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External And Internal Factors Affecting Growth and Sex Differentiation in European Eels, *anguilla Anguilla*

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ABSTRACT

Many biological and environmental aspects are involved in growth and development, including internal and external parameters and their interactions. In this mini-review, the relationship between environmental conditions and growth is described, as well as the hormones involved in growth and sex differentiation in the European eel, Anguilla anguilla. A model is proposed which describes the relationship between growth, sex hormones, environment and sex determination. Some important results that support the proposed model are presented.

Introduction

The European eel (*Anguilla anguilla*), also termed glass eel, elver eel and yellow eel, is a teleost species with a complex life cycle in both sea and freshwater environments. The European eel grows under aquaculture conditions [1,2] (Figure 1). Under natural conditions, many biological aspects of the European eel have been studied, including life cycle, spawning behavior, migration, growth and metamorphosis from larva to mature adult. The sex ratio in European eels varies considerably between localities, ranging from 0 to 100% females. The life cycle, evolution and reproduction of European eels have been reviewed in detail. Many aspects of eel growth and nutrition have been described under artificial conditions. The environment has been found to affect growth and sex determination in eels; females continue to grow, while males cease to do so. Some males weigh between 15 and 200 g. Many theoretical and applied aspects in European eel, including hormone involvement in growth and reproduction, have been explored [1,2].

Aims

In this mini-review, a potential model is presented of the relationships between environment, hormones and sex determination and their effects on growth of the European eel. The relevance of such a model, not only in providing basic information, but also with respect to aquaculture, is described.

Environmental Effects on Sex Differentiation and Growth of European eel

Under artificial conditions, high variation in growth has been found [3] (Figure 2), with density being an important growth-determining environmental factor [1].

The rapidly growing eels become females and the slow-growing eels become males [4]. High density significantly reduces growth, whereas estradiol increases growth and the percentage of females in the population [4]. The relationship between environment and sex differentiation among males and females is presented in Figure 4. Eels grow in hiding places in their habitat. The introduction of facilities that provide hiding places for eels (Figure 3) improved their growth and reduced aggression between individuals.

Hormonal Involvement in Sex Differentiation in Eel

Results of various studies have shown that sex hormones affect growth in European eel. Moreover, dietary administration of 17β-estradiol (E2) affects growth more than 17α-methyltestosterone (MT) [9]. A high percentage (70%) of females was found among European eels administered E_2 (60 mg/kg diet) [6]. Female eels grew faster than males and reached a bigger size (Figure 5). This result is supported by other studies [7,8]. A higher mRNA level

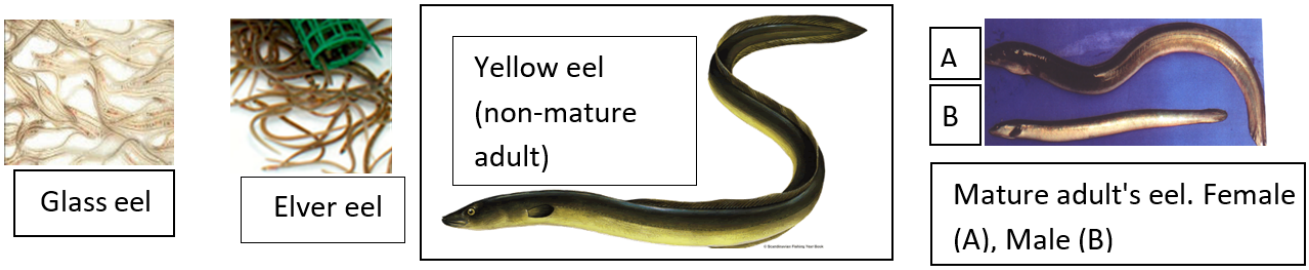


Figure 1: European eel at different stages of growth under aquaculture conditions [1].

