MODIFICATION OF PHOTOPERIOD IN REPRODUCTION OF EUROPEAN SEABASS (*Dicentrarchus labrax*).

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Abstract:

The modification of photoperiod is routinely used in aquaculture with the aim to enhance production by manipulating the timing of reproduction in several important fish species. In European sea bass was proved that photoperiod manipulation plays an important role in different aspects of reproduction performance. The present study review the effects of photoperiod modification on some physiological aspects related to period of spawning, sexual differentiation and early puberty of the sea bass kept in culture conditions. Long photoperiod followed by short ones and applied before the summer solstice, produce advancements of reproductive period, but . Long photoperiod followed by short ones and applied after the summer solstice, produce delays of reproductive period. The modification of photoperiod offers the possibility of controlling the sexual differentiation of sea bass, but is necessary more work to unveil many of its mechanisms of action. The sea bass in culture conditions face the problem of early maturing males or precocious males. Applying the modified photoperiod in a specific time of early gonadal development can reduce the number of the early maturing males of sea bass.

Keywords: photoperiod; sea bass; reproduction.

1. Introduction

European sea bass (*Dicentrarchus labrax*) is one of the most important commercial marine fish species in Mediterranean countries. Its production from aquaculture is increasing rapidly in the last decade. Despite the fact that production is steadily growing there are several factors which limit its maximization. A great part of these factors are related with its reproductive characteristics. The actual goal of different groups of researchers is to modify its reproductive cycle with the final scope to have all year spawning. Like many other fish species, in sea bass external environmental factors influence in reproduction performance. Among this photoperiod plays an important role [6]. This work aims at reviewing the effects of photoperiod on some physiological aspects related to period of spawning, sexual differentiation and early puberty of the sea bass kept in culture conditions.

2. Modification of the photoperiod to extend spawning season.

In Mediterranean countries sea bass breeding season is from December to March, tending to fall behind with increasing latitude. Bromage et al., [2] explained that light can affect the state of the reproductive organs in many species. The manipulation of photoperiod in sea bass consisted in extending the spawning season beyond the natural. Attaining this goal is possible to have continuous production of eggs and larvae of good quality throughout the year and thus meet the market demands.

In the study of Carrillo et al., [3] exposure of fish to 1 month of long day (LD 15/9) from either 2nd May, 3rd June or 3rd July in an otherwise constant short day (LD 9/15) photoperiod regime, speeded up the rates of maturation, thus increasing the proportions of oocytes entering exogenous vitellogenesis during October and November, and also brought forward the timings of ovulation and spawning. Fish maintained under constant short days throughout the experiment spawned up to 6 weeks in advance of the control fish. In contrast, constant long days from 2nd May delayed maturation and spawning time by 2–3 months. Meanwhile Prat et al., [12] found that under constant short photoperiod, the spawning time of 2-year-old sea bass was advanced as compared to controls, whereas spawning were delayed under constant long photoperiod.

An exposure of long photoperiods of two months (LD 15:9), and followed by the rest with short days (LD 9:15) is enough to advance the season of reproduction. This is true only if the long photoperiod is applied in the in the first half of the year. If this is applied by the second half of the year, the reproductive season is delayed. This two month interval of long photoperiod in an otherwise constant short light regime could be applied each month from March through to September to obtain spawning from October through to May [4] (Figure 1). Furthermore exposure of sea bass (of four years of age) to one year of constant short days, beginning in April, advances spawning whereas exposure to long days, starting from the same date, causes a delay [19].

