.27 | 54.94±8.61 | 27.96±11.37 | 57.70±7.42 | 34.53±12.04 | 60.92±8.57 | 41.68±14.85 |
| January-03 | 53.71±7.83 | 28.28±10.57 | 54.24±8.31 | 26.69±9.66 | 58.01±5.05 | 32.49±7.23 | 56.67±8.84 | 29.52±11.98 | 59.56±7.58 | 32.66±11.81 | 63.59±7.73 | 39.60±14.00 |
| February | 57.53±6.98 | 34.79±10.86 | 55.30±7.89 | 32.47±12.88 | 59.29±5.49 | 36.05±8.37 | 58.64±5.36 | 37.89±8.16 | 57.49±8.11 | 36.73±13.93 | 63.37±6.26 | 45.49±12.94 |
| March | 59.13±6.46 | 37.14±11.55 | 57.77±7.64 | 33.65±12.76 | 60.57±5.94 | 39.61±9.52 | 59.13±9.09 | 35.13±14.43 | 61.18±7.06 | 39.13±13.22 | 66.32±7.13 | 47.35±12.24 |
| April | 58.10±7.20 | 39.23±12.04 | 57.14±7.55 | 36.94±13.53 | 60.31±5.70 | 41.28±10.40 | 61.93±6.92 | 40.19±13.11 | 60.32±7.57 | 40.86±15.30 | 68.85±7.83 | 49.65±13.13 |
| May | 56.99±5.90 | 44.32±11.79 | 57.34±8.97 | 42.67±14.68 | 60.28±5.40 | 44.9±11.18 | 62.37±7.23 | 59.14±12.41 | 61.54±7.83 | 40.38±16.30 | 68.55±8.91 | 51.36±15.53 |
| June | 57.74±4.80 | 47.83±12.14 | 58.11±5.82 | 47.21±13.68 | 62.20±5.50 | 48.68±12.70 | 62.00±7.54 | 46.04±17.43 | 60.36±16.19 | 49.50±16.10 | 68.84±7.34 | 56.52±12.50 |
| July | 61.33±6.42 | 49.88±12.89 | 59.8±6.55 | 44.29±14.36 | 63.94±6.26 | 47.83±16.49 | 62.30±6.15 | 48.27±14.13 | 69.45±7.64 | 55.43±13.80 | 62.76±6.65 | 50.23±14.66 |
| August | 64.45±7.43 | 53.72±15.73 | 63.00±6.52 | 53.44±16.80 | 64.41±6.66 | 49.37±16.39 | 62.84±7.15 | 50.1±17.47 | 71.81±8.74 | 59.66±15.04 | 65.86±7.30 | 54.90±17.31 |
| Increment | 49.99 | 53.04 | 43.39 | 52.21 | 39.10 | 46.92 | 33.11 | 46.73 | 39.36 | 54.32 | 25.67 | 47.45 |

rate at each size groups was higher than other months. Negative values of specific growth rate were determined after December 2003 *(Fig. 3)*. Growth rate in shell length was correlated with chlorophyll-a for group 1, group 2 and group 6 ($P \leq 0.05$). In contrast, shell growth was not correlated with temperature and TPM ($P > 0.05$).

the minimum value of 6.65% in May but increased to the maximum value of 12.0% in December. According to MY, oyster quality changed from fine to spéciale oyster. Statistical analysis of change in CI and MY over the 16-month period showed significant difference ($P < 0.05$). In addition that, mean CI correlated with growth rate of