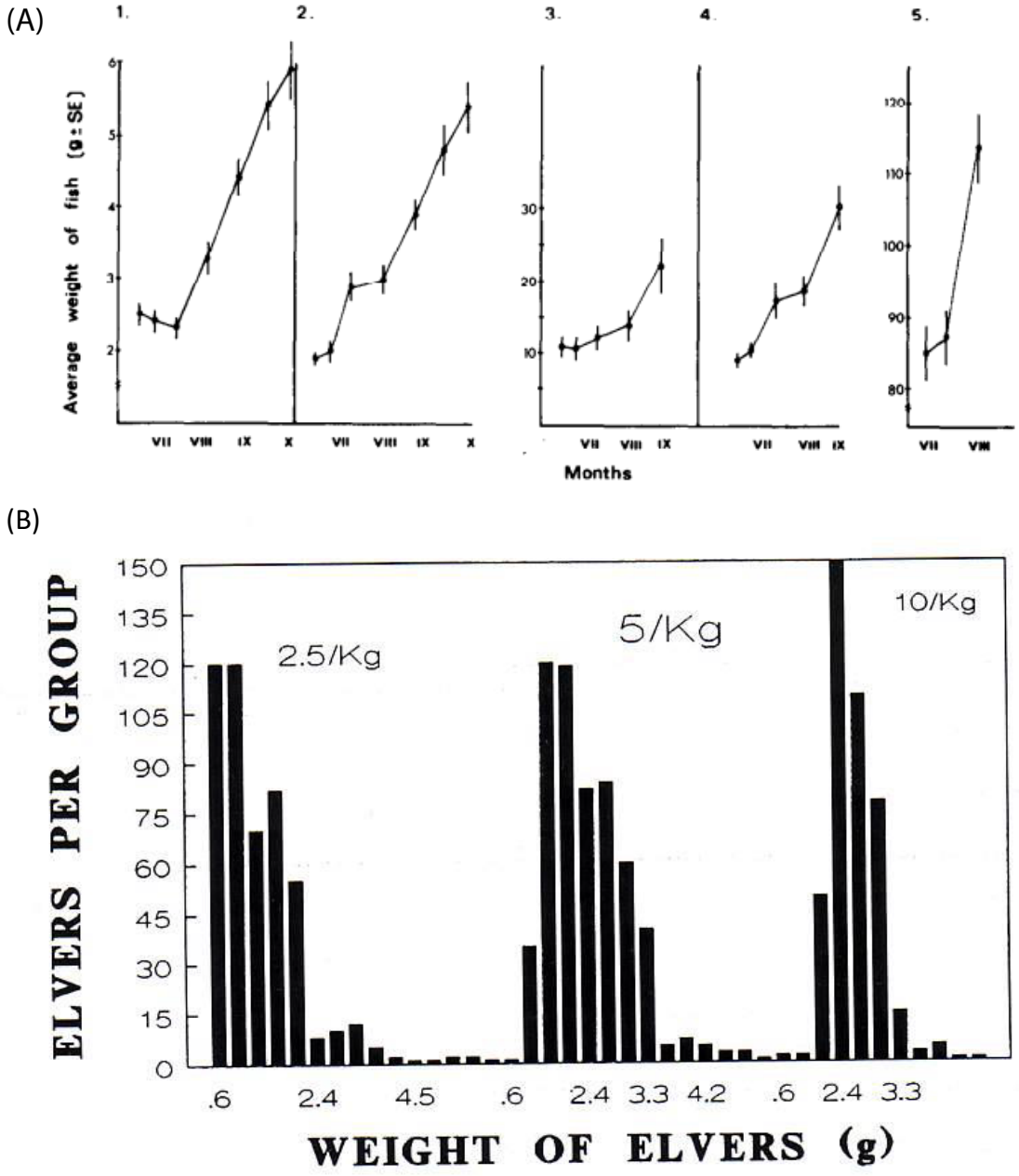


Figure 2: (**A**) Growth of eels stocked at different densities. 1, 2 – 30 kg/m3, moderate growth; 3, 4 – 4 kg/m3, slow growth; 5 – 30 kg/m2(. fast growth; (**B**) Weight distribution of elvers after 3 months of growth at various densities: 2.5 kg/m2, 5.0 kg/m2, 10 kg/m2.

of growth hormone (GH) was measured in females than in males (Figure 6) [10].

