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# Influence of water temperature on the economic value of growth rate in fish farming: The case of sea bass (*Dicentrarchus labrax*) cage farming in the Mediterranean

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ABSTRACT

In sea cage farming, fish are exposed to seasonal variations of water temperature, and these variations can differ from one location to another. A small increase in water temperature does not only stimulate growth of the fish (until an optimal level) but also lowers dissolved oxygen concentration in water. Dissolved oxygen may then become a rearing constraint during the production cycle if the oxygen requirement of fish is higher than the supply. The impact of this constraint on production parameters (stocking density of cages and/or batch rotation) and thus on economic profit of a farm will depend on both local thermal regime and growth potential of the fish. Increased growth is one of the most important traits in a breeding objective to increase production capacity and profitability. We used a bioeconomic model of seabass reared in cages to calculate the economic value (EV) of increasing thermal growth coefficient (TGC) by selection in different conditions of average temperature (Tm) and amplitude of temperature variation (Ta). Tm and Ta values were taken from different locations in the eastern and western Mediterranean. Results show that increasing TGC has two consequences: (i) fast growing fish reach harvest weight earlier, which increases the number of batches that can be produced per year, and (ii) fast growing fish have higher daily feed intake and, consequently, higher daily oxygen consumption. To balance the oxygen demand and availability in a cage, a farmer might have to reduce the average stocking density, resulting in fewer fish produced per batch. Consequently, EV of TGC is positive when Tm is 19.5 °C or 21 °C, when an increase in number of batches produced compensates for the decrease in stocking density. EV of TGC is negative or null in areas where Tm is closer to 18 °C because the increase in number of batches produced cannot compensate for the decrease in stocking density. Our results show, for the first time, the importance of variation in ambient temperatures for breeding programs in fish.

*Statement of relevance:* The economic impact of improving growth rate in sea cage farming system depends on temperature. This result is important for the development of breeding objectives maximizing economic return in fish breeding programs.



## 1. Introduction

Genetic improvement aims at modifying the performances of animals and, in case of production limitations, can affect the management strategy of a farm. In dairy farming, for instance, increasing milk yield in a situation with milk quota decreases the number of milking cows on farms (Groen, 1989). Such changes in the production system need to be accounted for when building breeding objectives, guaranteeing that expected gains will be met (Groen, 1989; Amer et al., 1994). According to this principle, Rose et al. (2015) calculated the economic values of several traits, including live weight at different live stages, for sheep farms across different environments that varied in the amount and distribution of annual pasture growth. Pasture growth is a key parameter because it determines how much feed is available for sheep farms. The economic values of live weights were higher in regions with high and low variation, compared to regions with medium variation in pasture growth. This result was explained by changes in energy requirements when live weight was increased, which required different management adaptations according to the region. The conclusion was that breeding objectives for live weights could be similar for regions

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with either high and low variation of pasture growth but should be different for regions with medium variation of pasture growth. Such results demonstrate that breeding objectives should be finely tuned to the local conditions of production, according to constraints on input availability, namely, pasture growth and feed availability.

In fish farming, the potential economic impact of selective breeding for growth has been studied by Besson et al. (2014) in a recirculating aquaculture system where production of African catfish (*Clarias gariepinus*) is alternatively constrained by two limiting factors, either the nitrogen treatment capacity of the bio-filter, or the density of fish. However, such recirculating system differs from most fish culture systems by the fact that the environment (temperature and water quality) are highly controlled and stable. In most open production systems, such as sea cages, fish are exposed to seasonal variation in water temperature, and these variations can differ from one location to another. Temperature has a major impact on farm management and productivity for two main reasons. Firstly, fish are poikilothermic animals, implying that their metabolic activity and growth depend on ambient water temperature. Secondly, changes in water temperature generate variation in oxygen supply because warmer water can hold less dissolved oxygen which is vital for fish growth (Thetmeyer et al., 1999; Pichavant et al., 2001).

Therefore, we decided to investigate a sea cage system producing sea bass (*Dicentrarchus labrax*) in the Mediterranean where temperature conditions differ across regions. For instance, the average temperature in south Turkey is about 21 °C, with an difference of 10.6 °C between winter and summer. In northwestern Italy, the average temperature is 18 °C and the difference is 9.5 °C (Llorente and Luna, 2013). For sea bass, growth is optimal around 24 °C (Person-Le Ruyet et al., 2004). Consequently, the time required to reach harvest weight, and therefore, costs associated with fish farming vary across regions (Gasca-Leyva et al., 2002). Llorente and Luna (2013) showed that the difference in water temperature between areas in the Mediterranean Sea is a major source of competitive advantages for fish farms. A higher annual average temperature generates faster growth and enables farmers to either produce more batches, or alternatively, bigger fish in a given production system. A lower seasonal difference is associated with less extreme summer and winter temperatures, closer to the optimum, resulting in better feed conversion ratio (Llorente and Luna, 2013). Moreover, the oxygen supply is potentially lower in south eastern Turkey than in eastern Spain (for the same level of water renewal). For sea bass, an oxygen concentration under 3.5 mg/L affects growth and causes mortality (Coves et al., 1991; Thetmeyer et al., 1999; Breitburg, 2002). Dissolved oxygen, therefore, may become a rearing constraint during the production cycle when the oxygen requirement of fish is higher than oxygen supply.

