www.trjfas.org
ISSN 1303-2712
Turkish Journal of Fisheries and Aquatic Sciences 12: 225-231 (2012) DOI: 10.4194/1303-2712-v12_2_05

Effects of Long-term Extended Photoperiod on Somatic Growth and Husbandry Parameters on Cultured Gilthead Seabream (*Sparus aurata*, L.) in the Net Cages

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Received 28 June 2011
Accepted 30 January 2012

Abstract

In this study, the effects of the long photoperiod regime (15L:9D) on both somatic growth and husbandry parameters were investigated in growing gilthead seabream (*Sparus aurata*). Experiments were conducted in high density polyethylene (HDPE) floating cages which have net depths of 14 m and diameters of 20 m. They contained approximately 180,000 gilthead seabream with average weights of 78.91±8.54 g and 71.39±4.06 g for experimental and control groups, respectively. Additionally, artificial illumination was applied to experimental cages for 13 months, while it was not performed on the control group. At the end of the experiments, fishes of experimental groups reached to 425.19±5.06 g on average (total n=362,676), while this value was estimated as 305.42±25.01 g (total n=345,829) on average in control groups ($P<0.05$). In addition, feed conversion ratio (FCR) was calculated as 2.04 and 2.37 for experimental and control groups, respectively, however significant differences were found between these groups ($P<0.05$). Moreover, gonadal weight of fish in the control group was significantly higher than the experimental group. Gonadosomatic index was recorded as 0.36 % in the control group and 0.15 % in the experimental group ($P<0.05$).

Keywords: Gilthead seabream, *S. aurata,* cage culture, long-term extended photoperiod, growth parameters, gonadal development.

Yapay Aydınlatma ile Gün Işığı Süresinin Uzatılmasının Ağ Kafeslerde Yetiştiriciliği Yapılan Çipuraların (*Sparus aurata*) Gelişimleri Üzerine Etkileri

Özet

Bu çalışmada, uzun fotoperiyot rejiminin (15L:9D) yetiştiriciliği yapılan çipura (*Sparus aurata*) balıklarının somatik gelişimleri üzerine olan etkileri araştırılmıştır. Denemeler 14 m ağ derinliğinde ve 20 m çapında, yüksek yoğunluklu polietilen (YYPE) ağ kafeslerde gerçekleştirilmiştir. Deneme ve kontrol grupları için her bir kafese, ortalama ağırlıkları, sırasıyla 78,91±8,54 g ve 71,39±4,06 g olan yaklaşık 180.000 adet çipura konulmuştur. 13 ay boyunca deneme grubu kafeslerine ilave aydınlatma uygulanırken kontrol grubu kafesine ilave aydınlatma uygulanmamıştır. Çalışma sonunda, deneme grupları 425,19±5,06 g ortalama canlı ağırlığa ulaşırken (toplam n=362.676), kontrol grubunun canlı ağırlığı 305,42±25,01 g (toplam n=345,829) olduğu saptanmıştır. Bununla birlikte, deneme gruplarında ve kontrol grubunda yem dönüşüm oranı (YDO) sırasıyla 2,04 ve 2,37 olarak hesaplanmış olup her iki grup arasında önemli farklılıklar tespit edilmiştir ($P<0,05$). Ayrıca, kontrol grubundaki balıkların gonad ağırlığı deneme grubundakilere göre belirgin ölçüde fazla çıkmıştır. Gonadosomatik indeks kontrol grubunda %0,36, deneme gruplarında ise %0,15 olarak kaydedilmiştir.