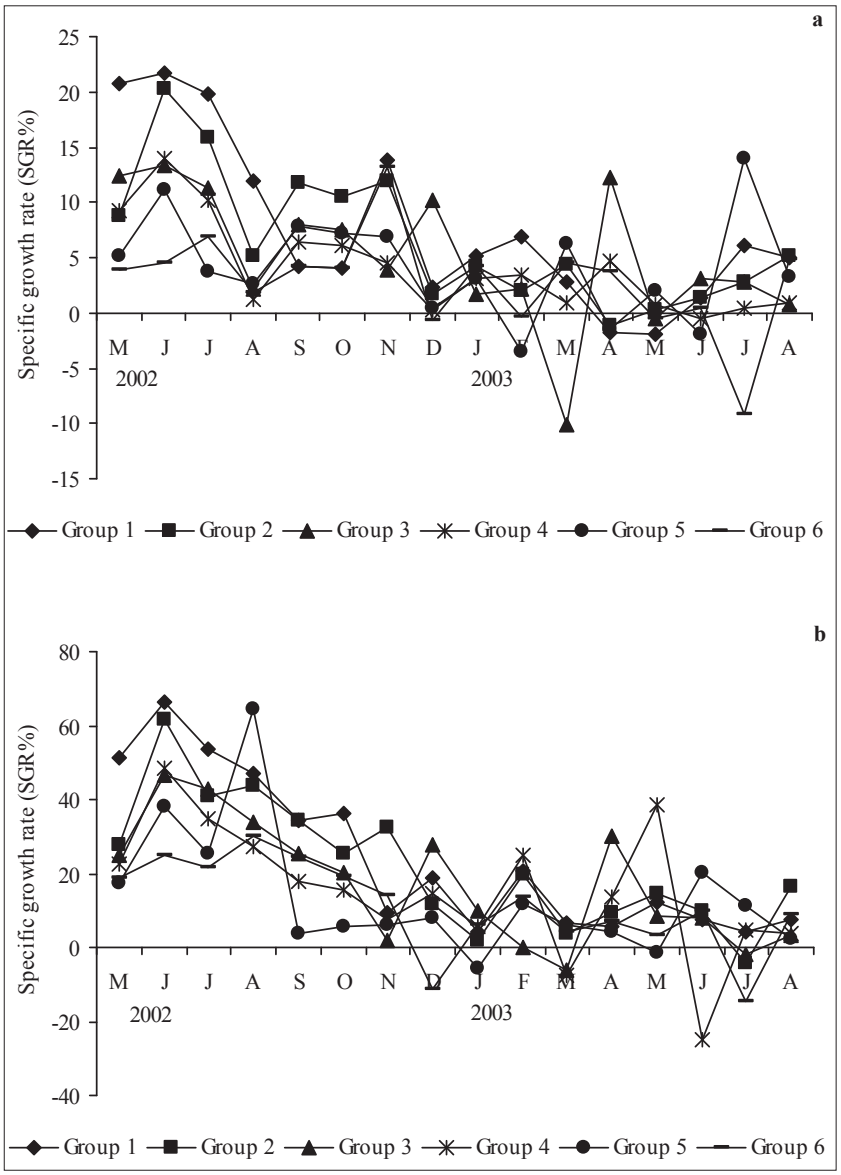



**Fig 3.** Monthly specific growth rates of *Ostrea edulis* in length (a) and weight (b) at each sampling time

**Şekil 3.** *Ostrea edulis*'in boy (a) ve ağırlığa (b) göre aylık spesifik büyüme oranları

Shell length-weight relationship was described as $W = 0.127L^{3.148}$ ($R^2 = 0.924$). The L/W morphometric relationship obtained in the present study exhibited a consistent isometric growth. The slope b and condition factor were 3.148 and 0.127, respectively *(Fig. 4)*.

### *Condition Index and Meat Yield*

Monthly changes of CI and MY of the oyster were shown in *Fig. 5*. CI increased rapidly starting from December and reached the maximum level in March (5.11%). Then the CI value sharply decreased in May (2.65%). MY showed oyster in respect of total live weight ($P < 0.05$) with simple regression analysis.

### *Survival Rate*

Survival decreased slightly in size groups in the first months except group 3. Afterwards, number of alive individuals were observed to decline gradually during the study. At the end of experiment, the highest survival was recorded in group 1 (60%) while the lowest in group 3 (12%) *(Fig. 6)*. Survival rate was significantly different between groups ($P < 0.05$).