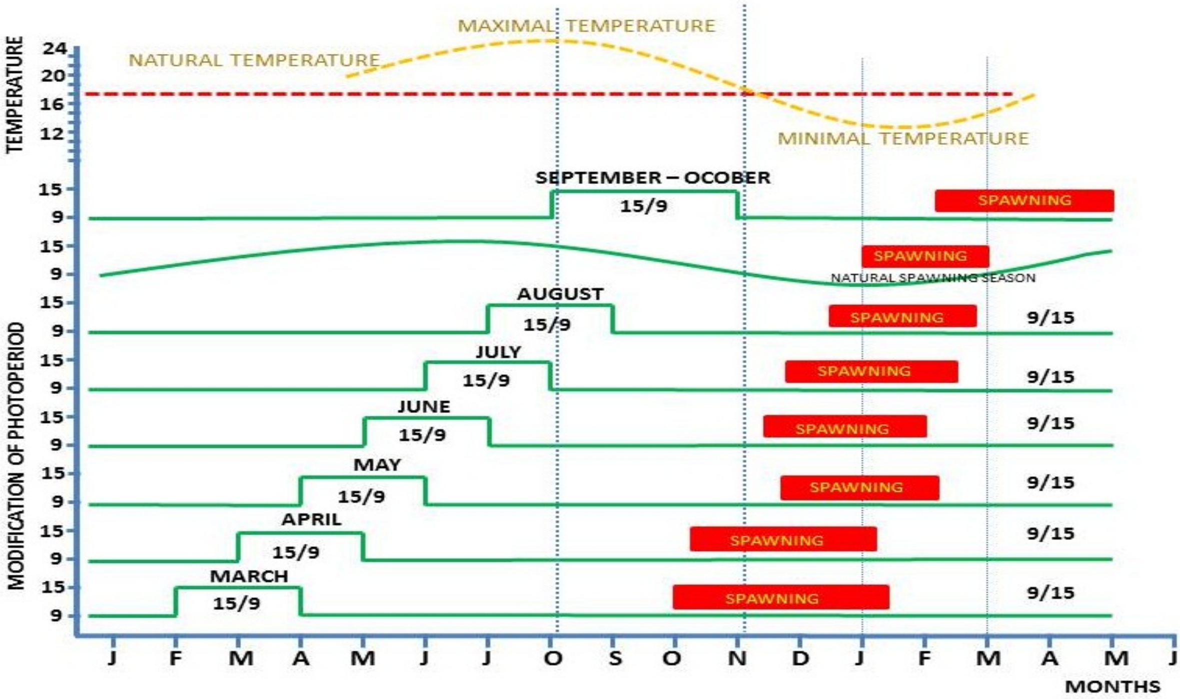

Figure 1. Extension of the spawning season for sea bass applying modified photoperiod regimes (modified from Carrillo et al [4])

The application of one or two months of constant long-days (LD15/9) in a constant short-day photoperiod regime (LD9/15) all-year-round, given early in the year (March and March–April), advanced spawning by 3 months. The same treatment applied later in the year (September–October) delayed spawning by 1 month, compared to controls [10].

In another study, the juvenile sea bass (4-5 months old) were kept during four or three consecutive years (respectively experiment I and II) under artificial photoperiod conditions. Compared with the control group, in experiment I, during the first reproductive cycle, the expanded (18 months) of simulated natural photoperiod group and constant long photoperiod (LD15/9) groups showed a statistically significant advance and delay of 53 and 58 days, respectively, in mean spawning time. In Experiment II, the SLmar (constant short (LD9/15) with an large LD15/9 in March) and CO (compressed natural cycle to 6 months) groups presented a significant advance in spawning time, of 1 and 2 months, respectively, compared with the controls. From these results, it can be concluded that long-term application of artificial photoperiods can advance or delay the time of first spawning in D. labrax, as well as altering their rates of relative fecundity, and the quality of eggs and larvae [13].

3. Modification of the photoperiod to advance sexual differentiation

In sea bass, the sexual differentiation is complete at nine months [9]. The importance of altering the time of onset of sexual differentiation and sex ratio is very beneficial in aquaculture and can be applied only on one of sexes (the fastest growing or largest of gonadal development, etc.). Fish show a high degree of plasticity in sexual differentiation processes. Moreover, these can be altered to a variety of factors such as the photoperiod, temperature, chemical composition, density and hormonal treatments [6].

Recently Rodriguez et al., [14] found that long photoperiods (LD 15/9) applied continuously from 4 to 11 months of age (period of sexual differentiation), do not alter the sex ratio, but significantly accelerate this process after 7 months of photoperiodic treatment. In this study the proportion of animals with no recognizable sex at 11 months of age, was significantly lower in those treated with long photoperiods (6.6%) than in controls, (16.7%). This acceleration of sexual differentiation was associated with increased somatic growth induced by photoperiod, indicating a close relationship between growth and sexual differentiation. The authors explain that these results offer the possibility of controlling the sexual differentiation of sea bass with natural methods, but unfortunately, is necessary more work to unveil many of its mechanisms of action.

In a latter study Rodrigues et al., [16] studied the effect of several photoperiods regimes in juvenile male sea bass during testicular differentiation and first testicular recrudescence. Fish were exposed during two consecutive years to constant long, expanded, constant short photoperiod with long photoperiod in October and constant short photoperiod with long photoperiod in December. Pituitary levels of three forms of gonadotropin-releasing were analyzed. The three GnRHs[1] had significantly lower values in November in groups exposed to artificial photoperiods during the testicular differentiation and growth period compared to the control group. During the first testicular recrudescence, the effect of the artificial photoperiods on the pituitary content of the three GnRHs there were no significances observed. These authors suggest that deeper studies are needed to understand the effect of artificial photoperiods on the endocrine events occurring during histological testicular differentiations.