Anahtar Kelimeler: Çipura, *S. aurata*, ağ kafeslerde yetiştiricilik, uzun fotoperiyot, büyüme parametreleri, gonad gelişimi

Introduction

Among the numerous abiotic factors which effect fish activity, light plays a major role in aquaculture. Therefore, many studies have compared effects of supplying light continuously for very long periods. The influences of light on the fish concern primarily their growth as a function of the photoperiod length (Boeuf, 1999; Jonassen *et al*., 2000; Konstantinov *et al*., 2002). Additionally, several researchers clearly noted that photoperiod and light intensity manipulation have been successfully used to improve the growth of larval and juvenile stages of a number of fish species. Also, improved fish growth in relation to light regime has been attributed to a number of factors including higher

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food conversion efficiency and growth parameters and also lower activity and lower oxygen consumption (Imsland *et al*., 1997; Appelbaum *et al*., 2000). Besides, exposure to extended photoperiods has been shown to lead to increased growth rates in salmonids, *Salmo salar* (Berg *et al*., 1992); Halibut, *Hippoglossus hippoglossus* (Simensen *et al*., 2000); Atlantic cod, *Gadus morhua* (Folkvord and Ottera, 1993); Atlantic turbot, *Scophthalmus maximus* (Imsland *et al*., 1997); Barramundi, *Lates calcarifer* (Barlow *et al*., 1995) and Black Sea turbot, *Psetta maeotica* (Türker *et al*., 2005). Otherwise, it is recorded that the possible introduction of photoperiod manipulation on a commercial scale must first involve confirmation of these favorable results up to commercial weights >400 g (Ginés *et al*., 2004). Additionally, in young fish (from 25 g to around 200 g) long and constant photoperiods of both 16:00 hours of light (16L:8D) and permanent light (24L:0D) have improved seabream growth (Silva-García, 1996). In older fish, long photoperiods increase growth efficiency, at least partially by delaying sexual maturity (Kissil *et al*., 2001; Ginés *et al*., 2003). But, this phenomenon contradicts the target of the culture of seabream which is to reach market size within the shortest time and the lowest cost as possible. In this phenomenon, second abiotic factor, water temperature, plays a major role in the net cages. Annual average sea temperatures increase 4°C and the average duration of day light is 15 minutes longer from the northern Aegean Sea to the Mediterranean Sea. Therefore, gilthead seabream reaches market size faster in the Mediterranean Sea than in the Aegean Sea (12-16 months) (Yıldırım, 2005). In autumn and winter, it is well known that depending on the decreased metabolic activity with decreased daylight and water temperatures, fish weight gain also decreases (Kissil *et al*., 2001). While environmental factors such as temperature and nutrients may change from year to year, photoperiodic changes are the same every year (Kissil *et al*., 2001; Ginés *et al*., 2004). It is not possible to change the water temperatures in the net cages; however it could be possible to extend the normal day period with artificial illumination. This experiment was conducted to study the effects of additional artificial lighting on somatic growth and husbandry parameters in gilthead seabream maintained in sea cages. Therefore, the main goal of the present study was to evaluate the effects of photoperiod regimes in the gilthead seabream which is one of the most valuable cultured species in Mediterranean countries.

Materials and Methods

Fish Culture Conditions

Experiments were carried out for one year (between April 2008 and April 2009) at Çamlı Feed Husbandry Corp. Marine Farm Inc. (38°24'13"N, 26°27'13"E, Ildır, İzmir, TURKEY). In total 180,000 seabream juveniles from the same batch (initial weight average was 75.15±3.76 g) were randomly selected and stocked into 4 HDPE floating cages which had net depths of 14 m and diameters of 20 m (distance was 2 kilometers from hatchery to cages). Sea water temperature had an annual range between 14.3–23.0°C (Figure 1). Salinity of seawater was 36-37‰. Seabream were fed 2-3 times a day with a commercial pellet food (Bioaqua feed, pellet 4-6 mm, Çamlı Feed Corp., İzmir, Turkey, 46 % crude protein, 18 % fat according to manufacturer’s declaration) according to fish size (Table 1).

