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GROWTH AND SURVIVAL RATES OF BEARDED HORSE MUSSEL *(MODIOLUS BARBATUS* LINNE, 1758) IN MERSIN BAY (TURKEY)

A. Lok[1]*, S. Acarli[1], S. Serdar[1], A. Kose[1] and P. Goulletquer[2]

[1] *Department of Aquaculture, Fisheries Faculty, Ege University, Bornova Izmir, 35100 Turkey*

[2] *Ifremer – Genetics, Aquaculture, Pathology Research Laboratory, La Tremblade, 17390 France*

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Abstract

The growth and survival rates of four size classes (10, 15, 20, and 25 mm) of bearded horse mussels (*Modiolus barbatus*) grown in net bags in Mersin Bay, Izmir, were assessed from May 2001 to May 2002. Temperature ranged 14-23°C, average chlorophyll *a* was 3.34±0.35 µg/l, average total particulate matter 12.43±0.68 mg/l, and average particulate organic carbon 210.23±18.00 µg/l. Shell lengths increased 23.05, 19.76, 19.40, and 12.09 mm in the four classes (from small to large) and live weights increased 13.21, 10.46, 10.06, and 4.96 g, respectively. Survival rates ranged from 25% in the smallest size class to 87.5% in the 20 mm class ($p<0.05$). Mussels grew significantly fastest in the smallest size class ($p<0.05$).

Introduction

The bearded horse mussel *Modiolus barbatus*, a boreal species, is a bivalve mollusk that inhabits coastal marine environments down to about 110 m, where it may occur in very large communities (Tebble, 1976; Jasim and Brand, 1989). It has been reported on the southern and western coasts of Great Britain, the west coast of Ireland, the southern part of the Iberian Peninsula, in the Mediterranean Sea, and along the Atlantic coast of Morocco (Tebble, 1976). In Turkish waters, it ranges from the Mediterranean to the Black Sea (Alpbaz, 1993). The mussel is harvested from natural beds for human consumption together with the Mediterranean mussel (*Mytilus galloprovincialis*) and exported. A rather limited amount of *M. barbatus* is consumed in Europe (Alpbaz, 1993).

* Corresponding author. E-mail: aynur.lok@ege.edu.tr

While extensive literature is available on *M. galloprovincialis* and *Mytilus edulis*, limited information is available on species of the mytilid *Modiolus* genus which has been poorly known until recently. Our study aims to estimate the seasonal growth of *M. barbatus* based on growth and survival rates of individually measured mussels in four distinct size classes, to aid in decision-making for future culture and fishery management.

Materials and Methods

Study area. The study site was located at a fish farm in Mersin Bay (38º 12.77'N, 26º 25.46'E), Aegean Sea, about 80 km west of Izmir, Turkey (Fig. 1). The depth at the farm varied 18-24 m. Subsurface water was sampled monthly from May 2001 to May 2002 at a depth of 5 m. Although we were not in the study area during July and November, the farmer took water samples. Temperature was measured with a mercury thermometer that ranged -10 to 100±0.5°C and salinity (‰) was measured with a hand refractometer. Phytoplankton biomass, the amount of seston (total particulate matter; TPM), and the concentration of particulate organic carbon (POC) were determined according to the methods of Strickland and Parsons (1972).

Growth and survival rates. The initial population of bearded horse mussels was sampled from the fish cages and hand-sorted to remove other organisms and debris. The mussels were divided by length into four size groups: 10 mm (9.88±0.35), 15 mm (14.86±0.23), 20 mm (19.61±0.26), and 25 mm (25.76±0.54 mm). The length and weight of each mussel were measured. One hundred and fifty mussels from each group were placed into plastic mesh bags at 50 per bag (experiment was conducted in triplicate) and the bags were hung in a cage at 0.5 m below the water surface. The mussels were sampled in early May 2001 and monthly, except for July and November, until May 2002. During each sample, the mussels were removed from their bags, measured as above, and placed into clean bags to avoid bio-fouling. Shell

