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EFFECTS OF PHOTOPERIOD ON GROWTH AND FEED UTILIZATION OF JUVENILE BLACK SEA TURBOT *(PSETTA MAEOTICA)*

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Abstract

A study was conducted to determine the effect of different photoperiods on the growth and survival of juveniles of the Black Sea turbot *(Psetta maeotica)*. Juvenile turbot (32.17±0.1 g) were reared under one of three experimental photoperiod regimes: natural, continuous light, or extended light (18 h light:6 h dark). The turbot were held in sea water (18 ppt) at 15-24°C from May 27 to July 29, 2004. The maximum growth rate, feed efficiency, and specific growth rate were recorded in the fish exposed to the extended light period ($p<0.05$). Continuous light may have acted as an irritant, inducing stress, suppressing growth, and reducing feed intake.

Introduction

Turbot is distributed along the European coast from Norway to the Mediterranean and Black Seas. Atlantic turbot (Baltic Sea and North Sea turbot) has been cultivated in Europe since the 1970s due to its commercial value. In the last decade, commercial turbot production benefited from improvements in larvae rearing methods and nutritional practices in the growout phase (Burel et al., 1996; Mallekh et al., 1998; Irwin et al., 1999) and the culture of turbot (*Scophthalmus maximus* Rafinesque) in Europe developed rapidly with production increasing from 5 metric tons in 1984 to 5068 tons in 2002 (FAO, 2004).

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Several studies have been carried out to investigate the effects of temperature, salinity, and oxygen on turbot growth (Person-Le Ruyet et al., 1981; Iglesias et al., 1987; Waller, 1992; Gaumet et al., 1995; Imsland et al., 1996; Ham et al., 2003). However, information on the effects of other environmental factors, such as photoperiod, on growth and feed utilization of turbot is limited.

Exposure to extended periods of light leads to increased growth rates in salmonids (Stefansson et al., 1991; Hansen et al., 1992), gadoids (Folkvord and Ottera, 1993), halibut (Simensen et al., 2000), haddock (Trippel and Neil, 2003), and marine flatfish (Hallaraker et al., 1995). Imsland et al. (1995) found that the growth rate of juvenile turbot exposed to continuous light was initially greater than but, five months later, fell behind the growth rate of fish kept in a 16 h light:8 h dark or natural light regime. Pichavant et al. (1998) found no difference in growth rate or food utilization of juvenile turbot over a 60-day experimental study period.

Although a considerable amount of work has reported the effect of photoperiod on fish growth, not much has been published on the effect of photoperiod on feed utilization and protein efficiency of juvenile turbot. The following study was designed to investigate the effects of photoperiod on the growth and feed utilization of juvenile turbot at 15-24°C.

Materials and Methods

Experimental design. First year juvenile turbot, *Psetta maeotica* (initial body weight 32.1±0.1 g), were obtained from the hatchery farm of the Japan International Cooperation Agency (JICA) and the Central Fisheries Research Institute in Trabzon, Turkey. The juveniles were stocked in 50-l rectangular polypropylene indoor rearing tanks filled with sea water in the marine facilities of Sinop Fisheries Faculty, Turkey (42°01'2"N, 35°09'00"E). Three light regimes, with three replicates of each, were established in nine tanks. The water flow was adjusted to exchange 100% of the total volume of the tanks every hour. The juveniles were held in the experimental system at 30 fish per tank for acclimatization to the feeding regime for two weeks prior to the start of the experiment. During acclimatization and the trial, the fish were fed a commercial extruded feed (3 mm) containing 40.2% crude protein, 18.05% crude lipid, crude fiber 2.8%, crude ash 6.84%, and 7.5% moisture.

The trial continued for 64 days, from May 27 to July 29, 2004. During the study, fish were fed to apparent satiation twice daily (at 09:00 and 15:00), seven days per week. Feed was distributed by hand and, on any particular day, the same person fed all the treatments. Satiation was defined as the point at which feed was not consumed in the water column and lay on the tank bottom without being consumed for approximately 20 s. Turbot normally rest on tank bottoms but, when fed, they rise to the surface and become hyperactive. The number of turbot rising to the water surface and aggressive behavior were observed to determine meal duration and food supplied (Mallekh et al., 1998). Feed consumption was measured daily by weighing feed boxes assigned to each treatment.