Experimental Design

All HDPE floating cages were classified into 2 groups as experimental and control groups. Artificial illumination was applied to experimental HDPE

Table 1. The feeds and the number of meals according to fish size

The feeds /dimensions	Fish sizes (g)	Number of meals
Extruder/4mm	70.1-150	3 times
Extruder/5mm	150.1-250	3 times
Extruder/6mm	250.1-450	2 times

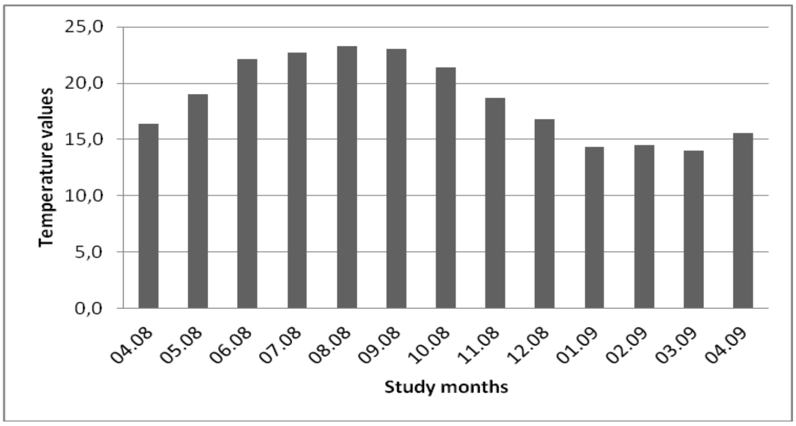

Figure 1. Changes of sea water temperature during the study.

floating cages for long-term extended daylight and control groups were exposed to the natural photoperiod. Distance between control and experimental group cages was 40 m. In order to provide artificial illumination, lamps (BGB Marine Underwater Light Pisces, 1000 W) were used in the experimental groups in the centre of the floating cages and placed at 1 and 5 m depths from the surface to extend the duration of daylight. Natural light ranged from 6 lux to a maximum of 1,300 lux at the water surface between sunrise and sunset (Kissil *et al*., 2001). Lamps provided approximately 1,000 lux at the surface of water. The artificial illumination was adjusted as 15L:9D daily for experimental group cages (Table 2). The duration of illumination was adjusted according to the longest daylight period observed in the geographical location of the experimental facility (38°24'13"N, 26°27'13"E, Ildır, İzmir, Turkey) in June. The lights were routinely switched on before sunrise and switched off immediately after sunset. Electrical power required for the lamps was provided by a power supply (John Deere, 96 kw diesel engine).

Sample Collection and Processing

In total 60 samples were collected in different depths randomly from each cage by using drag in the third week of each month during the 13 months from April 2008 to April 2009 (total of 780 samples were taken during the study). Fish were weighted at the laboratory; gonads were extricated with scalpel by dissection. By this way, live body weights and gonadal developments were followed monthly. Two parameters, feed conversion ratio (FCR); and specific growth rate (SGR), characterizing growth performance were calculated by the following formulae:

$$FCR = \frac{weight\ of\ total\ \ delivered}{biomass\ gain}$$

$$SGR = \frac{100(Ln\ Final\ body\ weight\ of\ \ fish - Ln\ initial\ body\ weight\ of\ \ fish)}{\Delta t\ (day)}$$

At the end of the experiments, survival was calculated by counting the market size (300/400 g) fishes remaining in the floating net cages. The gonadosomatic index (GSI) which is the percent ratio of gonadal to somatic weight, was also calculated by the formula:

$$GSI = \left(\frac{gonadal\ \ weight}{total\ weight}\right) x\,100$$

Statistical Analysis

Results are given as mean ±SD. The variance homogeneity of the data was performed using Levene's test. Survival datas were compared by Fisher's chi-square test. Somatic growth and husbandry parameters were compared by one–way ANOVA, followed by Newman–Keul's multiple range test when significant differences were found at a 0.05 level. All measurements in the study were performed in triplicates.

Results

Growth of *S. aurata* in 2 groups during the 13 months of the study is given in Table 3. In all experimental groups, fish increased their weight by a factor of more than 5-fold, while it was more than 4-fold for control groups after 13 months. The average initial live body weights were 78.91±8.54 g and 71.39±4.06 g for experimental and control groups, respectively. At the end of the experiments, final body weights were recorded as 425.19±5.06 g and 305.42±25.01 g for experimental and control groups, respectively (Table 3).

