Kafkas Univ Vet Fak Derg
17 (6): 995-1002, 2011
DOI:10.9775/kvfd.2011.4922

RESEARCH ARTICLE

Culture of Fan Mussel (*Pinna nobilis*, Linnaeus 1758) in Relation to Size on Suspended Culture System in Izmir Bay, Aegean Sea, Turkey

Sefa ACARLI * Aynur LOK ** Selcuk YIGITKURT ** Mustafa PALAZ *

* Canakkale Onsekiz Mart University Gokceada School of Applied Sciences, TR-17760 Canakkale - TURKEY
** Ege University, Fisheries Faculty Department of Aquaculture, TR-35100 Bornova/ Izmir - TURKEY

Makale Kodu (Article Code): KVFD-2011-4922

Summary

The growth and survival of fan mussel (*Pinna nobilis*, Linnaeus) juveniles, from natural spatfall, were compared in two groups (large and small size) in Karantina Island Izmir, Turkey, between December 2004 and April 2006. Total live weight, shell length, width and thickness of fan mussel were measured monthly during the study period. Small (32 mm) and large (73 mm) size groups of fan mussel individuals reached 140.25±10.46 mm and 154.36±16.12 mm in length and 64.64±17.98 g and 99.74±30.53 g in live weight, respectively. Significant differences were found in increases of shell length and live weight. Environmental parameters such as chlorophyll-a, seawater temperature, salinity, particulate organic matter (POM) and particulate inorganic matter (PIM) were determined during each sampling period. Shell length increase was affected by chlorophyll-a and PIM. However, increases in shell length did not correlate with temperature and POM. Survival rates for small and large groups were 93% and 100%, respectively.

Keywords: *Bivalvia, Fan mussel, Pinna nobilis, Growth rate, Survival rate, Suspended culture*

Pinanın (*Pinna nobilis*, Linnaeus 1758) Büyüklüğe Bağlı Olarak İzmir Körfezi Ege Denizi Türkiye de Askı Kültür Sisteminde Yetiştiriciliği

Özet

Izmir Karantina Adası, Türkiye de doğadan toplanan pina yavrularının (*Pinna nobilis*, Linnaeus), büyüme ve yaşamaları Aralık 2004 ve Nisan 2006 tarihleri arasında iki grup oluşturularak (büyük boy ve küçük boy) karşılaştırıldı. Çalışma boyuca, pinaların total canlı ağırlık, kabuk boyu, eni ve kalınlığı aylık olarak ölçüldü. Pinaların küçük (32 mm) ve büyük (73 mm) boy grupları sırasıyla 140.25±10.46 mm ve 154.36±16.12 mm boya ve 64.64±17.98 g ve 99.74±30.53 g canlı ağırlığa sırası ile ulaştı. Gruplar arasında kabuk boyu ve canlı ağırlık artışı bakımından farklılık görüldü. Klorofil-a, deniz suyu sıcaklığı, tuzluluk, partikül organik (POM) ve partikül inorganik madde (PIM) gibi çevresel parametreler her örnekleme zamanında takip edildi. Kabuk boyunun artışını klorofil-a ve PIM etkilemektedir. Bununla birlikte, kabuk boyu artışına sıcaklık ve POM etkilememektedir. Küçük ve büyük gruplar için yaşama oranı sırasıyla %93 ve %100 olarak belirlenmiştir.

Anahtar sözcükler: *Bivalvia, Pina, Pinna nobilis, Büyüme oranı, Yaşama oranı, Askı kültür*

INTRODUCTION

Fan mussel (Pen shell), *Pinna nobilis,* is an endemic species of the Mediterranean, belonging to the family of Pinnidae. Pinnids have a characteristically large, brown and fan-shape shell. The fan mussel lives with its pointed end buried into bottom sediments of mud, sandy mud or gravel, attached to small stones or pieces of shells by its byssus which passes through the anterior ventral gape [1]. *P. nobilis* lives longer than some other shellfish, for approximately 20 years, attaining a maximum size of at least 108 cm with a common size of 20-40 cm [2].

İletişim (Correspondence)
+90 286 8872302
sefaacarli@comu.edu.tr

The fan mussel *P. nobilis* is a particularly important species in the Mediterranean Sea. The population of *P. nobilis* has been significantly reduced over the last 2 to 3 decades as a result of recreational and commercial fisheries for food, the use of its shell for decorative purpose, and incidental depredation by trawling and anchoring [3]. In the north-east Spanish Mediterranean [4], in the Malo Jezero Adriatic Sea [5] and in Mar Grande of Taranto (Ionian Sea) [6], the densities of *P. nobilis* were recorded as < 1 ind ha^{-1}, 0.2 ind m^{-2} and from 0.1 to 0.7 ind.ha^{-1}, respectively. It is described as a considerable centre of species aggregation and it is known as being a very important biological substratum for many epibiont (sponges, molluscs, echinoderms, bryozoans, macroalgae etc.) [7-10]. They are affected by population decline of this species. For these reasons, *P. nobilis* is listed as endangered under the 1992 European Council Directive on the conservation of natural habitats and wild fauna and flora (92/43/EEC, Annex IV). It has been protected by the Protocol for Specially Protected Areas Biological Diversity in the Mediterranean (Barcelona Convention: UNEP) since 1996. In contrast to this endangered status, Pinnids such as *P. bicolor* (Gmelin 1791), *Atrina pectinata* (Linnaeus 1758) and *Atrina maura* (Sowerby 1835) are cultured and highly valued as a food source in Mexico [11]. Therefore studies on larvae culture [11,12] and spat collection [13,14] have been conducted for some time.

