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Research Article

Optimum temperature and growth performance of hatchery reared Black Sea flounder (*Platichthys flesus luscus* Pallas, 1814)

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Abstract: The present study focused on the effect of water temperature on growth and feed conversion ratio of juvenile Black Sea flounder (*Platichthys flesus luscus*; initial weight: 2.0 g ± 0.01 g). The experiment was carried out for 84 days with the following range of water temperatures: 13, 17, 21, and 25 °C. Growth, food consumption, and feed conversion ratio were the highest at 21 °C and the lowest at 13 °C. The growth rate of the fish increased with water temperatures up to 21 °C and it decreased significantly with a further increase in temperature. The conclusion of this study was that the optimal water temperatures for growth and feed conversion ratio for Black Sea flounder were 20.9 °C and 20.2 °C, respectively.

Key words: Optimal temperature, growth performance, feed conversion, Black Sea flounder, *Platichthys flesus luscus*

Kuluçkahanede yetiştirilen Karadeniz pisi balıklarının (*Platichthys flesus luscus* Pallas, 1814) büyüme performansı ve optimum sıcaklığı

Özet: Bu çalışmada, Karadeniz pisi balığı (*Platichthys flesus luscus*) yavrularının (ilk ağırlık; 2,0 g ± 0,01 g) büyüme performansı ve yem değerlendirme oranı üzerine yetiştirme sıcaklığının etkisi çalışıldı. Çalışma 13, 17, 21 ve 25 °C su sıcaklıklarında 84 gün sürdürüldü. Büyüme, yem tüketimi ve yem dönüşüm randımanı oranı 21 °C'de en yüksek, 13 °C de ise en düşük bulunmuştur. Büyüme oranı su sıcaklığının 21 °C'ye kadar artışına paralel artmış ve su sıcaklığındaki ilave artışla birlikte büyüme oranı önemli derecede düşmüştür. Büyüme ve yem dönüşüm katsayısı için optimum sıcaklık sırasıyla 20,9 °C ve 20,2 °C olarak hesaplanmıştır.

Anahtar sözcükler: Optimum sıcaklık, büyüme performansı, yem dönüşümü, Karadeniz pisisi, *Platichthys flesus luscus*

Introduction

The Black Sea flounder (*Platichthys flesus luscus* L.) has a wide geographical and ecological distribution. It is commonly found in shallow waters of the Mediterranean Sea and the Black Sea (1).

Fish farmers need to develop farming techniques for new fish commodities as the market becomes saturated with farmed sea bass and gilthead seabream (2). Recently, successful results in the reproduction of common pandora (*Pagellus erythrinus*), dentex

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(*Dentex dentex*), sharp-snout seabream (*Puntazzo puntazzo*), and common seabream (*Pagrus pagrus*) have been achieved by fish farmers (3). Research is underway to develop the technology to farm new species such as turbot (*Psetta maxima*) (2) and Black Sea flounder. For efficient rearing of Black Sea flounder, more information on optimal rearing is required. One of the most important conditions is water temperature.

Water temperature affects the growth rate of fish by influencing food consumption and metabolic rate (4,5). Each fish species has a species-specific optimal growth temperature. The effect of water temperature on fish growth has been studied in several flatfish species including Japanese flounder (*Paralichthys olivaceus*) (6), Atlantic halibut (*Hippoglossus hippoglossus*) (7), California halibut (*Paralichthys californicus*) (8), summer flounder (*Paralichthys dentatus*) (9), turbot (10,11), and European flounder (*Platichthys flesus*) (12,13). However, the relationship between temperature and growth has not been studied for Black Sea flounder. The objectives of this study were to investigate the effect of water temperature on the growth rate and feed conversion ratio of juvenile Black Sea flounder.

Materials and methods

Hatchery-reared juvenile flounders (2.0 ± 0.01 g) were obtained from brood stock in autumn 2006, originating from the southeastern coast of the Black Sea, and maintained at the Flatfish Hatchery at the Central Fisheries Research Institute, Trabzon, Turkey.

Fish were held in 300-L cylindrical polypropylene indoor flow-through rearing tanks. Filtered and ultraviolet treated sea water was distributed to each tank at about 200 mL/min. During the experiment, water salinity and oxygen saturation were 18 g/L and over 75%, respectively. A photoperiod was applied at 12L:12D with 300 lux light intensity.