Fish in experimental groups reached 425.19±5.06 g at the end of the thirteen month period (April 2009) but in control groups this value was 305.42±25.01 g for the same period**.** This suggests that fish in experimental groups could be harvested 2-3 months earlier than the control group ($P<0.05$) (Figure 2).

Specific growth rates in groups were recorded as 57.56% for experimental group in July and 28.66%

Table 2. Natural daylight time (in İzmir) and additional time for experimental group

Experimental group	Natural daylight time(h:min)	Additional illumination time (h:min)
May'08	14:05	00:55
June'08	15:00	00:00
July'08	14:18	00:42
Agust'08	13:34	01:26
September'08	12:21	02:39
October'08	11:21	03:39
November'08	09:59	05:01
December'08	10:03	04:57
January'09	09:58	05:02
February'09	10:47	04:13
March'09	12:09	02:51
April'09	13:36	01:24

Table 3. Initial average live body weights and final average live body weights of the two groups

Cages	The number of fish stocked	Initial average live body weight (g)	Final average live body weight (g)
Experimental-I	183,084	70.37±15.49	430.25±60.34
Experimental-II	179,592	87.45±16.43	420.13±57.78
Control-I	174,449	75.45±19.03	330.43±84.95
Control-II	171,380	67.33±17.02	280.41±54.53

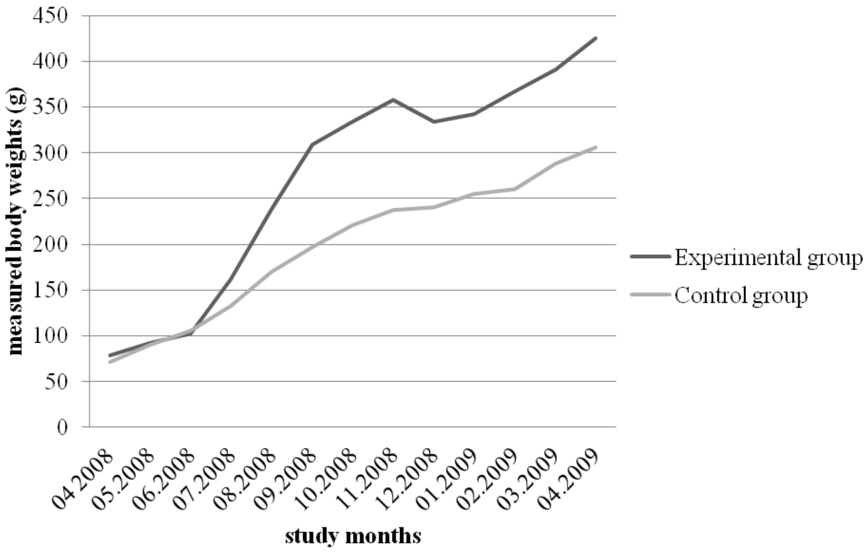

Figure 2. Changes in body weights of the two groups during the study.

for control group in August (P<0.05). Additionally, when the sea water temperature was above 22 °C in July, August and September, significant differences were found between the experimental and control groups for SGR values (P<0.05) (Table 4), however there were no differences between the groups in other months (P>0.05).

FCR values were recorded as 2.04 and 2.37 for experimental and control groups, respectively and there were significant differences between experimental and control groups at the end of the experiments (P<0.05). There were no significant differences in final survival rates between two groups (P>0.05). While it was 93.14% for the experimental group, it was 92.03% for the control group. Due to decreased water temperatures and daylight duration, natural reproduction starts in October and December in the İzmir coast. Therefore, gonad weights were different between the two groups in those months. Gonad weights in control groups were twice of those in experimental groups in December and January (P<0.05) (Figure 3).

Gonadosomatic index was higher in the control group compared to the experimental group during the study (Table 5) (Figure 4).

The maximum value of mean gonadosomatic index for control group was determined in December (0.93). However, it was 0.37 for experimental group in December.