Recent studies of *P. nobilis* have examined population [3,5,15], in situ growth, age, and mortality [16-19] and reproductive biology [20,21].

Three species of Pinnid, *P. nobilis, P. rudis* (Linnaeus 1758) and *A. pectinata* inhabit the coast of Turkey [22]. However, no growth studies on *P. nobilis* were previously conducted under culture conditions. The main objective of this study was the assess growth rate of fan mussel *(P. nobilis)* under hydrological conditions typical of the Aegean Sea, Turkey.

MATERIAL and METHODS

Experimental Site

This study was carried out from December 2004 to April 2006 at Karantina Island which is located in the central section of Izmir Bay, Turkey (38°22'44" N; 26°47'12"E) *(Fig. 1)*. Sampling could not be performed during in January 2006 due to adverse weather conditions. Fan mussel spats were cultured on a the single long line system.

Hydrological Parameters

Environmental parameters (water temperature, salinity, chlorophyll-a, particulate organic mater and inorganic matter) were determined at each sampling time except January during 2006. Water temperature and salinity were measured using a thermometer and light refractometer, respectively. Chlorophyll-a concentration, particulate inorganic (PIM) and organic matter (POM) in suspension were determined using the protocols of Strickland and Parsons [23].

Experimental Design

All the fan mussels used in this study were collected in the study area by pearl oyster collectors, which had been suspended at a depth of 0.5 m depth in July, 2004. Fan mussel spats were separated from these collectors early in December, 2004. They were divided into two size groups, small (32 mm) and large (73 mm) based on shell length (between the hinge and the bill margin). Both groups were placed in spherical PVC baskets covered with multifilament nets *(Fig. 2)*. Each group was composed of 30 fan mussel spats. Every month during the experimental period, shell length, width and thickness was measured using an electronic caliper (Mitutoyo CD-15PK). Before

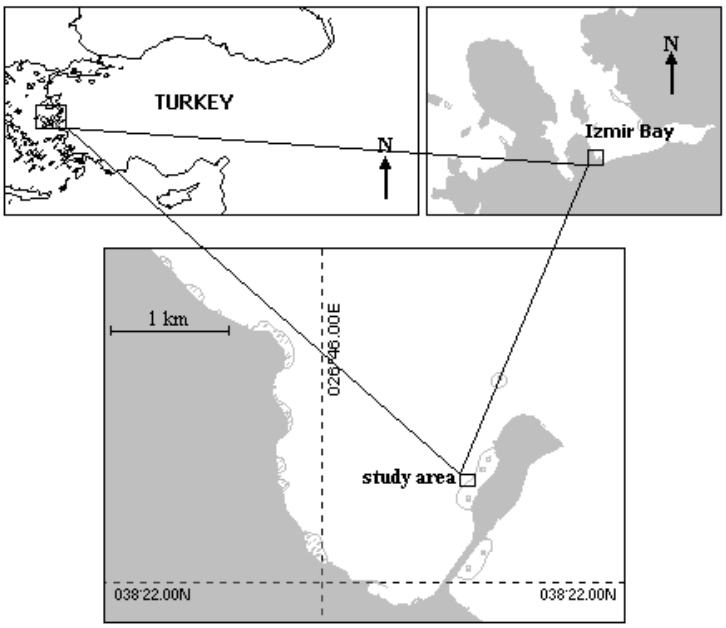

Fig 1. Map of Karantina Island (Izmir Bay-Turkey) showing the area where *Pinna nobilis* was cultured

Şekil 1. *Pinna nobilis*'in kültüre alındığı Karantina Adası bölgesinin (Izmir Körfezi-Türkiye) haritası

each weighing fan mussels were cleaned of fouling organisms with a knife. Total live weight was determined by an electronic scale (0.01 g, Sartorious, GE 412).

The specific growth rate (SGR%) was calculated according to the following formula [24]:

$SGR\% = [(\ln L_2 - \ln L_1) / \Delta t] \times 100$,

where L_1 and L_2 are the shell lengths or total weight at specific times (Δt) in days (t_2-t_1 is an average of 30 days).

The number of live fan mussels was recorded in each basket and total survival rate (%) was calculated at each sampling time by the following formula:

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

where N_t is the number of live fan mussels at time t and N_o the number of live fan mussel at the beginning of the experiment.

Data Analyses

The relationship between shell length (L) and total weight (W) was estimated by a series of allometric equations using the formula $W = aL^b$;where a is the intercept and b is the slope parameter. The allometry coefficient is expressed by the exponent b of the linear regression equations, in which when b=3, the biometric relationship describes an isometric growth. In order to confirm whether the value of b obtained in the linear regression was significantly different from isometric value (b=3) in a negative (b<3) or positive (b>3) allometric relationship, the data was fitted to a straight line by linear regression analysis (least squares method) and on log transformed data, the association degree between variables calculated by the determination coefficient (r^2).

Single regression analyses and the *t*-test were used to determine the relationship between shell length and total weight. The monthly length and weight data in both size groups were also analyzed using one-way analysis of variance (ANOVA). The metric multidimensional scaling technique (MDS) was used to investigate relationship between relations among the environmental parameters, growth rate in length and weight in small and large groups. Multidimensional scaling is an exploratory technique used to visualize proximities (proximity is a number that indicates the level of similarity or differences between different two objects or variables) in a low dimensional space. MDS allows researcher to uncover the hidden structure or relationship between variables. Each object is represented by a point a within multidimensional space. Two similar objects are represented by two points close to each other, while two different or dissimilar objects are represented by two points remote from each other [25].

