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Effect of Water Temperature on Growth of Hatchery Reared Black Sea Turbot, *Scophthalmus maximus* (Linnaeus, 1758)

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Abstract: A rearing experiment was carried out to examine the effect of water temperature on the growth of the Black Sea turbot, *Scophthalmus maximus*, at ambient temperature (mean 15.2±0.6°C), 18, 20, 22 and 24°C with fish of 34.4±9.9 g initial body weight. The experiment lasted 30 days and the fish were fed to satiation three times a day with a commercial pelleted diet.

Survival rates starting with the control group were 100, 83.4, 68.4, 3.4, and 1.7%, respectively. Although the mean weights of the groups were very similar at the beginning of the experiment, they had become markedly varied by the end. The growth rate gradually decreased with increasing temperature, and the highest specific growth rate of 2.2% was observed in the control group reared at ambient temperature, and the growth was negative in the 22 and 24°C groups.

For all temperature groups, the daily feeding rates varied between 2.3 and 2.8% of body weight, and the food conversion ratio of the control group was significantly lower than that of the other groups ($P<0.05$).

In conclusion, it seems clear that the rearing temperature of the Black Sea turbot juveniles should not exceed 18°C.

Key Words: Turbot, *Scophthalmus maximus*, Temperature, Growth, Feeding, Conversion Rate, Survival Rate, Black Sea.

Kuluçkahanede Yetiştirilen Karadeniz Kalkan Balığı, *Scophthalmus maximus* (Linnaeus, 1758)'nın Büyümesi Üzerine Sıcaklığın Etkisi

Özet: Karadeniz kalkan balığı *Scophthalmus maximus*'nın büyümesi üzerine sıcaklığın etkisini araştırmak amacıyla, doğal (ortalama 15.2±0.6°C), 18, 20, 22 ve 24°C su sıcaklıklarında 34.4±9.9 g başlangıç ağırlığındaki balıklarla yetiştiricilik denemeleri yapılmıştır. 30 gün süren deneme süresince balıklar günde üç kez doyuncaya kadar ticari pelet yem ile yemlendiler.

Yaşama oranları kontrol grubundan başlayarak sıra ile %100, 83.4, 68.4, 3.4 ve 1.7 olarak gerçekleşti. Ortalama ağırlıklar denemenin başlangıcında hemen hemen eşit olmasına rağmen, deneme sonunda önemli oranda değişti. Büyüme oranı yükselen sıcaklıkla azaldı ve en yüksek spesifik büyüme %2.2 ile kontrol grubunda gözlendi, 22 ve 24°C gruplarda negatif büyüme elde edildi. Bütün sıcaklık grupları için günlük yemleme oranı %2.3-2.8 arasında değişti ve kontrol grubunda yem değerlendirme oranı diğer gruplardan önemli oranda düşük çıktı ($p<0.05$).

Sonuç olarak Karadeniz kalkanı yavrularının yetiştiriciliğinde su sıcaklığının 18°C'den yüksek olmaması gerektiği ortaya konmuştur.

Anahtar Sözcükler: Kalkan Balığı, *Scophthalmus maximus*, Sıcaklık, Büyüme, Yemleme, Yem Değerlendirme Oranı, Yaşama Oranı, Karadeniz.

Introduction

The turbot, *Scophthalmus maximus*, is distributed from Norway along the European coast to the Mediterranean and Black Seas. The production of Atlantic turbot (Baltic Sea and North Sea turbots) has been attempted since the 1970's in some European countries due to its high commercial value, and in recent years the commercial culture of this species has benefited from improvements in larval rearing methods, and nutrition and husbandry practices in the ongrowing phase (1-10). With respect to the Black Sea turbot (*S. maximus*), which differs from the Atlantic turbot mainly by the presence of the tubercles on the blind side, although it is an endemic species in the Black Sea (11), studies on seed production of the Black Sea turbot are still in the phase of development. Previous studies on production of the Black Sea turbot have been conducted in Russia and Ukraine. But current research results are very limited and particularly information on optimal environmental conditions such as temperature for production of this species is far from satisfactory. An essential step in the successful culture of any species is the definition of optimal environmental conditions. Temperature is one of the most influential environmental factors affecting the growth of fish (12), along with the metabolic rate (including maintenance and growth metabolism) of fish larvae (13). Therefore, information on the effects of temperature on the growth of fish is necessary to improve fish culture techniques.