Discussion

The results of the present study show that the somatic growth and husbandry performance such as FCR and SGR of gilthead seabream were significantly affected by long photoperiod regimes over the 13 months of the experiment. Growth in all groups was satisfactory, but long-term photoperiod treatments demonstrated significant increases in growth performance of seabream. At the end of the experiments, final body weights were 425.19±5.06 g and 305.42±25.01 g for experimental and control groups, respectively. These findings suggest that long-term extended photoperiod has a growth promoting effect on gilthead seabream. Improved appetite, greater specific growth rate and higher food conversion ratio are factors commonly reported to be responsible for this species' growth under long-term extended light conditions. Similar findings were reported both in gilthead seabream (Kadmon *et al*., 1985; Kentouri *et al*., 1993; Kissil *et al*., 2001) and the other cultured species such as *S. maximus* (Imsland *et al*., 1997), *O. mykiss* (Pavlidis *et al*., 1992), *P.maeotica* (Türker *et al*., 2005), *H. hippoglossus* (Jonassen *et al*., 2000). In addition long-term extended artificial photoperiod caused 40 % more growth in Codfish (*Gadus morhua*) (Davie, 2005), which was 30 % in our study after 13 months.

On the other hand, in terms of FCR and SGR,

Table 4. Average live body weights of experimental and control groups (P<0.05) with measured average surface temperatures of the sea water

Months	Experimental group Body weight(g)	Monthly S.G.R. (%)	Control group Body weight (g)	Monthly S.G.R. (%)	Sea water temp. (°C)
Apr.’08	78.91±8.54	-	71.39±4.06	-	16.4
May.’08	92.34±3.50	17.02	90.14±0.86	26.27	19.0
June’08	102.50±2.50	11.00	106.11±1.11	17.72	22.0
July’08	161.50±18.50	57.56	132.50±7.50	24.87	22.7
Aug.’08	238.43±30.58	47.63	170.48±5.48	28.66	23.3
Sep.’08	308.50±18.50	29.38	196.50±1.50	15.26	23.0
Oct.’08	333.43±22.58	8.08	220.37±10.63	12.15	21.4
Nov.’08	357.50±15.50	7.22	237.50±3.50	7.77	18.7
Dec.’08	334.31±13.69	-6.49	240.18±9.82	1.12	16.8
Jan.’09	342.50±12.50	2.45	255.19±4.82	6.25	14.3
Feb.’09	367.50±12.50	7.30	260.20±5.20	1.96	14.5
Mar.’09	391.41±29.41	6.50	288.50±21.50	10.87	14.0
Apr.’09	425.19±5.06	8.63	305.42±25.01	5.86	15.6

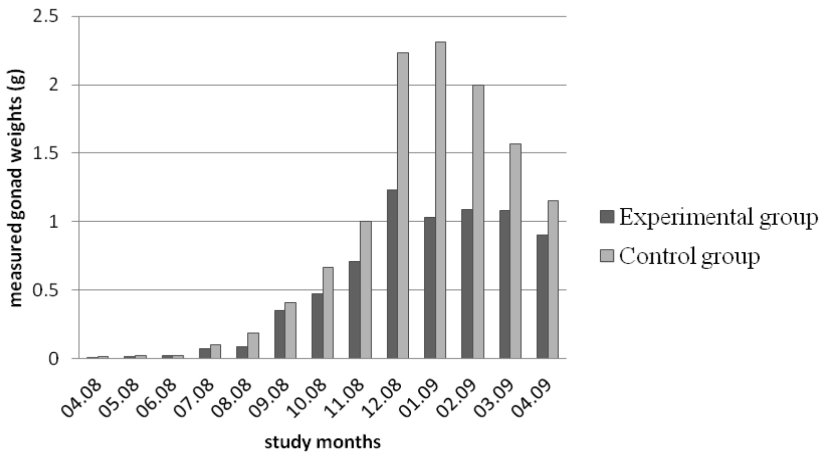

Figure 3. Changes in gonad weights for each group.