RESULTS

Hydrological Parameters

The results of water temperature, salinity, chlorophyll-a, particulate inorganic matter (PIM) and particulate organic matter (POM) are shown in *Fig. 3*. Temperature showed a clear seasonal pattern, with a maximal value observed in August 2005 (24°C) and the a minimum value in December 2004, February 2005, February and March 2006 (12°C). Salinity ranged from 36 to 37‰ irrespective of potential seasonal variability. Mean particulate inorganic matter (PIM) and particulate organic matter (POM) were measured as 2.4±2.0 mgL-1 and 1.49±0.6 mg L-1, respectively. Chlorophyll-a concentrations were observed between 0.18 µg L-1 (December 2004) and 1.39 µg L-1 (August 2005).

Growth and Survival

Growth

At the end of the experimental period, small and large size groups reached 140.25±10.46 and 154.36±16.12 mm in shell length, respectively. Total growth within the small size group was 108.06 mm, with a monthly average value of 7.2 mm, compared with total growth of 80.92 mm for the large size group with a monthly average value of 5.39 mm ($P<0.05$) *(Fig. 3)*. A comparison of the mean monthly trends in width of small and large size groups indicated a similarity in all months except May and December 2005 *(Fig. 3)*. Mean shell thicknesses in the small size group (2.49 mm) and large size group (6.04 mm) reached 16.13 mm and 18.13 mm, respectively at the end of the study period. The final weights for small and large size groups were 64.64±17.98 g and 99.74±30.53 g, respectively ($P<0.05$). The greatest increase in total live weight for the small size group (with 8.41 g) was observed from June to July and from March to April (with 13.02 g) in the large size group *(Fig. 4)*.

Mean monthly specific growth rates for length and weight were 9.87% and 5.2%, respectively, for the small

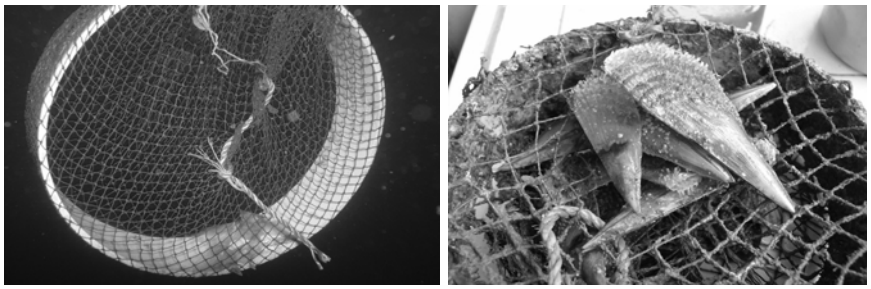

Fig 2. Spherical PVC baskets

Şekil 2. Yuvarlak şekilli PVC sepet

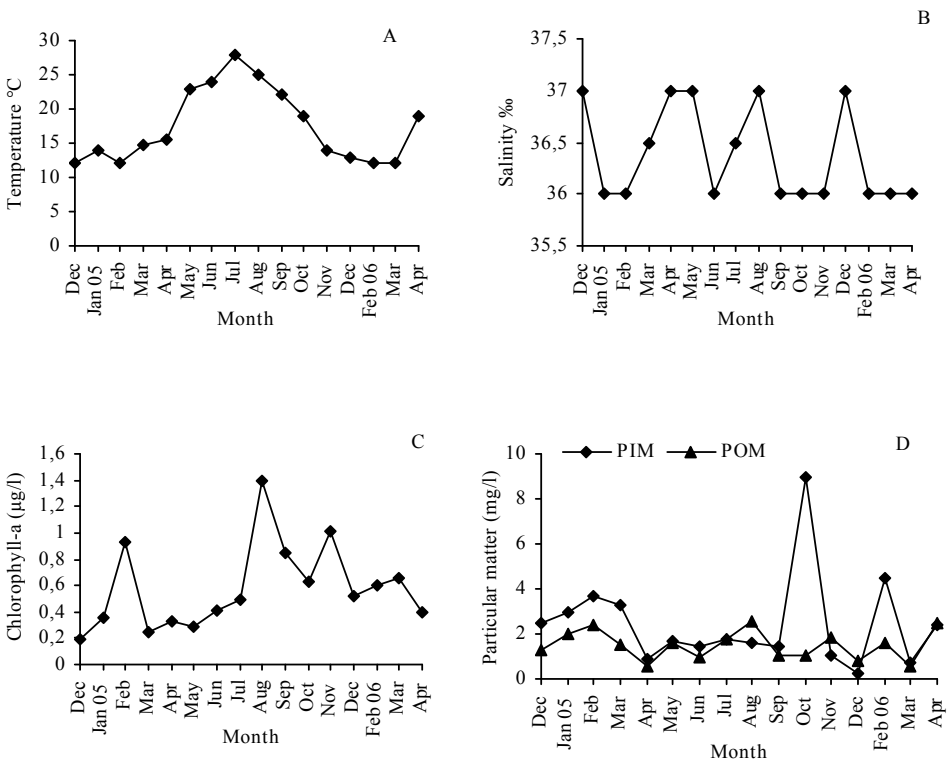

Fig 3. Variations of temperature (a), salinity (b), chlorophyll-a (c) and particulate inorganic and organic matter (PIM and POM) (d) in the study area

Şekil 3. Çalışma alanın sıcaklık (a), tuzluluk (b), klorofil-a (c), partikül organik ve partikül inorganik madde (PIM ve POM) (d) değişimi