Moles et al., [11] studied the role of sbGnRH[2] in gonadal differentiation through an enhancement of FSH gene expression, showing a peak of brain sbGnRH content at 250 days post-hatching, which coincided with the time of our first sbGnRH increase. The rapid rise in pituitary sbGnRH levels correlated with plasma LH levels and GSI, particularly from December to January in the second sexual cycle, which illustrates the role of sbGnRH in the release of LH by the pituitary gland. Seasonal hormonal changes in the second annual cycle resembled those observed during the first cycle, except for the absence of the LH peak in September. At this time, fish were already differentiated and did not require additional levels of LH to complete this process, as occurred the previous year. However, during the second annual cycle, hormone levels experienced a dramatic increase, which is in agreement with the sizeable gonadal enlargement observed.

4. Effect of modified photoperiod in the process of puberty

The sea bass is a gonochoristic species (i.e., sexes are separate). Males reach first sexual maturation at 2-years of age and females at 3 years [4]. Although in intensive culture conditions an important percentage of males (20-30% of population) mature at 1-year old. They are called, early maturing or precocious males [5]. On the other hand, males are smaller (20-30%) than females and in captivity the sex ratio of this specie is 70 – 99% in favor of males [8].

Although early maturing males are larger than their non-precocious counterparts during their first year of life, evidences for reduced growth during their second year of life (around time of commercialization) have been confirmed [7]. Thus, the early sexual maturation occurring in male sea bass is a current problem in the culture industry of this species that need to be solved to avoid those negative aspects, due to reproduction, such as reduced growth and low conversion efficiency.

The first work on the endocrine control of puberty was done by Zanuy et al. [18], when was seen that the administration of testosterone (T) stimulated spermatogenesis in prepubertal sea bass. These results suggested that T might be involved in the onset of puberty in this species probably via feedback in the GnRH system.

In a more detailed study of Rodríguez et al. [14] 4 months old male sea bass were maintained during three consecutive years to different photoperiod regimes including an expanded natural light cycle (during 18 months, EX) and a constant long cycle (LD 15/9 LO). Effects on somatic growth and the reproductive process of prepubertal fish were monitored. From the first reproductive season (18 months old) to the beginning of the second reproductive season (aprox. 29 months old), fish kept under EX and LO regimes grew more than control (natural photoperiod). On the other hand, significant differences were found in GSI at the first sexual cycle with lower values in experimental groups in comparison to that observed in the control. In addition, at the second sexual cycle, the proportion of spermiating males in the control group was significantly higher than that in EX and LO groups. These findings demonstrated that under these

[1] In fishes there are three different forms of GnRH (salmon GnRH; chicken GnRH and sea bream GnRH)
[2] Sea bream GnRH

photoperiod conditions, a negative relationship between gonadal maturation and somatic growth was found.

In a second study [15], 5 months old sea bass were maintained under compressed natural photoperiod (for 6 months; CO) during two years. A two-phase pattern of gonadal development was observed under these conditions, although some environmental mismatches (i.e., photoperiod and temperature) avoided a complete gonadogenesis. In addition, few spermiating males appeared 2 months earlier than in controls, indicating its effects in the onset of puberty.

Furthermore, four-month-old male sea bass maintaining at continuous light (LL) regime for 24 h a day during 12 consecutive months showed that gonadal development and male maturation rate were drastically reduced in 1-year-old male fish in comparison to those results observed in fish maintained under a simulated natural photoperiod (SNP) [1] (Fig. 2). These results evidenced that photoperiod may have a significant effect on the gonadogenesis. Similar reduction of sexual maturation in male sea bass was evidenced by Felip et al. [7] using LL regimes both before (i.e., a 4-month LL regime from June to September) and during gametogenesis (i.e., a 6-month LL regime from October to March). These results evidenced that GSI in the LL groups was < 0.2% with < 3% early-maturing males, whereas in the SNP group the GSI reached 0.8% with 22% early-maturing males (Fig. 2).