Table 5. Gonadosomatic index (GSI) values of experimental and control groups (P<0.05)

Study months	Gonad weights (g)		Body weights (g)		GSI %	
	Experimental group	Control group	Experimental group	Control group	Experimental group	Control group
04.08	0.01	0.02	78.91	71.39	0.01	0.02
05.08	0.02	0.03	92.34	90.14	0.02	0.03
06.08	0.02	0.03	102.50	106.11	0.02	0.02
07.08	0.08	0.11	161.50	132.50	0.05	0.08
08.08	0.09	0.19	238.43	170.48	0.04	0.11
09.08	0.35	0.41	308.50	196.50	0.11	0.21
10.08	0.48	0.67	333.43	220.37	0.14	0.30
11.08	0.71	1.00	357.50	237.50	0.20	0.42
12.08	1.23	2.24	334.31	240.18	0.37	0.93
01.09	1.04	2.32	342.50	255.19	0.30	0.91
02.09	1.09	2.00	367.50	260.20	0.30	0.77
03.09	1.08	1.57	391.41	288.50	0.28	0.54
04.09	0.90	1.15	425.19	305.42	0.21	0.38

several studies suggested that long-term extended photoperiod regimes usually improve the husbandry parameters. Moreover, to ensure that the growth rate is not influenced by a limited food supply in fish reared under long photoperiods, excess feeding would be necessary (Purchase *et al*., 2000). In this study, long-term extended photoperiod treatments improved both SGR and FCR in this species. In contrast to

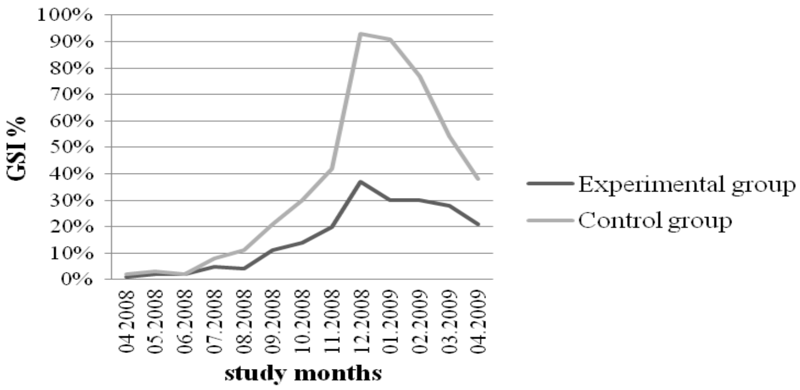

Figure 4. Changes in GSI % for each group.

control groups, these parameters were more than 20 % and 14 % in the experimental groups, respectively. It is clear that the positive effects of long-term photoperiod on fish growth rates are achieved through increased specific growth rate and food conversion ratio rather than stimulation of feeding. In previous studies of gilthead seabream, long and constant photoperiods had a positive effect on juvenile growth until they achieved commercially desirable weights (Kadmon *et al*., 1985; Micale *et al*., 1990; Kissil *et al*., 2001). Several researchers reported similar findings in some cultured teleosts such as *S. maximus* (Imsland *et al*., 1997), *P.maeotica* (Türker *et al*., 2005), *H. hippoglossus* (Jonassen *et al*., 2000). Additionally feed consumption increased with applying long-term photoperiod on diurnal and with short-time photoperiod on nocturnal feeders, where their feed conversion rates improved (Davie, 2005).

The use of artificial photoperiods to manipulate the timing of maturation is now a well-recognized tool within the aquaculture industry. By photoperiod applications, the period of gonadal development was brought to a halt at spawning periods causing an increase in the live weights of salmons (Peterson *et al*., 2005). However, in our study it is difficult to estimate similar effects in gilthead seabream. We expected a decrease in the duration of the gonadal development and reaching harvest size by increasing daylight via additional artificial illumination in winter months, however this hypothesis was not supported with our data. As presented in results, monthly changes of body weight and SGR were similar for each group especially between October 2008 and March 2009 (Table 2). This phenomenon could be an advantage especially in immature fish for annual production, where additional illumination provides a useful commercial strategy in the recovery of previously mature fish. Moreover, the long day photoperiod mimics a subjective summer during the ambient winter and hence accelerates oocyte resorption. Similar findings were reported by several researchers in some cultured teleosts (Jonassen *et al*., 2000; Porter *et al*., 2003; Ginés *et al*., 2004).