Water temperature was recorded daily, with a low of 15°C and a high of 24°C (Fig. 1). A sudden decrease in temperature occurred during a stormy wind from the east. Oxygen ranged 7.8-8 mg/l, pH 7.5-6.5, and salinity 17.8-18.1‰.

Three groups of fish were kept in the natural photoperiod (about 12 hours of light and 12 of dark), three groups were kept in the extended-light photoperiod (18 h light:6 h dark) with light extending from 06:00 to midnight, and three groups were kept in constant light. One overhead 26W fluorescent light bulb (40 cm above surface) supplied light to every three tanks. Lights were controlled by automatic timers beginning May 27.

Fish were weighed individually to the nearest gram at the beginning of the experiment and every fifteen days thereafter. Specific growth rate (%/day), feed conversion ratio (FCR), and protein efficiency rate (PER) were calculated using formulae outlined by Yang et al. (2004).

Chemical analysis. Juvenile turbot were sacrificed to determine the initial carcass

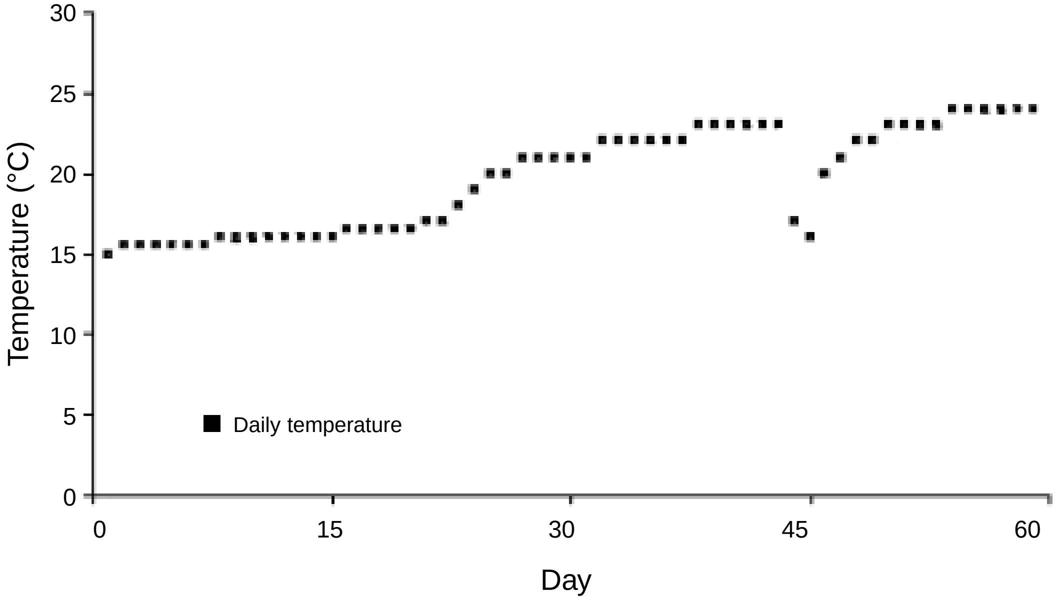

Fig. 1. Daily temperatures (°C) throughout the experimental period.

composition. The fish body was macerated with a mortar and pestle for proximate analysis. Analyses were performed in triplicate. All fish from all treatments were weighed at the end of the experiment and some were sacrificed and treated as described for proximate analysis. Proximate carcass analyses followed procedures used to analyze the diets.

Statistical analysis. One-way analysis of variance (ANOVA) was used to test the effect of photoperiod. Duncan's multiple procedure was used for multiple comparisons. Differences were regarded as significant when $p<0.05$.

Results

There were no mortalities during the experiment. Growth began to differ between treatments on day 30 (Fig. 2). At the end of the experiment, fish exposed to the extended photoperiod (18L:6D) had a larger higher weight gain than those in the other treatments (Table 1). Daily dry feed, protein, and energy intakes, protein efficiency rate, and apparent net protein retention were significantly higher while the feed conversion ratio was significantly lower in the 18L:6D regime (Table 2).

Compared to the initial value, body moisture content decreased significantly in the natural and extended photoperiods while it increased in the continuous light group (Table 3). Whole body ash decreased significantly in all groups, with a higher ash content in fish exposed to continuous light and natural photoperiods than to the extended photoperiod. Whole body protein and lipid contents were significantly higher in the 18L:6D group.