Divided into 12 groups were 420 juvenile flounders (4 groups, with 3 replicates). The fish were initially kept at a density of 35 individuals per tank. At the initial weighing-in the preceding week, fish were acclimatized to selected temperatures. The water temperature was increased gradually (2 °C per day) from 12 °C to 13 °C, 17 °C, 21 °C, and 25 °C. The rearing tanks were supplied with heated water from reservoir tanks. Water was heated with a central heating system and open rearing systems were used. During the 3-month feeding-trial, the total length and weight of all of the fish in each experimental tank were measured without anesthesia, every 4 weeks.

The fish were fed commercial turbot diet (Turbot Dan-ex 1362, Dana Feed A/S; diameter 1.8 mm; 62.0% crude protein; 13.0% crude lipid; 11.7% crude ash; 0.82% crude fiber; 1.72% phosphorus; 15 mg/kg copper; 1.02 IU/g vitamin A; 0.25 IU vitamin D3; 447 mg/kg vitamin E; 5051 kcal/g diet gross energy; 83.96% fish meal; 11.71% wheat, 2.89% fish oil; and 1.44% vitamin premix) to satiation 3 times (at 0815, 1215, and 1615) a day. All of the fish were hand-fed and feed was provided in excess. Uneaten pellets were collected from the water outlet by net 45 min after each feeding and counted to calculate the feed intake.

Specific growth rate (SGR) and condition factors (K) were calculated using the following standard formulas:

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

$$K = (W/L^3) \times 100,$$

where t = time (days), W_0 = initial body weight of fish (g), W_t = final body weight (g), W = weight (g), and L = total length (cm).

The feed conversion ratio (FCR) was calculated as weight of food consumed per unit biomass gain (12). Data are presented as means ± SE. The initial (CV_i) and final (CV_f) coefficient of variation (CV (%) = SD × 100/mean weight) was calculated and used to examine the interindividual weight variation among the fish in each tank (14).

Data were tested for normal distribution using Kolmogorov-Smirnov. Homogeneity of variances was tested using Levene's F-test (15). Growth rates were compared with parametric analysis using a one-way ANOVA and followed by Fisher's multiple range tests when the differences were significant. The relationship between growth rate, feed conversion ratio and temperature was analyzed with regression (15) and optimal temperatures for growth ($t_{opt\,SGR}$) and feed conversion ratio ($t_{opt\,FCR}$) were calculated as the zero solution to the first derivative of the polynomial regression equations, i.e. the solution of SGR or FCR = $at^2 + bt + c$, where t is temperature and a, b, and c

are constants determined by the regression. Statistical analyses were carried out by Statistica 7 (StatSoft. Inc. Tulsa, Oklahoma, USA).

Results

During the experiment, no mortality was observed in any of the experimental groups. After 4 weeks, no significant differences were observed in the growth performance among the treatments. At the end of the experiment, the mean body weight and total length of fish reared at selected temperatures were significantly different. The highest mean body weight and total length were observed in fish held at 21 °C. Fish cultured at 17 °C and 25 °C had similar mean body weights and total lengths, which were higher than the mean body weights and total lengths of fish cultured at 13 °C (Table, Figure 1).

The mean weight gain ranged from 3.61 g to 8.12 g (13°C to 21 °C) (Table). At the end of the 8 weeks, the fish weight of fish reared at 13 °C had doubled and tripled in those reared at 21 °C, compared to the initial weight of the fish. At the end of the experiment, the average initial weight had increased 3 times (13 °C), 4 times (17 °C and 25 °C), and 5 times (21 °C) (Figure 1).

The specific growth rate (SGR) of juvenile flounder in each treatment ranged from 1.18 ± 0.06 (13 °C) to 1.93 ± 0.01 (17 °C). Fish held at 21 °C grew significantly faster than those reared at 13 °C or 17 °C, and fish held at 17 °C or 25 °C grew significantly faster than those at 13 °C ($P < 0.05$) (Table). The specific growth rate increased with increasing temperature up to 21 °C, and then decreased with a further increase in temperature. The predicted maximum specific growth rate of fish was estimated at 20.9 °C (Figure 2).

The feed conversion ratio of juvenile flounder in all of the treatments ranged from 1.15 ± 0.01 to 1.68 ± 0.03 (Table). The feed conversion ratio followed an

Table. Initial and final total length, initial and final body weight, weight gain, specific growth rate (SGR), final condition factor (K), feed conversion ratio (FCR), initial coefficient of variation of fish weight ($CV_{initial}$), and final coefficient of variation (CV_{final}) of juvenile flounders during 84 days of temperature trials. Values shown are means (± SE) which based on 3 trials per temperature treatment followed by different superscripts in the same row are statistically different ($P < 0.05$).