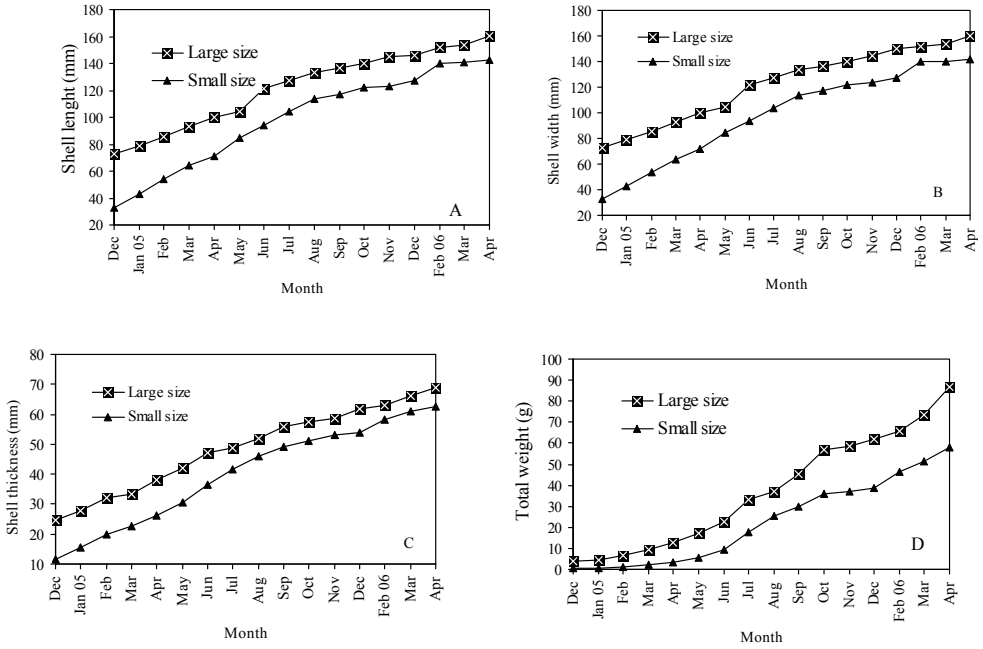

Fig 4. Mean shell length (a), width (b), thickness (c), and total weight (d) of small and large size groups of fan mussel *(Pinna nobilis)* over 15 months

Şekil 4. Onbeş ay süresince Pinnanın *(Pinna nobilis)* büyük ve küçük boy gruplarının kabuk boyu (a), eni (b), kalınlığı (c) ve total ağırlığı (d)

group, and 35% and 21.96%, for the large size group *(Fig. 5)*. A comparison of mean monthly specific growth rate in shell length and total weight showed that there was no difference between the two groups (P>0.05).

In the third month of the study (March 2005), only 93% survival rate (mortality rate 7%) was observed for the small size group. In comparison, no mortality was observed in the large size group, with all mussels surviving the study period.

Data Analyses

The MDS analysis indicates a strong relationship between chlorophyll-a, PIM and POM values, and suggests that these parameters affect LL *(Table 1, Fig. 6)*. It was determined that PIM has considerabe effect on WS, primarily LS, in the environment *(Table 2, Fig. 7)*.

Based on the results, it can be conclued that chlorophyl-a, PIM and POM, that form the nutrients of pinna considerably

affect the growth performance of the individuals within the large group, and that temperature is not significant growth factor.

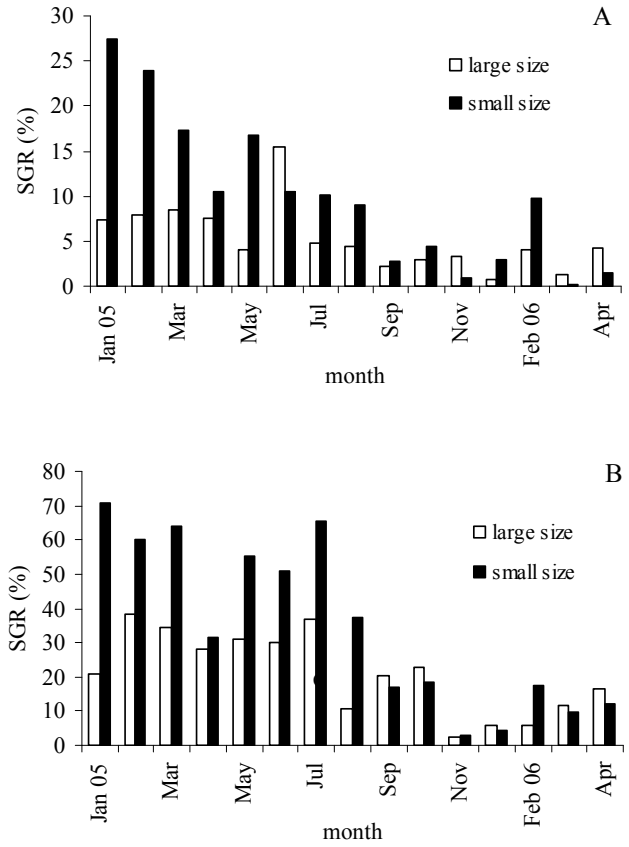

Fig 5. Monthly specific growth rate of length (A) and weight (B) for *Pinna nobilis*

Şekil 5. *Pinna nobilis*'in her iki gruburunun boy (A) ve ağırlığa (B) göre aylık spesifik büyüme oranı

The relationship between shell length and total weight was described by the equation $W=0.003L^{3.6451}$ (r^2 0.9625). Mean value of *b* was calculated as 3.6451±0.0332. The result revealed that there was a positive allometric growth between shell length and total weight (P≤0.05) *(Fig. 8)*.