Discussion

At the end of the experiment, fish in the group exposed to 18L:6D were larger than those exposed to continuous light or a natural photoperiod, suggesting that extended light has a growth-promoting effect while continuous light may have a growth-suppressing effect. Our findings agree with studies on salmonids that show the growth promoting effect of extended light (Stefansson et al., 1989; Stewart et al., 1990; Krakenes et al., 1991; Ergun et al., 2003). In addition, Hole and Pittman (1995)

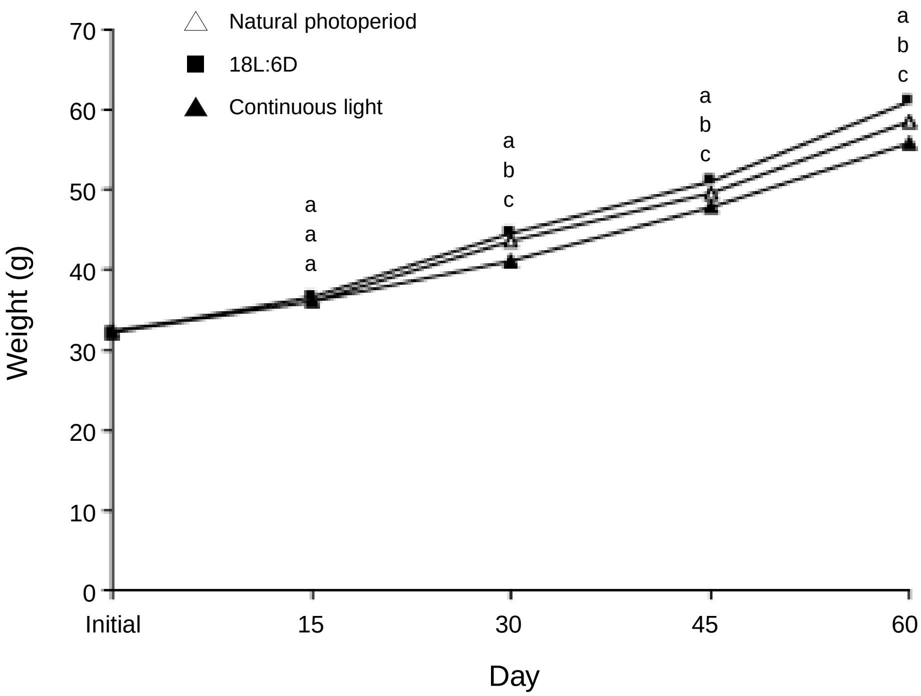

Fig. 2. Mean weight of juvenile turbot raised in different photoperiods.

Table 1. Growth and survival of juvenile Black Sea turbot (*Psetta maeotica*) reared in different photoperiods for **64** days (n = 3, means±SD).

	Continuous light	*18 h light:6 h dark*	*Natural photoperiod*
Initial wet weight (g)	32.18±1.56[a]	32.07±1.92[a]	32.27±1.89[a]
Final wet weight (g)	55.87±3.28	61.03±3.63	58.48±3.7
Weight gain (g)	23.7±0.72[b]	28.97±0.72[c]	26.21±0.16[a]
Relative growth rate (%)	73.68±2.03[a]	90.33±1.86[c]	81.23±0.44[b]
Specific growth rate (%/day)	0.92±0.02[a]	1.07±0.02[c]	0.99±0.00[b]
Survival (%)	100	100	100

Values in a row with different superscripts are significantly different (p<0.05).
Relative growth rate = 100[(final wet weight – initial wet weight)/initial wet weight]
Specific growth rate = 100[(ln final wet weight – ln initial wet weight)/days]

Table 2. Feed utilization in juvenile turbot (*Psetta maeotica*) exposed to different photoperiod regimes for 64 days.