In fish farming, rearing constraints were shown to affect the economic impact of selective breeding for growth because the management strategy must be adapted to fit the change in fish performances (Besson et al., 2014). In case of sea cage farming, increasing growth will change the oxygen requirement at both individual and cage level which would imply changes in stocking management. Similarly to pasture growth in sheep farming, temperature conditions might affect the economic value of traits differently according to the location, with potential implications on the definition of breeding objectives. To our knowledge, the impact of temperature profiles on the economic impact of genetic improvement in cage farming has never been studied.

We investigated the economic impact of selection for growth rate in sea bass cages exposed to variations of water temperature inducing limitation on oxygen supply, using a bioeconomic modelling approach. Growth rate is considered the most important trait by fish farmers (Sae-Lim et al., 2012) and is consistently part of the breeding objectives. The bioeconomic model developed for recirculating aquaculture systems by Besson et al. (2014) was adapted to a sea cage system. By modelling the whole farm, we enable quantification of economic impacts from changes in management, such as stocking density, due to genetic improvement.

## 2. Materials and methods

### *2.1. Bioeconomic model in the reference scenario*

The bioeconomic model developed in R (R Development Core Team, 2008) is based on the model presented by Besson et al. (2014) to calculate economic values of growth rate and feed conversion ratio in a recirculating aquaculture system. The reference scenario of the model describes a hypothetical sea cage farm producing 1000 t of sea bass in southern France. The farm was composed of 34 circular cages of 600 $m^3$ for pre-growing and 34 circular cages of 1800 $m^3$ for on-growing. Fish were stocked in pre-growing cages at 10 g and the fish were sold at a fixed harvest weight of 400 g. Stocking took place all year round. The hypothetical farm and the bioeconomic model were based on information provided by Gloria Maris and Kefalonia Fisheries. The symbols used for different parameters of the bioeconomic model are summarized in Table 4.

#### *2.1.1. Physical parameters of sea water*

The daily temperature $T_n$ is modeled using a sinusoidal function with a period of 365 days (Fig. 1). As suggested by Seginer and Halachmi (2008), $T_n$ is given by:

$$T_n = Tm - Ta \times \sin\left(2\pi\frac{n+\phi_T}{365}\right). \tag{1}$$

n = day (1 to 365).

Tm = mean water temperature = 18 °C in the reference scenario.

Ta = amplitude of the variation = 5.77 °C in the reference scenario (corresponding to a difference of 2 × 5.77 = 11.54 °C between the maximum and minimum daily value across the whole year).

ϕT = phase shift (time-delay) = 27.36 days.

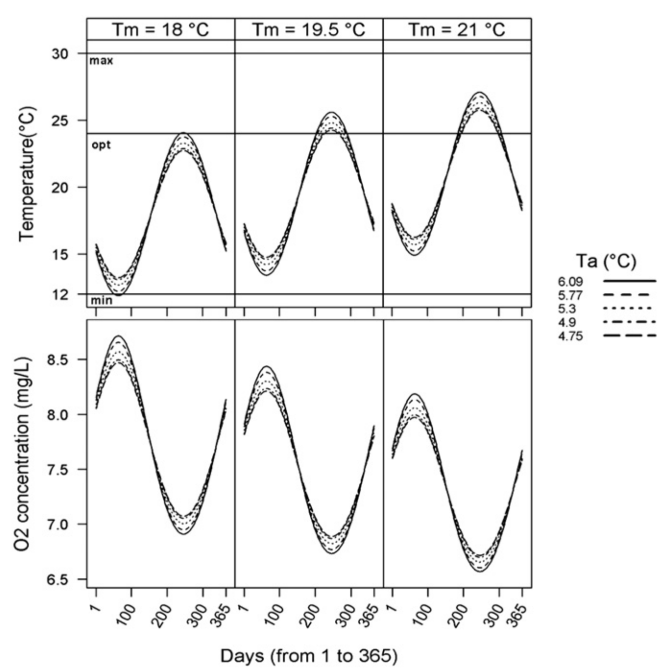


**Fig. 1.** Graphical presentation of the temperature conditions tested and the resulting oxygen concentration in sea water. Tm is the average temperature and Ta is the amplitude of the temperature. max, opt and min are respectively the maximum, optimum and minimum temperature for sea bass rearing.