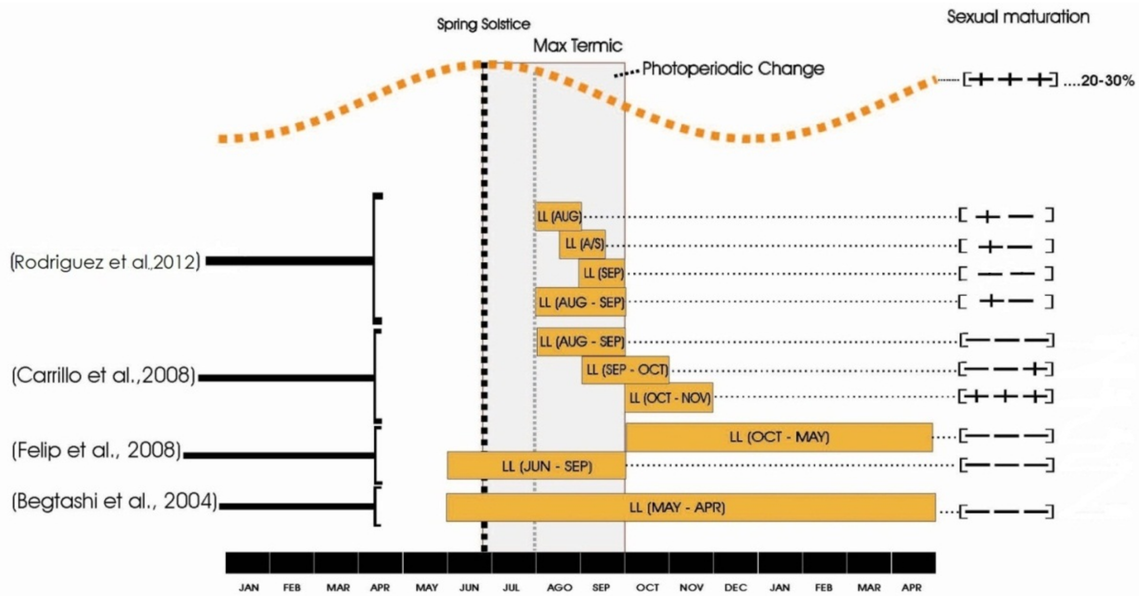

Figure 2. Schematic representation of different photoperiod regimes used in juvenile sea bass for controlling the early puberty process. (-) effective treatment, (+) non effective treatment

These authors suggested that a potential photo-labile period exist somewhere in the autumn, in the sea bass. This study provided the first step to define the location of a window of light sensitivity to arrest early puberty in male sea bass.

A second study to localize the sensitive period to control the gonadal maturation in sea bass was reported by Carrillo et al. [6] using windows of light of 2-months duration from August to November (Fig. 2). This study suggested that a critical period between August and October might exist in which the action of LL might inhibit the gonadal maturation in this species.

In a third study Rodriguez et al [17] succeeded to identify a photolabil period in order to reduce precocious gametogenesis in sea bass. These authors used discrete windows of continuous light (LL), 1–2 months in duration, in late summer-early autumn. Somatic growth, 11-ketotestosterone plasma levels, and the rates of testicular maturation and spermiation were analyzed to evaluate the effect of the applied photoperiodic regimes. Three LL treatments, with duration of 2 months each, were previously screened between the months of August and November. Administration of LL during the October–November period failed to show any differential effects in reducing early maturation, as compared to the simulated natural photoperiod. However, the August–September period was considered to be a likely candidate for photolability. To define this photolabile period, four LL treatments with duration of 1 month were then screened within the same late summer period. Our results demonstrate that the time interval including the month of September is the most sensitive photolabile period in order to reduce precocious gametogenesis in sea bass.

5. Conclusions

The European sea bass is an aquaculture species that modification of photoperiod can alter the timing of reproductive events. Thus, was proven that modification of photoperiod can extend beyond the natural the season of reproduction. Applying long photoperiod for two month interval in an otherwise constant short light regime could be applied each month from March through to September to obtain spawning from October through to May. This is possible by creating enough groups of broodstocks for the respective photoperiodic treatments. Long photoperiod followed by short ones and applied before the summer solstice, produce advancements of reproductive period, but long photoperiod followed by short ones and applied after the summer solstice, produce delays of reproductive period.

The modification of photoperiod offers the possibility of controlling the sexual differentiation of sea bass, but is necessary more work to unveil many of its mechanisms of action. The latter studies prove the importance of light in starting reproductive events in the brain by acting the sbGnRH which increase levels of pituitary LH and GSI.

The sea bass in culture conditions face the problem of early maturing males or precocious males. A long-term exposure to continuous light (LL), 12-month duration, during the whole sexual cycle including both pregametogenesis and gametogenesis is the most effective treatment to inhibit the number of precocious males. Short-term exposures to continuous light (one-month or two-month duration) were also effective to alter the reproductive wave in comparison to a simulated natural photoperiod (positive control group). The most sensible period to apply the continuous light was the month of September.

6. References

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