Table 1. *Contribution of the variables on each dimension for large group*
Tablo 1. *Büyük grup için her boyutta değişken katkısı*

Variables	Dimension 1	Dimension 1
Temperature	1.4665	0.6875
Chlorophyll-a	-1.2495	-0.1597
PIM	-0.9608	-0.1640
POM	-1.1027	-.1398
WL	2.4930	-0.6638
LL	-0.4385	-0.3353
Month	-0.2081	0.7751

Table 2. *Contribution of the variables on each dimension for small group*
Tablo 2. *Büyük grup için her boyutta değişken katkısı*

Variables	Dimension 1	Dimension 2
Temperature	2.1647	-0.8398
Chlorophyll-a	0.3324	0.7019
PIM	-1.2732	0.6383
POM	0.3919	-0.4299
WS	-0.8964	-0.7910
LS	-1.4136	-0.4970
Month	0.6942	1.2175

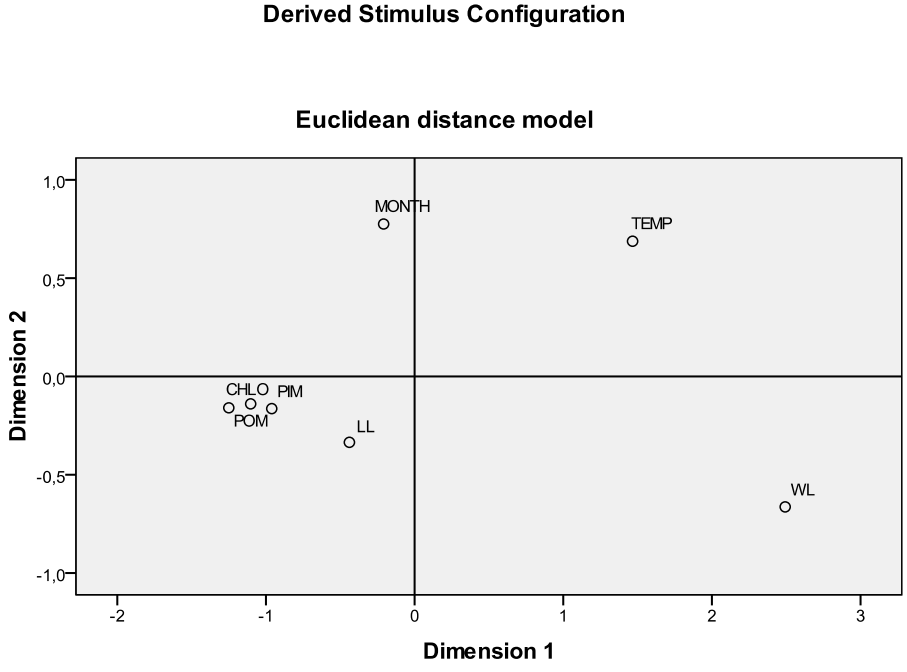

Fig 6. Multidimensional scaling map for environmental parameters, weight and length of large group

Şekil 6. Büyük boy grubu için çevre parametreleri, ağırlık ve uzunluğa bağlı olarak çok boyutlu ölçekleme haritası

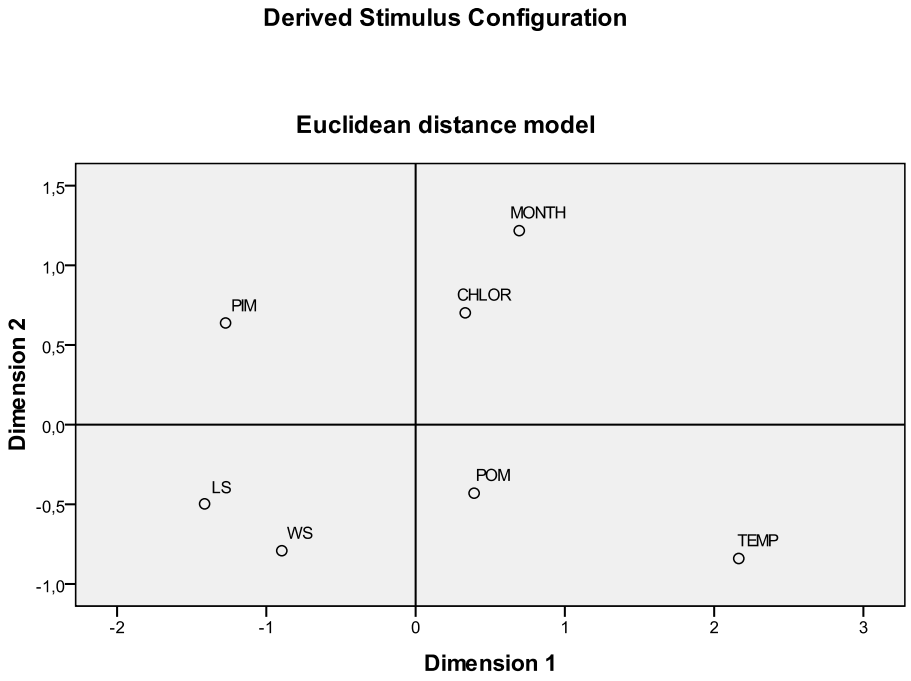

Fig 7. Multidimensional scaling map for environmental parameters, weight and length of small group