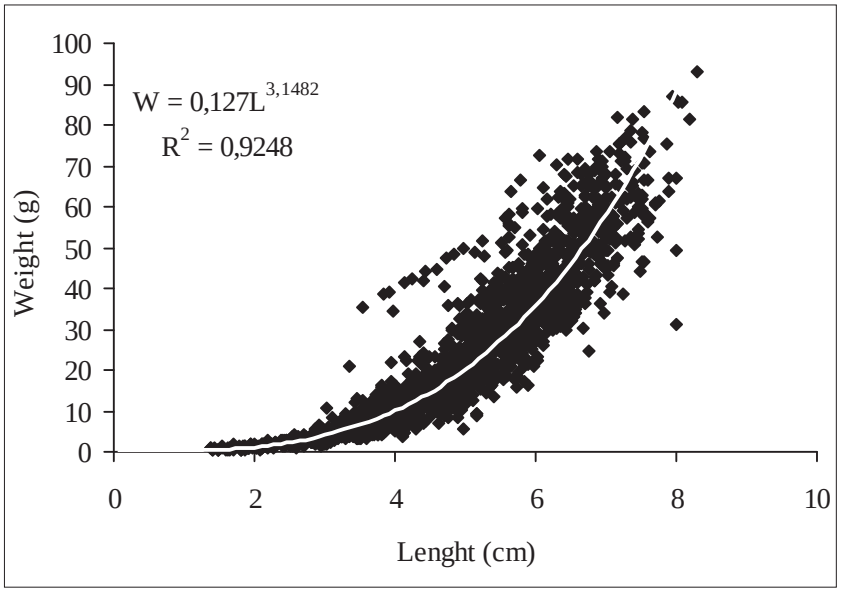
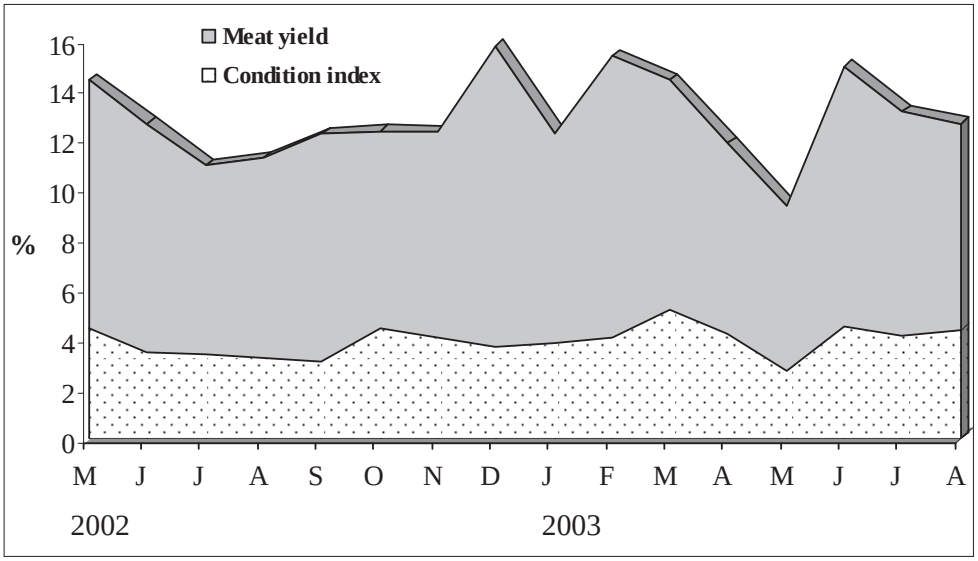