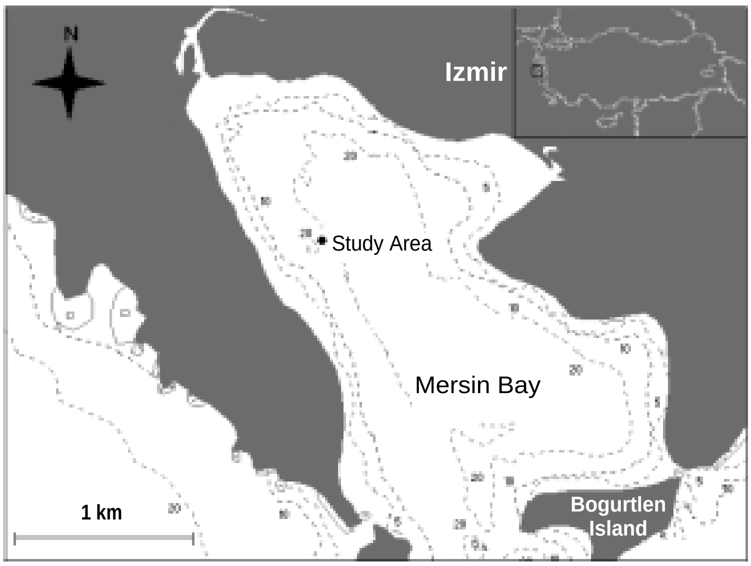

Fig. 1. Location of study site in Mersin Bay (Cesme), Izmir, Turkey. Bathymetric lines in meters.

length and total weight were individually measured using calipers (0.1 mm) and a balance (0.01 g), respectively.

The specific growth rate (SGR; %) was calculated using the following equation (Chatterji et al., 1984): SGR = $[(\mathrm{Ln}L_2 - \mathrm{Ln}L_1)/(T_2 - T_1)] \times 100$, where L_1 and L_2 are the lengths at times 1 and 2 and T_1 and T_2 are times 1 and 2 in days. The von Bertalanffy Growth Function, developed by von Bertalanffy (Pauly, 1982), is described by the equation: $L_t = L_\infty[1 - e^{-K(t_1 - t_0)}]$, where L_∞ is the asymptotic (or theoretical maximum) length in millimeters, K is the growth constant, L_t is the length at time t, and t_0 is the theoretical time when length equals zero. The model was applied to calculate the maximum size (L_∞) and K for each size class.

Survival (%) was estimated as $(N_t/N_o) \times 100$, where N_t is the number of live mussels removed from the bags after time t and N_o is the number of mussels at the beginning of the experiment.

Regression model. Relationships between shell length and live weight were described by a series of allometric equations in the form $Y = aX^b$, where Y = weight, X = length, and a and b are fitted parameters (Gould, 1966). The data fitted to a straight line by least squares regression analysis. Data were pooled for regression analysis.

Statistical analysis. One-way ANOVA was used to test for differences in means between size classes for each sampling date. Levels within a significantly different experimental factor were analyzed using Tukey's Honest Significant Difference (HSD) multiple comparison test. Survival data (percentage) were arcsine transformed to test for significant differences among size groups. Chi-square was used to test the significance of variance in the mortality rate. The functional relationship between shell characteristics was tested using regression analysis. All statistics were executed using SPSS software.

Results

Hydrological conditions. The study area had favorable salinity, temperature, and food availability throughout the year. Salinity ranged 36-37‰ without seasonal variability, water temperature ranged 14-23ºC with a significant peak in summer and a low in December, and chlorophyll *a* concentration had an irregular pattern ranging 1.97-5.37 µg/l (Fig. 2). The average total particulate matter was 12.43±0.68 mg/l (7.2 in March to 17.5 in November).