Water temperature (nominal)	13 °C	17 °C	21 °C	25 °C
Water temperature (measured)	13.2 ± 0.01 °C	16.8 ± 0.01 °C	20.8 ± 0.0 °C	24.9 ± 0.0°C
Initial total length (cm)	5.34 ± 0.035	5.25 ± 0.040	5.31 ± 0.039	5.28 ± 0.042
Final total length (cm)	7.56 ± 0.080^{c}	8.40 ± 0.119^{b}	9.34 ± 0.121^{a}	8.69 ± 0.096^{b}
Absolute growth (mm/day)	0.26 ± 0.010^{d}	0.37 ± 0.002^{c}	0.48 ± 0.009^{a}	0.41 ± 0.010^{b}
Initial weight (g)	2.13 ± 0.039	2.00 ± 0.045	1.99 ± 0.043	1.98 ± 0.048
Final weight (g)	5.74 ± 0.222^{c}	8.10 ± 0.415^{b}	10.11 ± 0.454^{a}	8.35 ± 0.283^{b}
Mean weight gain (g)	3.61	6.10	8.12	6.37
Mean food intake (g)	194.17	259.26	328.70	297.97
SGR weight (%/day)	1.18 ± 0.076^{c}	1.66 ± 0.022^{b}	1.94 ± 0.016^{a}	1.71 ± 0.075^{ab}
FCR	1.68 ± 0.029^{c}	1.22 ± 0.018^{ab}	1.15 ± 0.009^{a}	1.34 ± 0.015^{b}
K-end	1.33 ± 0.016	1.37 ± 0.054	1.24 ± 0.020	1.27 ± 0.027
$CV_{initial}$	18.4 ± 0.2	27.4 ± 1.7	22.3 ± 0.6	24.4 ± 1.5
CV_{final}	30.3 ± 6.6	58.0 ± 2.7	46.0 ± 5.3	34.3 ± 1.2

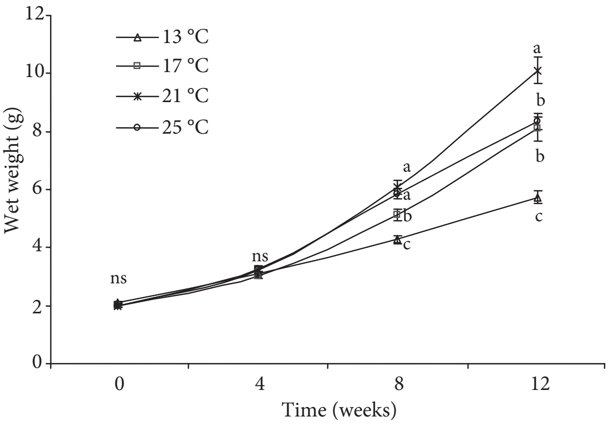

Figure 1. Growth of juvenile flounder held at 4 different rearing temperatures, expressed in mean weight ± S.E. Different superscripts indicate statistically significant difference (P < 0.05), ns: no significant difference.

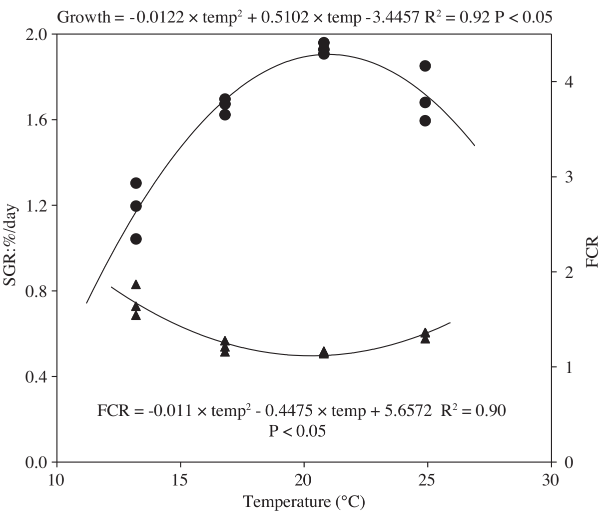

Figure 2. Response curve for feed conversion ratio (FCR, triangles) and specific growth rate (SGR, circles) of juvenile flounder in relation to temperature. Each point represents the mean value of a tank.

opposite pattern to the growth rate. The maximum value for mean FCR (1.68 ± 0.029) was found at 13 °C and the lowest value (1.15 ± 0.01) at 21 °C (Figure 2). The predicted minimum FCR (1.14 ± 0.01) was estimated at 20.2 °C (Figure 2).

The CV_i and CV_f in fish weight in all of the treatments ranged from 18%-27% and 30%-58%, respectively. Among the different rearing temperature regimes, there was no significant difference in condition factor and CV_f (Table).