Şekil 7. Küçük boy grubu için çevre parametreleri, ağırlık ve uzunluğa bağlı olarak çok boyutlu ölçekleme haritası

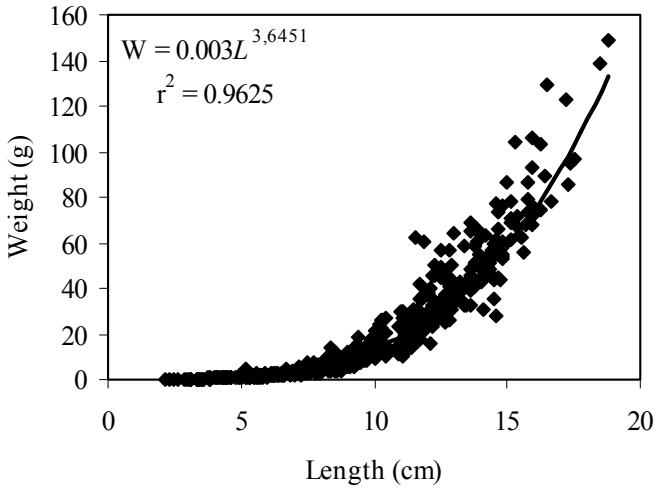

Fig 8. Relationship between shell length and total weight of *Pinna nobilis*
Şekil 8. *Pinna nobilis*'in kabuki boyu ve total ağırlığı arasındaki ilişki

DISCUSSION

The growth of bivalves depends on the quantity and quality of food in the water column [26,27], surrounding water temperature[28,29], salinity, population density, age and on size [30]. Of these parameters, food supply is considered to be most important for bivalves since, without this, sustainable growth is difficult or impossible [31]. Previous studies have indicated that the growth of bivalve spat is positively related to the concentration of chlorophyll-a in the water [32-34]. This study showed that the growth rate of shell length for both size groups was related to chlorophyll-a and PIM. Evidently, bivalve shells are mainly composed of calcium carbonate [35]. Watabe *et al.*[36] and Kuwatani [37] reported that *Pinctada fucata martensii* (Dunker 1872) could assimilate calcium from seawater into mantle or gill, and that uptake efficiency was enhanced by ingestion of plankton food. Although calcium carbonate was not determined in seawater in the study area, it can be transferred to fan mussels by ingestion of plankton for shell growth.

Katsanevakis [15] reported that temperature for the growth and reproduction of *P. nobilis* was relatively constant in Marine Lake Vouliagmeni, in Greece (annual temperature range of 11 to 29°C at deeps < 15m). *P. bicolor* was cultured at water temperatures ranging from 16.6 to 24.88°C in the northeastern part of Hong Kong [38]. During the present study temperature ranged between 12°C (February and March) and 24°C (August). The present results indicate that temperature was not a limiting factor for fan mussel growth in the study area.

Bear and Sauthgate [39] stated that of *P. bicolor* spats that were collected on the Orpeheaus Island of the Pioner Gulf (North Australia) grew very rapidly and reached from 75 mm up to 150 mm within 1 year. In a study in the Mali Ston Gulf of Croatia, whicht has an average temperature of 16.3°C and an average salinity of 36‰, Kožul *et al.*[40] reported that *P. nobilis* grew very rapidly and reached from 29 mm up to 157 mm within 1 year. Similar growth performances were observed in the present study, which showed similar in water temperature and salinity values *(Fig 3a, 3b)*. It can therefore be concluded that the study area provides appropriate conditions for culturing *Pinna nobilis*.

Growth rate was significantly different between groups ($P<0.05$). Shell growth rate for small size (32 mm)

individuals was more rapid than large size (72 mm) within the first year and reduced thereafter. Mason *et al.*[41] reported that immature oyster spat showed faster growth rate than those with developing gonads, and provided a possible explanation for the decrease in relative growth rates in the larger size group. Gonad development in *P. bicolor* was observed in many individuals at 8 months of age (150 < mm hinge length) [42]. At the end of this study, juveniles were approximately 18 months old. During the following 12 months, growth rate showed a decrease that could be linked to the progressive investment in reproduction and to age.

Most previous researchers reported that *Pinna* spp. have relatively thin shells which may present a potential problem for suspended culture in areas with predators (fish, crabs and muricid gastropods) [38,39,43]. In the present study, predators did not affect the fan mussels which were placed in spherical PVC baskets and mortality was clearly lower than in some other studies. Wu and Shin [38] reported mortality of 18% for *P. bicolor* transplanted inside cages and 24% among those suspended on rafts during the initial 12-month study period. In contrast, a study of for *P. nobilis* by García-March *et al.*[19] reported that total annual mortality at two depth zones of 6 m and 13 m was 44.4% and 23.7%, respectively in natural stock in Moraira Bay (Western Mediterranean-Spain). In a study of 160 *P. nobilis* individuals on Vauliagmeni lake, Katsanevakis[18] stated that only 7 of 69 deaths between May 2005-September 2006 were due to natural causes. Since the present study was carried out in a controlled environment, no deaths were caused by fishing. The natural death rate of 7% in the present study is similar to the results of Katsanevakis [18].

In conclusion, this study is the first report on the growth and culture of *P. nobilis* in a suspended system in Turkey. Higher growth was determined within large size group. However, high survival rate was observed in both group (93% and100%). This means that the environmental factors within the study area in Izmir Bay, Aegean Sea are suitable for mussel cultivation.