**Fig 4.** Length-weight relationship of *Ostrea edulis* cultured from Mersin Bay, Aegean Sea Turkey

**Şekil 4.** Mersin Körfezi'nde (Ege Denizi, Türkiye) kültüre alınan *Ostrea edulis*'in boy ve ağırlık ilişkisi

**Fig 5.** Variations in mean value of condition index and meat yield

**Şekil 5.** Kondisyon indeksi ve et verimi değerlerinin ortalamalarındaki değişim



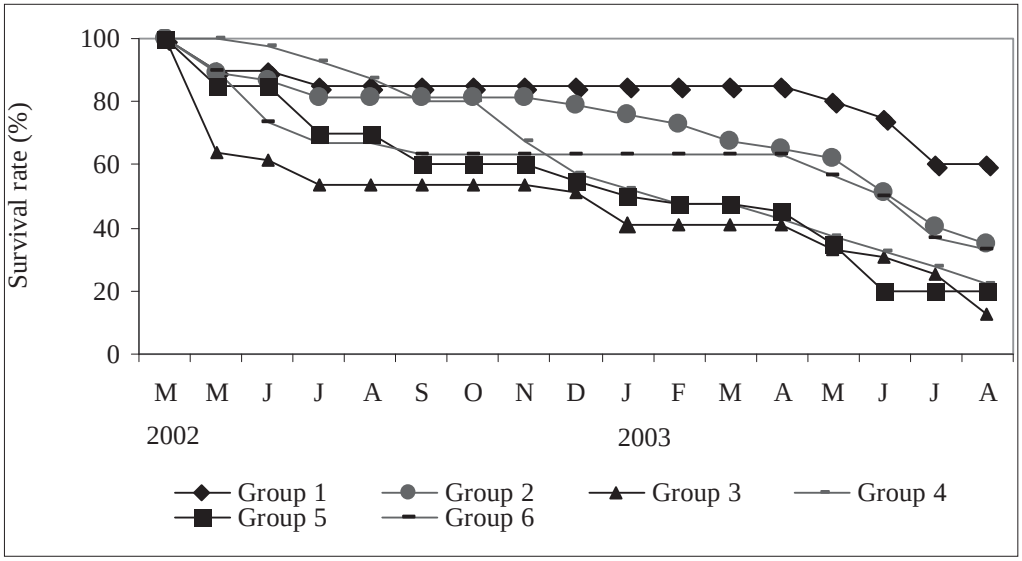




**Fig 6.** Change of survival rate of the size groups of *Ostrea edulis*

**Şekil 6.** *Ostrea edulis* boy gruplarının yaşama oranındaki değişim

## DISCUSSION

In shellfish culture, there are many environmental variables such as temperature [20], quality and quantity of the product [21,22], salinity [23] and tidal exposure [24], that affect the survival, reproduction, growth and yield of cultured species. During the cultivation process it is especially important to ensure that growth and survival are kept adequately high by manipulating biotic and abiotic factors that control them [1]. In this study, the growth rate of shell length has a significant correlation with chlorophyll-a concentration ($P<0.05$). However; shell growth rate and total live weight were not correlated with temperature and TPM ($P>0.05$). Water pH ranged from 7.34 to 8.32 during the experiment period. This range was accepted for oyster survival and reproduction [25].

Average monthly growth of shell length 3.12, 2.71, 2.44, 1.38, 2.4 and 1.6 mm/month$^{-1}$ was reached in group 1, group 2, group 3, group 4, group 5, and group 6, respectively. The smaller size groups showed significantly faster growth than larger size groups ($P<0.05$) when the size groups' growth was compared. These groups reached commercial size at the same time. The results of this experiment confirm the finding of Mitchell et al.[26]. Increase in shell length was relatively the greatest in small oyster groups. This implies that immature oyster spat would have faster growth rate than spat with developing gonads, and provides a possible explanation for the decrease in relatively growth rates in the larger size groups of spat [27].

In this study, oyster shell growth rate for length increased positively until December, after which the increase in the growth rate declined negatively. Shell length measurements showed considerable variation on occasions because shells were easily damaged (particularly of the frill). This may occur naturally or during the process of handling [25].

The potential mortality factors of bivalve are known to be affected by senility physical factors (storms, salinity, excessive silt, and temperature) and natural enemies (predators, competitors and parasites) [28]. In this study survival rate for group 3 (25 mm) was lower than the other size groups within the first month of culture in the natural environment. Condition of temperature or change in culture system between hatchery and natural environment may probably account for this early mortality [29]. Although Cáceres-Martinez et al.[30] reported that small oysters (*O. edulis*) were more sensitive to hanging, in this study small oysters (group 1) was more resistant and showed the highest survival rate (60%) at the end of experiment ($P<0.05$). This situation can be explained by small oysters adapting more rapidly than larger ones.

The commercial quality and physiological state of bivalve mollusc are adequately described by the condition index, a parameter of economic relevance reflecting the ecophysiological conditions and the health of animals [31]. The fluctuation of the CI index is associated with the reproductive condition or environmental parameters (temperature, salinity and nutrition) of bivalve [32,33]. Lok et al.[34] reported that reproduction of *O. edulis* in Mersin Bay continued all year round. It is assumed that food availability and environmental parameters such as temperature are suitable.

The condition index and meat yield values recorded in this study were between 5.11% and 2.65%, between 6.65% and 12.0%, respectively. Condition index of *O. edulis* was similar to *Crassostrea gigas* in Tunisia [35], *Crassostrea virginica* in Mexico [36]. Meat yield result was high as those registered by Soletchnik et al.[37] in France (semi-closed ponds) and by Fleury et al.[38] in France (Brittany).

As a result, we observed that growth and survival of group 1 (15 mm) were higher than other groups in mesh bags on long line system for 15 month in Mersin Bay. In this period, a commercial size of oysters (>50 mm) in shell length reached within 9 month. Condition index and meat yield of oyster were found to be fairly well according to other oyster culture areas. Results of the study show that environmental parameters are suitable for culture of oysters in Mersin Bay.

### Acknowledgments

We wish to thank Nihat KURTULUS (ACAR Fish Farmers) for logistic supporting and construction of longline system. We also thank Dr. Deniz ACARLI helping for sampling and Dr. Hulya SAYGI helping for statistical analyses of data.

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