The main aim of this study was to examine the effect of water temperature on the growth of the Black Sea turbot juveniles.

Materials and Methods

The Black Sea turbot juveniles used in this study were obtained from brood stock at Trabzon Central Fisheries Research Institute. The experiment lasted 30 days, from 18 November to 17 December 1998.

Rearing experiments were carried out in 10 circular polyethylene tanks placed in an indoor experimental area. Total water volume of each tank was 500 l and the water was exchanged continuously at a rate of 3 turnovers/day. In addition, the water was aerated with an air stone at a moderate rate. Natural illumination and day-length were maintained in the tanks during the experimental period. Temperature, dissolved oxygen and pH values were measured twice a day.

A total of 5 experimental temperature groups were set up in replicates as follows: control (ambient water), 18, 20, 22 and 24°C. Three hundred juveniles (mean live weight of 34.4±9.9 g) were divided into 10 groups (5x2, replicates) with mean weights ranging from 33.4±10.0 to 35.6±8.7 g. The juvenile turbots were initially maintained at a density of 30 ind./tank (about 1.3 kg/m^2). Before starting the experiments, the groups were assigned to tanks at random, and the water temperature in each tank was then gradually adjusted to the intended experimental temperatures over a 4-day period using a 2 kW heater.

During the experiment, juveniles were fed a commercial pelleted diet until satiation three times a day. Daily feed supply was recorded for each tank. The diet contained about 55% crude protein, 10% crude lipid, 13% crude ash, and 1.5% crude fiber on a dry basis.

Specific growth rate (SGR), the daily feeding rate (FR), and food conversion ratio (FCR) were calculated as follows (14):

$$SGR=100[\ln(W_t)-\ln(W_0)/t]$$

$$FR=\{(\sum f_k)/[t^*(W_t+W_0)/2]\}^*100$$

$FCR=(\sum f_k)/(W_t-W_0)+m$; where t: feeding days (day), W_0: initial live weight of fish (g), W_t: final live weight of fish (g) and f_k: dry weight of feed supplied by the group of fish at each feeding (g), m: weight of dead fish (g).

Weights of fish were measured at the beginning and the end of the experiments, after they were starved for about a day. Data are represented as arithmetic means of individual weights ±SD. A t-test was used to determine differences between replicates. One-way ANOVA was used to test for differences among experimental groups and was followed by Tukey's multiple range test when the differences were significant.

Results

Sea water temperature, dissolved oxygen and pH values measured during the experimental period are given in the Figure.

Dissolved oxygen and pH values ranged within optimal limits (DO: 6.4-8.9 mg/l, pH: 8.2-8.4), and there were no significant differences among experimental treatments in terms of DO and pH values.

Initial and final body weights, specific growth rates, daily feeding rates, food conversion ratios, and survival rates are presented in Table.

Although only a few fish remained alive at over 20°C, a 100% survival rate was obtained in the control group, where the temperature ranged from 14.2°C to 16.5°C (mean 15.2±0.6°C).

There were no significant differences in weight between experimental groups at the beginning of the experiment. No significant differences were found between replicates of the groups over the course of the experiment and so data from replicates were pooled for each treatment prior to analysis. At each temperature tested, mean body weights of fish in all groups increased except those held at 22 and 24°C.

The growth rate gradually decreased with increasing temperature, and the highest specific growth rate of 2.2% occurred in the control group, and the growth rate showed considerable decreases at 22 and 24°C, i.e., fish in these groups lost weight. In the control group, the specific growth rate was significantly higher than in the other temperature groups ($P<0.05$). However, there was no

Groups	N	Initial body weight (g)	Final body weight (g)	SGR (%)	FR (%)	FCR	Survival (%)	(N)
I (control)	60	35.6±8.7	68.2±15.9	2.2	2.3	1.1	100	(60)
II (18°C)	60	33.4±10.0	48.0±12.9	1.2	2.4	2.9	83.4	(50)
III (20°C)	60	33.9±11.3	49.9±12.8	1.3	2.8	2.3	68.4	(41)
IV (22°C)	60	34.0±10.3	27.8±7.4	-0.7	2.4	-	3.4	(2)
V (24°C)	60	34.9±9.3	18,8	-1.8	2.6	-	1.7	(1)

Table Number of fish (N), initial and final body weights, specific growth rates (SGR), daily feeding rate (FR), food conversion ratio (FCR), and survival of the Black Sea turbot reared at different water temperatures.