Our results will contribute to the development of more efficient culture techniques to support populations of this species in natural environments for this species. However, spat settlement and reproduction of *P. nobilis* is not described in the present work, which will form the subject of a further study in Turkish water.

Acknowledgements

The authors are grateful to the personnel of the Urla Research Unit of the Aquaculture Department of Fisheries Faculty, Ege University and in particularly the crew of the Hipocampus for technical assistance. We are also grateful to Ali Kırtık for help with the field and laboratory work.

REFERENCES

1. Tebble N: British bivalve seashells a hand book identification. Trustees of the British Muesum, p. 213, London, 1966.

2. Fischer W, Bauchot ML, Schneider M: Mèditerranèe et mer Noire, Zone de pêche 37. Revission1, Vol. 1 Vegetauxet Invertebres, p. 631, Rome, 1987.

3. Katsanevakis S: Density surface modeling with line transect sampling as a tool for abundance estimation of marine benthic species: The *Pinna nobilis* example in marine lake. *Mar Biol,* 152, 77-85, 2007.

4. Richardson CA, Kennedy H, Duarte CM, Kennedy DP, Proud SV: Age and growth of the fan mussel *Pinna nobilis* from south-east Spanish Mediterranean seagrass (*Posidonia oceanica*). *Mar Biol,* 133, 205-212, 1999.

5. Šiletić T, Peharda M: Population study of the fan shell *Pinna nobilis* L. in Malo and Veliko Jezero of the Mljet National Park (Adriatic Sea). *Scientia Marina,* 67 (1): 91-98, 2003.

6. Centoducati G, Tarsitano E, Bottalico A, Marvulli M, Lia OR, Crescenzo G: Monitoring of the endangered *Pinna nobilis* Linné, 1758in the Mar Grande of Taranto (Ionian Sea Italy). *Environ Monit Assess*, 131, 339-347, 2007.

7. Zavodnik D: *Pinna nobilis* L., comme centre d'association. Rapports et Procès verbaux. Rapp. *Comm Int Expl Sci Mer Médit,* 17, 273-275, 1963.

8. Zavodnik D: Contribution to the ecology of *Pinna nobilis* L. (Moll., Bivalvia) in the northern Adriatic. *Thalassia Jugosl,* 3, 93-10, 1967.

9. Raboui L, Tlig-Zouari S, Cosentino A, Hassine, OKB: Associated fauna of the fan shell *Pinna nobilis* (Mollusca:Bivalvia) in the northern and eastern Tunisian coasts. *Scientia Marina,* 73 (1): 129-141, 2009.

10. Acarlı S, Lök A, Acarlı D, Serdar S, Köse A, Yiğitkurt S, Kırtık A, Güler, M: Urla Karantina Adası civarında dağılım gösteren pina (*Pinna nobilis,* Linnaeus 1758) kabukları üzerine tutunan makrobentik türler. *Ulusal Kıyı Alanları Yönetimi Sempozyumu, 27 Nisan-1 Mayıs, 2010 Trabzon,* 741-746, 2010.

11. Cendejas JM, Carvallo MG, Juarez LM: Experimental spat collection and early growth of the pen shell, *Pinna rugosa* (Plecypoda: Pinnidae) from the gulf California. *Aquaculture,* 48, 331-336, 1985.

12. Sumpton WD, Brown IW, Dredge MCI: Settlement of bivalve spat on artificial collectors in a subtropical embayment in Queensland, Australia. *J Shellfish Res,* 9, 227-231, 1990.

13. Guo S, Chengcong C, He L, Wang Q: A preliminary study on the artificial rearing of larval pen shell *Pinna pectinata* Linne. *Mar Sci (Beijing),* 1, 34-39, 1987 (in Japanese with English abstract).

14. Sahavacharin S, Chindanond A, Amomjaruchit S, Nugranad J, Silipajam K, Chawivanskom V, Limsurat S: Hatchery, techniques for tropical bivalve molluscs. World Fish Center Technical Report 0115-5547, World Fish Centre Penang, p. 170, Malasia, 1988.

15. Katsanevakis S: Population ecology of the endangered fan mussel *Pinna nobilis* in a marine lake. *Endangered Species Res,* 1, 1-9, 2005.

16. García-March JR, García-Carrascosa AM, Peña A: The problems of *in situ* measurement of *Pinna nobilis* Linnaeus, 1758 shell, for age and growth studies: A new device. Mar Biol, 150, 861-871, 2007.

17. Richardson CA, Peharda M, Kennedy H, Kennedy P, Onofri V: Age, growth rate and season of recruitment of *Pinna nobilis* (L) in Croatian Adriatic determined from Mg:Ca and Sr:Ca shell profiles. *J Exp Mar Biol Ecol,* 299, 1-16, 2004.

18. Katsanevakis S: Growth and mortality rates of the fan mussel *Pinna nobilis* in Lake Vouliagmeni (Korinthhiakos Gulf, Greece): A generalized additive modeling approach. *Mar Biol,* 152, 1319-1331, 2007.

19. Garcı´a-March JR, Garcı´a-Carrascosa AM, Pen˜a Cantero AL, Wang YG: Population structure, mortality and growth of Pinna nobilis *Linnaeus*, 1758 (Mollusca: Bivalvia) at different depths in Moraira Bay (Alicante, Western Mediterranean. *Mar Biol,* 150, 861-871, 2007.

20. De Gaulejac B, Henry M, Vicente N: An ultrastructural study of gametogenesis of the marine bivalve Pinna nobilis (Linnaeus 1758) I. oogenesis. *J Moll Stud,* 61, 375-392, 1995.