Growth rate. Length and weight data are plotted in Fig. 3 and the equation with the best fit is shown. Growth is shown in Fig. 4. The time of initiation of the experiment clearly influenced the growth rate during the first half year; the total weight gains of the smaller size groups were less impacted than those of the larger size groups during the cold months of December and January. Mean shell length in the smallest size group reached 32.93±0.65 mm, in the 15 mm group 34.62±0.76 mm, in the 20 mm group 39.01±0.76 mm, and in the largest 37.85±2.55 cm ($p<0.05$). The length increment of the 10 mm group was approximately twice that of the 25 mm group, 233.2% for the small size compared to 46.9% for the large ($p<0.05$). Monthly SGRs ranged 5.51-22.23% in June and 2.66-3.93% in October, and then stabilized for all size classes (Fig. 5).

Survival rate. The lowest survival rate occurred in the 10 mm group (25%) and significantly differed from survival in the remaining three groups ($p<0.05$). Mortality in the 10 mm group occurred in five months (Fig. 6). In the 15 mm group, overall survival was 83.6% with mortality occurring in August (4.34%), October (9.09%) and March (4.34%). The highest survival rate occurred in the 20 mm group (87.50%), where mortality was observed only in December. In the 25 mm group, mortality occurred in August (33.33%) and January (25%).

Discussion

The successful cultivation of any shellfish species of commercial significance depends directly on seed availability, suitable environmental conditions for growth, and limited predation (Hickman, 1992). The ambient chlorophyll *a* concentration in water suitable for mussel culture ranges 17-40 µg chlorophyll/l (Cheung, 1982), higher than the values mea-

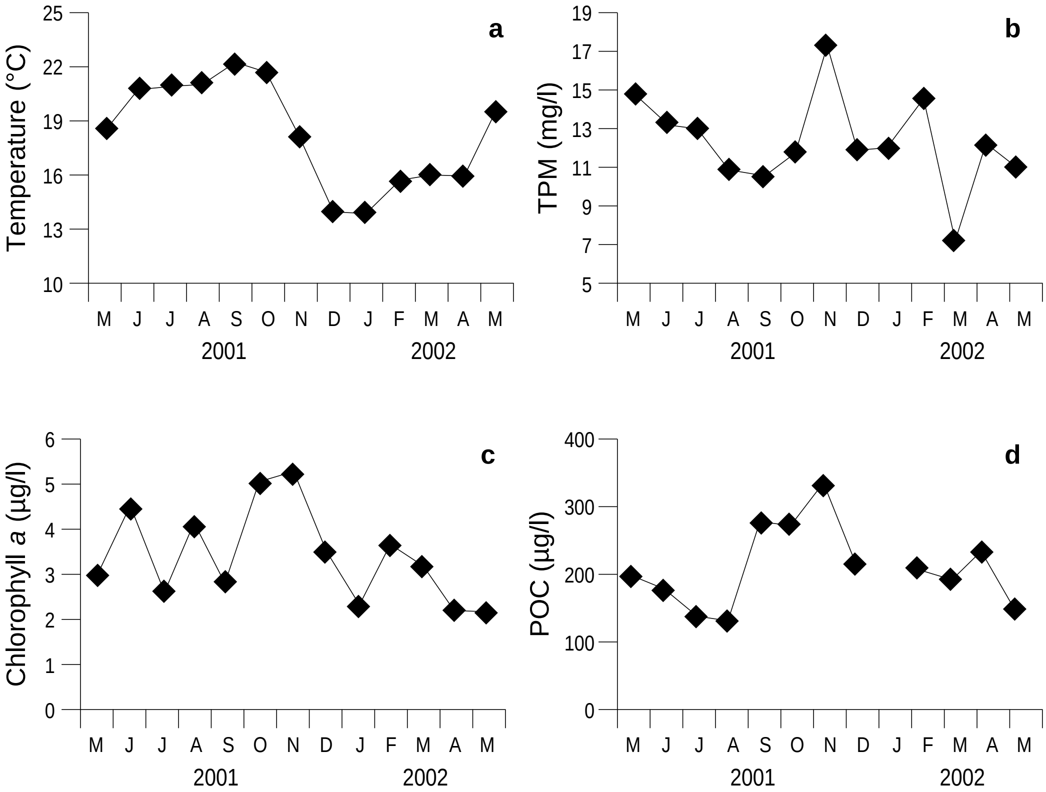

Fig. 2. Monthly (a) temperature, (b) total particulate matter (TPM), (c) chlorophyll *a*, and (d) particulate organic carbon (POC).