Our results suggest that long-term extended photoperiod would not affect growth parameters when the reproduction period starts in autumn and winter. Significant differences were also detected in SGR values in experimental and control groups above 22°C in July, August and September. Moreover, the use of photoperiod to postpone gonadal development and spawning to conserve body reserves is not applied commercially on a wide scale (Porter *et al*., 2003). Therefore, we recommend the application of long-term extended artificial illumination to increase somatic growth and husbandry parameters in gilthead seabream when surface sea water temperature is above 22°C.

Acknowledgments

This work was supported by the Çamlı Feed Husbandry Corp. Marine Farm. Inc. The authors thank to Managing Director Mr. Salih KÖSELER and also staff of the Çamlı Feed Husbandry Corp., Marine Farm, (Ildır, Çeşme, İzmir, TURKEY) where the experiments were conducted.

References

Appelbaum, S. and Kamler, E. 2000. Survival, growth, metabolism and behaviour of *Clarias gariepinus* (Burchell 1822) early stages under different light conditions. Aquaculture Engineering, 22: 269-287. doi: 10.1016/S0144-8609(00)00054-6

Barlow, C.G., Pearce, M.G., Rodgers, L.J. and Clayton, P. 1995. Effects of photoperiod on growth, survival, and feeding periodicity of larval and juvenile barramundi, *Lates calcarifer* (Bloch). Aquaculture, 138: 159-168. doi: 10.1016/0044-8486(95)01073-4

Berg, A., Hansen, T. and Stefansson, S.O. 1992. First feeding of Atlantic salmon (*Salmo salar* L.) under different photoperiods. J. Appl. Ichthyol., 8: 251-256. doi: 10.1111/j.1439-0426.1992.tb00691.x

Boeuf G. and Le Bail P.Y. 1999. Does light have an influence on fish growth. Aquaculture, 177: 129-152. doi: 10.1016/S0044-8486(99)00074-5

Davie, A. 2005. Effect of photoperiod manuplation on growth and reproduction in Atlantic cod (*Gadus morhua*). PhD thesis. Inst. Of Aquaculture, Unv. of Stirling, Scotland.

Folkvord, A. and Ottera, H. 1993. Effects of initial size distribution, day length, and feeding frequency on growth, survival, and cannibalism in juvenile Atlantic cod (*Gadus morhua* L.). Aquaculture, 114: 243-260. doi: 10.1016/0044-8486(93)90300-N

Ginés, R., Afonso, J.M., Argüello, A., Zamorano, M.J. and López, J.L. 2003. Growth in adult gilthead sea bream (*Sparus aurata* L) as a result of interference in sexual maturation by different photoperiod regimes. Aquaculture Research, 34: 73-83. doi: 10.1046/j.1365-2109.2003.00801.x

Ginés, R., Afonso, J.M., Argüello, A., Zamorano, M.J. and López, J.L. 2004. The effects of long-day photoperiod on growth, body composition and skin colour in immature gilthead sea bream (*Sparus aurata* L.). Aquaculture Research, 35: 1207-1212. doi: 10.1111/j.1365-2109.2004.01126.x

Imsland, A.K, Folkvord, A., Jónsdóttir, Ó.D.B. and Stefansson, O.S. 1997. Effects of exposure to extended photoperiods during the first winter on long-term growth and age at first maturity in turbot (*Scophthalmus maximus*). Aquaculture, 159: 125-141. doi: 10.1016/S0044-8486(97)00152-X

Jonassen, T.M., Imsland, A.K., Kadowaki, S. and Stefansson, S.O. 2000. Interaction of temperature and photoperiod on growth of Atlantic halibut *Hippoglossus hippoglossus* L. Aquaculture Research, 31: 219-227. doi: 10.1046/j.1365-2109.2000.00447.x