Discussion

Culture of fish at optimum water temperature is very important for better growth performance and food utilization. This study shows that the growth performance and feed conversion ratio of the juvenile Black Sea flounder is significantly influenced by water temperature. The optimal temperatures for feed conversion ratio and growth rate found in the present study were comparable to those of the similar size European flounder (18-22 °C) (12), turbot (21.8 °C) (16), and Japanese flounder (21.7 °C) (17). In comparison to some other species, the optimal water temperature for Black Sea flounder was lower [Southern flounder: 27-29 °C (18)] or higher [Summer flounder: 18 °C (19) and Greenback flounder (*Rhombosolea tapirina*): 17 °C (20)].

Differences in the optimal water temperature among flounder species may be due to species variation, culture conditions, water salinity, and source of food. Differences between flounder species become clear when comparing the results of the present study with studies on European flounder (12,13,21). Optimal water temperature for this species varies between 18 °C and 22 °C. For Black Sea flounder, a subspecies of European flounder, a similar optimum water temperature was found (21 °C) but the difference is that growth at 17 °C is far from optimum. This difference might be caused by species variation.

The growth rate of fish can decrease with water temperatures higher than the optimal water temperature. For example, the growth rate of European flounder decreased significantly when the water temperature exceeded the optimal temperature of 22 °C (12). The same effect was seen in the present study. However, the growth rate of fish held at 25 °C was still significantly higher than that of the fish held at 17 °C.

In the literature, the growth rate of juvenile European flounder expressed in length was reported between 0.01 and 0.83 mm/day (12,22-24). These values are comparable with the results (0.26-0.48 mm/day) in the present study.

Salinity (25) and food quality (24) are important factors influencing flounder growth. Brackish water results in the highest food intake or food conversion efficiency (25) and a constant salinity has a positive effect on the growth of fish compared to fluctuating salinities (24). In the present study, optimum constant water salinity and commercial flat fish diet were used.

The mean food intake and SGR of fish were highest at 21 °C while the mean FCR was lowest. Mean food intake, FCR, and SGR of fish reared at 25 °C were higher than those of the fish reared at 17 °C. The reason for a higher FCR in the 25 °C group may be higher metabolic rates (loss of energy) due to high temperature. The lower growth rate in the 17 °C group may be caused by lower food intake. The minimum feed conversion ratio was obtained at 21 °C. It increased with both increasing and decreasing water temperature. In the present study, the estimated optimal temperature for FCR (20.2 °C) was slightly lower than the optimal temperature for growth (20.9 °C), as found for fish in general (5). The CV increased with the rearing period, and it doubled in most of the treatments. However, the CV_f at the selected temperature were not significantly different. This suggests that fish culture at optimum temperature may not yield more uniform sizes.

In conclusion, the results of the present study indicate that optimal growth and feed conversion ratio occur at about 21 °C in juvenile Black Sea flounder. This knowledge can be used for improvement of the rearing of flounder.