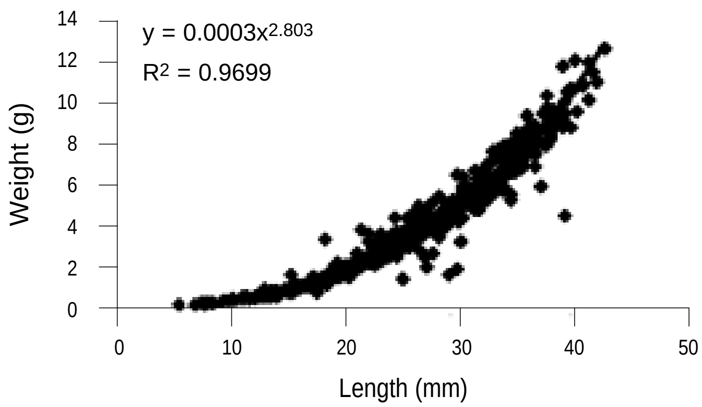

Fig. 3. Shell length vs live weight in bearded horse mussel, *Modiolus barbatus*, raised in Mersin Bay, Turkey.

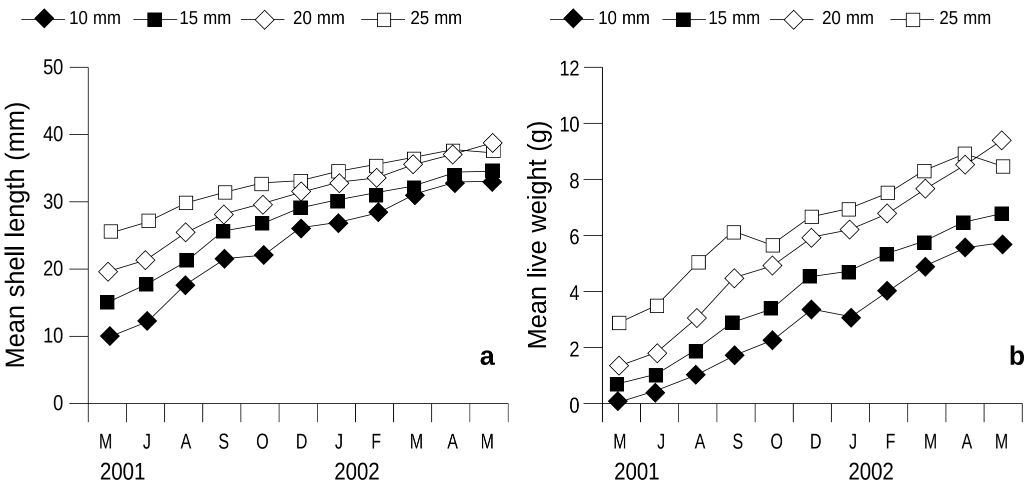

Fig. 4. Mean (a) shell length (mm) and (b) live weight (g) of four size classes of horse mussel.