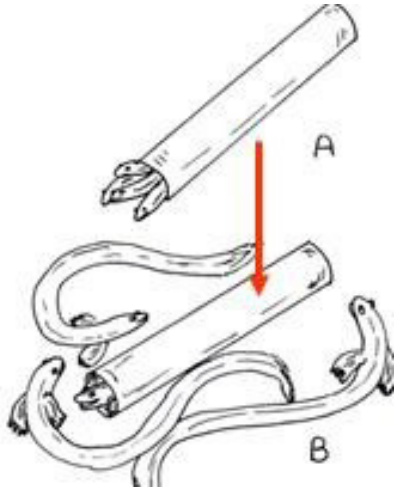
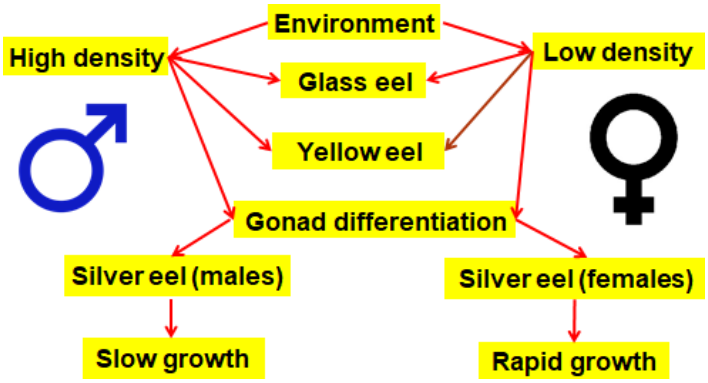


Figure 3: Development of dominance within a group of eels. (**A**) A few eels squeeze into the shelter at the start of experiment; (**B**) A single occupant, the biggest eel in the group, appropriates the shelter (Kushnirov and Degani, unpublished data).

Figure 4: Proposed model of the effect of environment and density on sex



differentiation and growth of European eels [1,3,5–8].

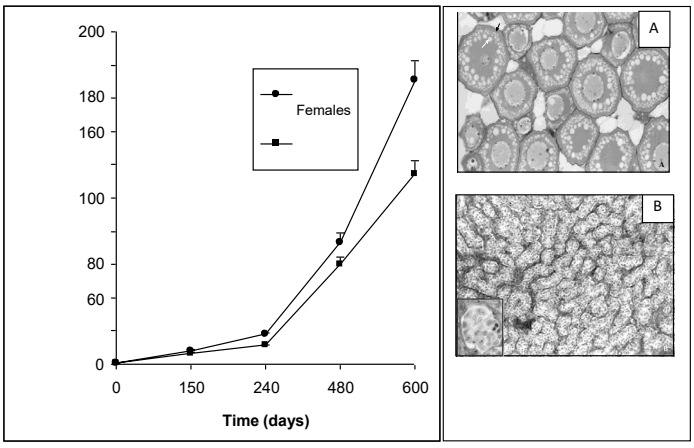


Figure 5: Female and male eel growth and gonad development. European eel gonads: (**A**) ovary and (**B**) testis [10].

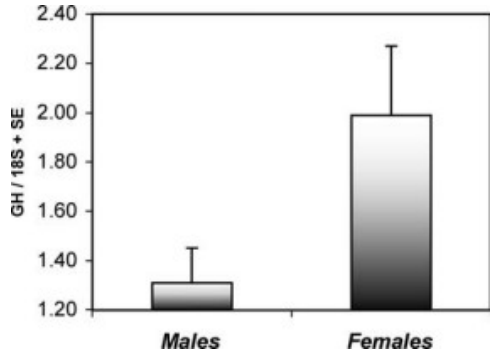


Figure 6: Growth hormone (GH) transcription in male and female *Anguilla anguilla* [10].

Follicle-stimulating hormone (FSH) controls E_2. Cloned cDNA of European eel and the mRNA level of FSH (Figure 7) [11] were significantly higher in females than in males. Moreover, gene expression of the aromatase CYP19 during the process of sex determination in adult male gonads was lower than in the adult female [7,8] (Figure 7).