21. De Gaulejac B, Henry M, Vicente, N: An ultrastructural study of gametogenesis of the marine bivalve *Pinna nobilis* (Linnaeus 1758) II. Spermatogenesis. *J Moll Stud,* 61, 393-403, 1995.

22. Öztürk B, Çevik, C: Mollusca fauna of Turkish Seas. *Club Conchylia Informationen,* 32, 27-53, 2000.

23. Strickland JDH, Parsons TR, A practical handbook of seawater analysis. Bulletin of Fishery Research Board, p. 310, Canada, 1972.

24. Chatterji A, Ansari JA, Ingole BS, Parulekar AH: Growth of green mussels, *Perna viridis* L., in a sea water circulation system. *Aquaculture,* 40, 7-55, 1984.

25. Kruskal JB, Wish M: Multidimensional scaling: Quantitative applications in the social sciences. Sage Publ., Newbury Park, CA, USA, 1978.

26. Sarà G, Mozola A: Effects of trophic and environmental conditions on the growth of *Crassostrea gigas* in culture. *Aquaculture,* 153, 81-91, 1997.

27. Yıldız H, Lök A, Acarli S, Serdar S, Köse A: A preliminary survey on settlement and recruitment patterns of Mediterranean *(Mytillus galloprovincialis)* in Dardanelles Turkey. *Kafkas Univ Vet Fak Derg,* 16 (Suppl-B), S319-S324, 2010.

28. Gosling, E: Bivalve Molluscs Biology Ecology and Culture. Fishing News Books, p. 443, London, 2003.

29. Acarli S, Lok A, Kucukdremenci A, Yildiz H, Serdar S: Comparative growth, survival and condition index of flat oyster, *Ostrea edulis* (Linnaeus 1758) in Mersin Bay, Aegean Sea, Turkey. *Kafkas Univ Vet Fak Derg,* 17 (2): 203-210, 2011.

30. Bayne BL: Marine mussels: Their ecology and Physiology. International Biological Programme 10, p. 506, Cambridge University Press, London, 1976.

31. Seed R, Suchanek TH: Population and community ecology of *Mytilus.* **In,** Gosling E (Ed): The Mussel Mytilus: Ecology, Physiology, Genetics and Culture. pp. 87-169, Elsevier Science Publishers BV, Amsterdam, 1992.

32. Tomaru Y, Kumatabara Y, Kawabata Z. Nakona S: Effect of water temperature and chlorophyll abundance on shell growth of Japanese pearl oyster, *Pinctada fucata martensii,* in suspended culture at different depths and sites. *Aquaculture Res,* 33, 109-116, 2002.

33. Lodeiros C, Pico D, Prieto A, Narváez N, Guerra A: Growth and survival of the pearl oyster *Pinctada imbricate* (Röding 1758) in suspended and bottom culture in the Golfo de Cariaco, Venezuela. *Aquaculture Int,* 10, 327-338, 2002.

34. Lök A, Acarlı S, Serdar S, Köse A, Yıldız H: Growth and mortality of Mediterranean mussel *Mytilus galloprovincialis* Lam., 1819 in relation to size on longline in Mersin Bay, Izmir (Turkey-Aegean Sea). *Aquaculture Res,* 38, 819-826, 2007.

35. Awang-Hazmi AJ, Zuki ABZ, Noordin MM, Jalila A, Norimah Y: Mineral composition of the cockle *(Anadara gronasa)* shells of west of Peninsular Malaysia and it's potential as biometrical for use in bone repair. *J Animal Veterinary Adv*, 6 (5): 591-594, 2007.

36. Watabe N, Yoshii G, Okada Y: Studies of shell formation in young pearl oyster, *Pinctada martensii* (Dunker) using Ca^{45}: Comparison of uptake of Ca^{45} from seawater and food. *Bull Jpn Soc Scie Fish,* 23, 139-143, 1957 (in Japanse with English abstract).

37. Kuwatani Y: Rearing of pearl oyster, *Pinctada martensii* (Dunker), on the diet of *Skeletonema costatum. Bull Jpn Soc Scie Fish*, 30, 104-113, 1964 (in Japanse with English abstract).

38. Wu RSS, Shin PKS: Transplant experiments on growth and mortality of the fan mussel *Pinna Bicolor Aquaculture,* 163, 47-62, 1998.

39. Beer AC, Southgate PC: Spat collection, growth and meat yield of *Pinna bicolor* (Gmelin) in suspended culture in northern Australia. *Aquaculture,* 258, 424-429, 2006.

40. Kožul V, Glavić N, Bolotin J, Antolović, N: The experimental rearing of fan mussel *Pinna nobilis* (Linnaeus, 1758). *46th Croatian and 6th International Symposium on Agriculture,* pp. 803-806, 2011

41. Mason CJ, Reid DD, John AN: Growth characteristics of Sydney rock oysters *Saccostrea commercialis* in relation to size and temperature. *J Ex Mar Bio Eco,* 227, 55-168, 1998.

42. Butler AJ: Ecology of *Pinna bicolor* Gmelin (Mollusca: Bivalvia) in Gulf St. Vincent, South Australia: Density, reproductive cycle, recruitment, growth and mortality at three sites. *J Marine Freeshwater Res,* 8, 743-769, 1987.

43. Butler AJ, Vincente N, Gaulejac B: Ecology of the pteroid bivalves *Pinna bicolor* Gmelin and Pinna nobilis Linnaeus. Marine Life, 3, 37-45, 1993.