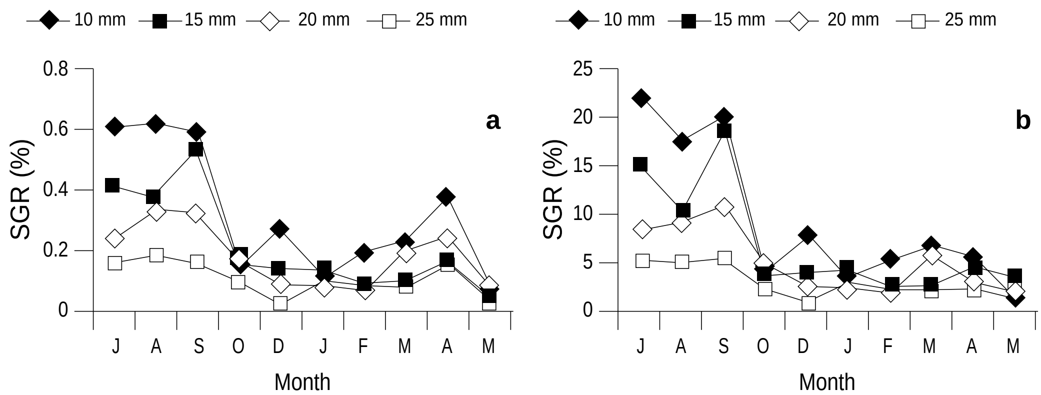

Fig. 5. Mean (a) daily and (b) monthly specific growth rates of *Modiolus barbatus* in Mersin Bay.

sured in this study, although a phytoplankton content of about 3.5-5.2 µg chlorophyll/l can be sufficient for rapid mussel growth (Sivalingam, 1977). Filter-feeding organisms are able to remove a large amount of particulate matter from suspension (Navarro and Thompson, 1997). Tumanda et al. (1997) reported that POC values of 240.5-4041.4 µg/l with a mean of 977.9 µg/l have high food content. The POC content in this study was usually lower than this range. Therefore, our results tend to indicate that the growth rate of *M. barbatus* in Mersin Bay is dominated mainly by temperature.

In the present study, the shell length increased almost continuously from the beginning of the experiment. Total weight increased almost continuously until October, then became irregular until the end of the experiment. This may be related to the water temperature which limited the feeding time and food availability. Most shell growth occurs during warm months with a limited shell increase in cold months (Mitchell et al., 2000). Below the water temper-

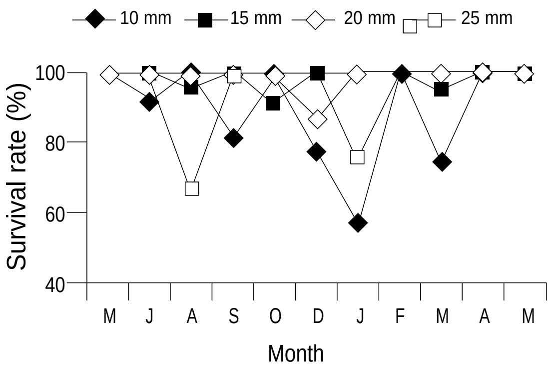

Fig. 6. Monthly survival rates of *Modilus barbatus* of different size classes.

ature of 14°C (in December and January), growth in both length and weight dropped, similar to that of *M. galloprovincialis* in the Black Sea (Karayucel et al., 2003). Although the von Bertalanffy growth equation did not reflect the seasonal variation in growth, a main cause of such variations is the variation in temperature (Theisen, 1968). The estimated value of K is inversely related to the estimated value of L_∞ (Theisen, 1973). The von Bertalanffy growth model generated the following result: $L_t = 39.907\ [1 - e^{-0.14(t+0.95)}]$. Compared to the growth parameter of *Modiolus metcalfei* (K = 2.04; Tumanda et al., 1997), the K value of the *M. barbatus* in this study, 0.95, was very low.

The survival rate was relatively high for the 20 mm and 15 mm groups and lowest in the 10 mm group. The process of handling every month for measurement may have affected the survival rate of the mussels in the smallest size class. Okumus (1993) reported that the mortality rate of *M. edulis* in Scotland was 4.7-14.4%, lower than the mortality rate of *M. barbatus* in Mersin Bay.

The present study shows that Mersin Bay is a suitable site for successful cultivation of mussels. As this is the first experiment on *M. barbatus* growth in Turkey, further experiments are needed to improve and optimize growth in Mersin Bay. Some might compare the effects of growout facilities such as bags or ropes on growth and mortality rates or on limiting fouling settlement. Others may search for a biological control of fouling. Both should be complemented by biological data on gonad maturity, spawning, meat yield, and biochemical composition of *M. barbatus*.

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