Kadmon, G., Yaron, Z. and Gordin, H. 1985. Sequence of gonadal events and oestradiol levels in *Sparus aurata* (L.) under two photoperiod regimes. Journal of Fish Biology, 26: 609-620. doi: 10.1111/j.1095-8649.1985.tb04301.x

Kentouri, M., Divanach, P., Papandroulakis, N., Stefanakis, S. and Anastasiadis, P. 1993. Intensive larval rearing technique for sea bream *Sparus aurata*. In: E. Papathanasiou and E. Charou (Eds.), Proceedings of the 4th National Symposium on Oceanography and Fisheries. National Centre of Marine Research, Athens, Greece: 495-496.

Kissil, G. Wm., Lupatsch, I., Elizur, A. and Zohar, Y. 2001. Long photoperiod delayed spawning and increased somatic growth in Gilt-head sea bream (*Sparus aurata*). Aquaculture, 200: 363-379. doi: 10.1016/S0044-8486(01)00527-0

Konstantinov, A.S., Zdanovich, V.V., Pushkar’, V.Ya. and Solov’eva, E.A. 2002. Influence of Illumination oscillations on growth and energetics of the Goldfish *Carassius auratus*. Biology Bulletin, 29(2): 168–171. doi: 10.1023/A:1014363201514

Micale, V. and Perdichizzi F. 1990. A quantitative and histochemical study on melano macrophage centres in the spleen of the teleost fish *Diplodus annularis* L. Journal of Fish Biology, 37(2): 191-197. doi: 10.1111/j.1095-8649.1990.tb05851.x

Pavlidis, M., Theochari, V., Paschos, J. and Dessypris, A. 1992. Effect of six photoperiod protocols on the spawning time of two rainbow trout, *Oncorhynchus mykiss* (Walbaum), populations in north-west Greece. Aquaculture and Fisheries Management, 23: 431-441.

Peterson, R.H. and Harmon, P.R. 2005. Changes in condition factor and gonadosomatic index in maturing and non-maturing Atlantic salmon (*Salmo salar*) in bay of Fundy sea cages, and the effectiveness of photoperiod manipulation in reducing early maturation. Aquaculture Research, 36: 882-889. doi: 10.1111/j.1365-2109.2005.01297.x

Porter, M.J.R., Woolcott, H.M. and Pankhurst, N.W. 2003. The use of additional lighting and artificial photoperiods to recondition early maturing Atlantic salmon (*Salmo salar*) in Tasmania. Fish Physiology and Biochemistry, 28: 391-393. doi: 10.1023/B:FISH.0000030603.30648.90

Purchase, C.F., Boyce, D.L. and Brown, J.A. 2000. Growth and survival of juvenile yellowtail flounder *Pleuronectes ferrugineus* (Storer) under different photoperiods. Aquaculture Research, 31: 547-552. doi: 10.1046/j.1365-2109.2000.00480.x

Silva-Garcia, A.J. 1996. Growth of juvenile gilthead seabream *Sparus aurata* L. reared under different photoperiod regimes. Isr. J. Aquacult., 48 2, 84-93.

Simensen, L.M., Jonassen, T.M., Imsland, A.K. and Stefansson, S.O. 2000. Photoperiod regulation of growth of juvenile Atlantic halibut *Hippoglossus hippoglossus* L. Aquaculture, 190: 119-128. doi: 10.1016/S0044-8486(00)00397-5

Türker, A., Yiğit, M. and Ergin, S. 2005. Growth and feed utilization in juvenile Black Sea turbot (*Psetta maeotica*) under different photoperiod regimes. Turk J. Vet. Anim Sci., 29: 1203-1208.

Yıldırım, Ş. and Alpbaz, A. 2005. An investigation on some of the production characteristics of the fish farms in Turkish Seas whose annual productions are 100 tonnes and over. E.U. Journal of Fisheries and Aquatic Science, 22(3-4): 251-255.