	Continuous light	*18 h light:6 h dark*	*Natural photoperiod*
Total feed intake (g)	793.33±20.82[a]	920.0±17.32[b]	856.67±5.77[c]
Daily dry feed intake (g/fish)	0.41±0.01[a]	0.47±0.01[c]	0.44±0.00[b]
Daily dry protein intake (g/fish)	0.16±0.00[a]	0.19±0.00[c]	0.18±0.00[b]
Daily dry energy intake (kJ/fish)	8.45±0.22[a]	9.80±0.18[c]	9.12±0.06[b]
Food conversion rate (FCR)	1.11±0.17[b]	1.06±0.01[a]	1.09±0.01[b]
Protein efficiency rate (PER)	2.42±0.04[a]	2.55±0.02[b]	2.48±0.01[a]
Apparent net protein retention (ANPR; %)	37.00±0.73[a]	44.44±0.84[b]	39.77±1.37[c]

Values in a row with different superscripts are significantly different ($p<0.05$).
FCR = wet feed intake/wet weight gain
PER = wet wt gain/dry protein intake
ANPR = 100[(final wet weight x final wet body protein) – (initial wet weight x initial wet body protein)/dry protein]

Table 3. Final whole body composition (%) of juvenile turbot (*Psetta maeotica*) exposed to different light regimes.

	Initial	*Continuous light*	*18 h light:6 h dark*	*Natural photoperiod*
Moisture	76.80	77.12[c]	75.25[a]	76.52[b]
Crude protein	16.32	16.44[a]	17.55[b]	16.66[a]
Crude lipid	2.78	3.63[a]	4.86[c]	3.98[b]
Crude ash	1.16	1.11[a]	1.08[b]	1.12[a]

Values in a row with different superscripts are significantly different ($p<0.05$).

observed the best growth at 1-10 lx compared to 500 lx (12 h light at 11 and 14°C) in Atlantic halibut. Imsland et al. (1995), working with juvenile turbot, found that continuous light slightly enhanced the growth rate above that of the natural and extended (16L:8D) photoperiods after three months of exposure at 10 and 16°C, but not throughout the 6-month experiment; the group exposed to extended light had the highest final mean weight. However, in a more recent paper, Imsland et al. (1997) obtained better long-term (18 months) growth in turbot exposed to continuous and extended light (16L:8D) photoperiods during the first winter.

One of the most important factors influencing fish growth is water temperature (Xiao-Jun and Ruyung, 1992; Jobling, 1993). The temperature regime of the current study fluctated between 15 and 24°C, corresponding to the optimum temperature ranges reported for Norwegian turbot weighing 25-75 g (16-19°C; Imsland et al., 1996) and French turbot weighing 35-40 g (16-20°C; Burel et al., 1996).

In this study, fish exposed to continuous light had a considerably lower growth rate and feed intake than the other groups while fish exposed to extended light had the highest growth rate and the best feed conversion and feed efficiency ratios. Pichavant et al. (1998) found no growth promoting effects of an extended photoperiod on the growth of juvenile turbot over a 60-day period, nor did Hallaraker et al. (1995) for halibut over a 56-day period. A long-term fixed extended photoperiod had no growth promoting effects and may have suppressed growth performance, while short-term variations in the photoperiod did not significantly affect growth in juvenile turbot (Stefansson et al., 2002).

Pichavant et al. (1998) found no difference in food utilization over a 60-day photoperiod experiment. However, in the current study, feed intake varied between groups and was consistently lowest in the continuous light group. An increase in growth rate with increased feed intake was observed in turbot by Bromley (1980) and Burel et al. (1996). The same trend was observed here as the growth rate increased with increased feed intake and a better feed conversion ratio. Fish growth and feed efficiency were closely correlated and generally highest in the extended daylight regime. Growth might be influenced by light through better feed conversion efficiency and not just stimulated food intake (Boeuf and LeBail, 1999).

Daily protein intake, energy intake, FCR, PER, and apparent net protein retention (ANPR) were better for the extended photoperiod than for the other regimes, demonstrating that this group utilized feed more efficiently and, thus, FCR was lower. Similar results were obtained by Stefansson et al. (2002) who explained this result by possible growth-suppressing effects of a long-term, extended, fixed photoperiod on fish. In our case, fish in the 18L:6D photoperiod were less affected by extensive light intensity and, as a result, may have consumed more food. The growth rate shared a peak with relative feed intake and conversion efficiency whereas the lowest points of these three parameters also occurred at the same times (Stefansson et al., 2002).

In conclusion, our results indicate that feed intake and growth in juvenile turbot are influenced by photoperiod. The results suggest that 18L:6D is adequate for good growth of juvenile turbot in 15-24°C and that continuous light (24L:0D) may act as an irritant that suppresses the growth rate and reduces feed intake. Further detailed studies should be conducted on the effects of light intensity on growth not only in juvenile but also on large turbot.

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