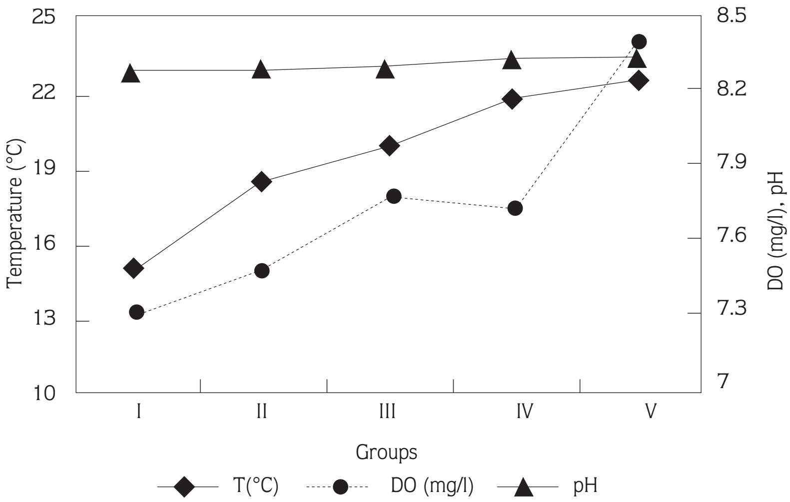

Figure Variations in mean temperature, dissolved oxygen and pH values.

significant difference between the rates in the 18 and 20°C groups.

For all the temperature groups, the daily feeding rates varied between 2.3 and 2.8%. The food conversion ratios showed some fluctuations among the experimental groups and the value of the control group was significantly lower than that of the others ($P<0.05$).

Discussion

The density of the experimental fish is not excessive when compared with previous turbot growth trials (5,10). In these previous trials, initial biomass stocking densities varied between 0.7 and 5.0 kg/m^3. Turbot can be reared at very high stocking densities, and in commercial operations stocking densities can be as high as 25 to 30 kg/m^3 (5).

It is recommended that turbot juveniles of 40-60 g should be fed at 1.5-2.0 percent of body weight at 16-18°C (15,16). In the present study, the daily feeding rate was higher than the recommended ones. Feeding rates were sufficient. It is, therefore, reasonable to suppose that stocking density and food were not responsible for the growth differences among the groups, and it can be assumed that water temperature was the major factor influencing the growth of turbot juveniles under the described conditions.

The mean specific growth rate of Atlantic turbot of 50 g has been reported as 2.2% (6), which is similar to the maximum specific growth rate obtained in the present experiment. But growth was found to be suppressed over 20°C, and there were weight losses at 22 and 24°C. In other words, in this study the turbot reared at a sea water temperature of around 15°C exhibited a significantly higher growth rate than those held at higher temperatures (Table).

Anthouard et al. (17) found that temperature is the major influence on the appetite of the fish. During the present experiment, the juveniles were fed more than 2.0% of body weight with dry pellets, but it was observed that fish at 22 and 24°C did not consume the feed given. Mallekh et al. (9) reported that the appetite of turbot increases at temperatures up to between 17 and 19°C. The best growth for 100 g individuals was found by Waller (18) to occur between 16 and 19°C. Burel et al. (8) noted that appetite in juveniles changed little between 14, 17 and 20°C. In our study, the specific growth rate increased when the rearing water temperature dropped, and the highest growth was obtained in the control group, which was held at 15.2±0.6°C. This is because feed consumption in the control group was higher than in the others.

Devesa (7) stated that the food conversion ratio ranges from 0.9 to 1.9 for turbot fed on dry pellets. In our experiment, the food conversion ratio in the control group was within this range. For other groups, the food conversion ratios were significantly higher than the values reported by Devesa (7).

There was also a negative relationship between temperature and survival rate. The control group showed the highest survival rate, 100%. When the rearing water temperature increased, inversely, the survival rate decreased. These results demonstrated that increasing rearing water temperature had adverse effects on growth performance.

Although some authors have reported that the optimal temperature for turbot juveniles appeared to be around 15-19°C (9,16,18), in our study, growth performances observed for turbot juveniles kept ambient temperature (in the control group, 15.2±0.6°C) were better than those recorded at 18, 20, 22 and 24°C.

Therefore, it can be concluded that the rearing temperature of Black Sea turbot juveniles should not exceed 18°C.

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