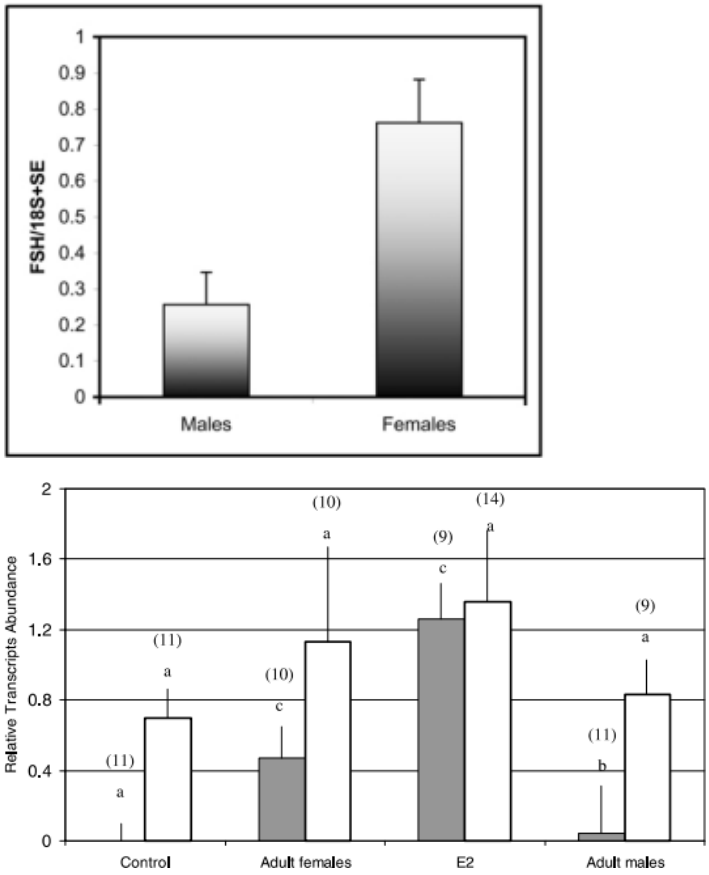


Figure 7: (**A**) Variations in mRNA level of FSH-β in male and female eels. [11]; (**B**) mRNA level of aromatase (CYP19) in male and female gonads (black bars) and brains (white bars) of European eel [7].

A model of the relationship between the complex phenomena of eel growth and the hormones involved in its reproduction is proposed, to potentially clarify the interaction between the two complex systems (growth and reproduction) and the environment (Figure 8).

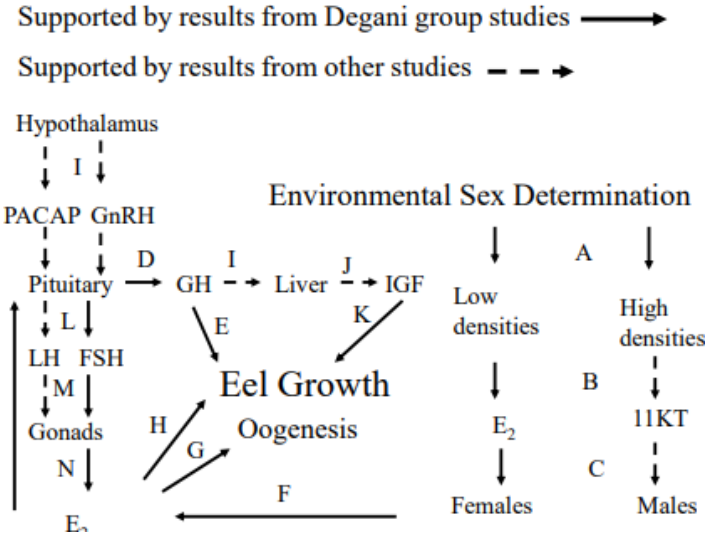


Figure 8: Model proposing hormonal involvement in sex determination, growth, gonad development and oogenesis in the European eel. E_2, 17β-estradiol; FSH, follicle-stimulating hormone; LH, luteinizing hormone; GH, growth hormone; PACAP, cyclase-activating polypeptide; GnRH, gonadotropin- releasing hormone; 11KT, 11-ketotestosterone; IGF, insulin-like growth factor [12].

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