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References

1. Turksat. Turkish Statistical Institute, fishery statistics, 2006.
2. Çiftci, Y., Üstündağ, C., Erteken, A., Özongun, M., Ceylan, B., Haşimoğlu, A., Güneş, E., Yoseda, K., Sakamoto, F., Nezaki, G., Hara, S.: Manual for the Seed Production of Turbot, *Psetta maxima* in the Black Sea. Special Publication No. 2, Central Fisheries Research Institute, Trabzon, 2002; 80 pp.
3. Başçınar, N.: Aquaculture in the world and overview to the future of Turkey. SÜMAE YUNUS Research Bulletin, 2004; 4: 1-3.
4. Dunham, J.B., Young, M.K., Gresswell, R., Rieman, B.E.: Effects of fire on fish populations: landscape perspectives on persistence of native and non-native fish invasions. Forest Ecol. Manag., 2003; 178: 183-196.
5. Jobling, M.: Temperature and growth: Modulation of growth rate via temperature change. In: Wood, C.M., McDonald, D.G., Eds. Global Warming: Implications for Freshwater and Marine Fish. Cambridge University Press, Cambridge, 1997; 225-253.
6. Dou, S.Z., Masudaş, R., Tanaka, M., Tsukamoto, K.: Effects of temperature and delayed initial feeding on the survival and growth of Japanese flounder larvae. J. Fish Biol., 2005; 66: 362-377.
7. Bjornsson B., Tryggvadottır S.V.: Effects of size on optimal temperature for growth and growth efficiency of immature Atlantic halibut (*Hippoglossus hippoglossus* L.) Aquaculture, 1996; 142: 33-42.
8. Gadomski, D.M., Caddell, S.M.: Effects of temperature on early-life-history stages of California halibut *Paralichthys californicus*. Fish. B-NOAA., 1991; 89: 567-576.
9. Bisbal, G. A., Bengtson, D.A.: Effects of delayed feeding on survival and growth of summer flounder *P. dentatus* larvae. Mar. Ecol. Prog. Ser., 1995; 121: 301-306.
10. Burel, C., Person-Le Ruyet P., Gaumet, F., Le Roux, A., Severe, A., Boeuf, G.: Effects of temperature on growth and metabolism in juvenile turbot. J. Fish Biol., 1996; 49: 678-692.
11. Şahin, T.: Effect of Water Temperature on Growth of Hatchery Reared Black Sea Turbot, *Scophthalmus maximus* (Linnaeus, 1758). Turk. J. Zool., 2001; 25; 183-186.
12. Fonds, M., Cronie, R., Vethaak, A.D., Van Der Puyl, P.: Metabolism, food consumption and growth of plaice (*Pleuronectes platessa*) and flounder (*Platichthys flesus*) in relation to fish size and temperature. Neth. J. Sea Res., 1992: 29; 127-143.
13. Antoszek A., Krzykawski, S.: Growth pattern of flounder, *Platichthys flesus* (L.), from the Gulf of Gdańsk (southern Baltic Sea). Acta Ichthyol. Piscat., 2005; 35: 51-60.
14. Wang, N., Hayward, R.S., Noltie, D.B.: Effect of feeding frequency on food consumption, growth, size variation, and feeding pattern of age-0 hybrid sunfish. Aquaculture, 1998; 165: 261-267.
15. Zar, J.H.: Biostatistical Analysis. 4th ed., A Viacom Company, New Jersey, 1999; 35-870.

16. Imsland, A.K., Foss, A., Gunnarsson, S., Berntssen, M.H.G., Fitz Gerald, R., Bonga, S.W., Ham, E.V., Naevdal, G., Stefansson, S.O.: The interaction of temperature and salinity on growth and food conversion in juvenile turbot (*Scophthalmus maximus*). Aquaculture, 2001; 198: 353-367.

17. Lee, S.M., Cho, S.H., Kim, D.J.: Effects of feeding frequency and dietary energy level on growth and body composition of juvenile flounder, *Paralichthys olivaceus* (Temminck and Schlegel). Aquacult. Res., 2000; 31: 917-921.

18. Del Toro-Silva, F.M., Miller, J.M., Taylor, J.C., Ellis, T.A.: Influence of oxygen and temperature on growth and metabolic performance of *Paralichthys lethostigma* (Pleuronectiformes: Paralichthyidae). J. Exp. Mar. Biol. Ecol., 2008; 358: 113-123.

19. Malloy, K.D., Targett T.E.: Feeding, growth and survival of juvenile summer flounder *Paralichthys dentatus:* Experimental analysis of the effects of temperature and salinity. Mar. Ecol. Prog. Ser., 1991; 72: 213-223.

20. Girling, P., Purser, J., Nowak, B.: Effects of acute salinity and water quality changes on juvenile greenback flounder, *Rhombosolea tapirina* (Günther, 1862). Acta Ichthyol. Pisc., 2003; 33: 1-16.

21. Cięglewicz, W., Hoppe, G.: The relation between the water temperature and the rate of growth of flounder *Platichtchys flesus* (L.) in Gdańsk Bay. Acta Ichtyol. Pisc., 1970; 1: 67-72.

22. Tarpgaard, E., Mogensen, M., Grønkjaer, P., Carl, J.: Using short-term growth of enclosed 0-group European flounder, *Platichthys flesus*, to assess habitat quality in a Danish bay. J. Appl. Ichthyol., 2005; 21: 53-63.

23. Andersen B.S., Carl J.D., Grønkjaer P., Støttrup J.G.: Feeding ecology and growth of age 0 year *Platichthys flesus* (L.) in a vegetated and a bare sand habitat in a nutrient rich fjord. J. Fish Biol., 2005; 66: 531-552.

24. Andersen, A.K., Schou, J., Sparrevohn, C.R., Nicolajsen, H., Støttrup, J.G.: The quality of release habitat for reared juvenile flounder *Platichthys flesus*, with respect to salinity and depth. Fish. Manag. Ecol., 2005; 12: 211-219.

25. Gutt, J.: The growth of flounders (*Platichthys flesus* L.) at salinities of 0, 5, 15 and 35‰. J. Appl. Ichthyol., 1985; 1: 17-26.