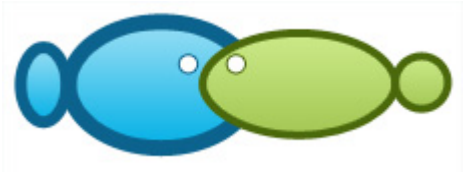

Biology, growth and parasitism of *Anguilla anguilla* in the mouth of Martil River, Mediterranean Coast, Morocco

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Abstract. This study investigates the growth and the parasitism of eels (*Anguilla anguilla*) caught in 2003 from Martil river (Mediterranean coast of Morocco). *A. anguilla* is considered as a critically endangered species listed by the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES). In Morocco, many studies of eels were carried out in Atlantic coast, therefore this investigation will focus on studying eels found in Mediterranean Moroccan coast. The biometric parameters data of eels show a positive correlation between th weight and the size specimens. The results also revealed a sex ratio in favor of females. The otolithometric analysis of sagittae show positive correlation between the small diameter (d) and the large diameter (D) of sagittae and size of these eels. More than half of eel samples (52%) were infested by the nematode parasite *Anguillicoloides crassus*, silver eels were more infested (prevalence between 86 and 100%), that could compromise the success of their spawning migration to Sargasso Sea.
Key Words: biometric parameters, otholitometry, sex-ratio, *Anguillicoloides crassus*, prevalence.

Introduction. Morocco is currently at the southern limit of eel (*Anguilla anguilla* L.) distribution (28°N at Dr'a river) (Qninba et al 2011), which means that this source is extremely vulnerable and facing eel extinction. "In the absence of security measures for protecting eels in Morocco, this fish species could follow a probable disappearance like Moroccan Shad (*Alosa alosa*)" (Yahyaoui et al 2004).

A. anguilla is a catadromic fish species with its spawning area thousands of kilometers away in the ocean, the Sargasso Sea. Silver eels leave the continental rivers at different times, depending on lunar phase and atmospheric conditions. Then they are assumed to swim southward using the Canary and North-Equatorial currents and arrive six to seven months later at the Sargasso Sea to spawn and then die (Desaunay & Guérault 1997; Tesch 2003). The leptocephalus larvae are transported along the Gulf Stream and North-Atlantic Drift for a journey of six to nine months back to the eastern Atlantic coast (Lecomte-Finiger 1994; Arai et al 2000), where they metamorphose to glass eels (Tesch 2003).

Eel remains one of the most overly exploited species in Morocco. Fishing campaigns and surveys have been carried out to show that eels are still being fished even though they are at their lowest level of population (ICES 2010, 2011). However, stocks of this species are currently showing a dramatic decline (Stone 2003). The reasons for this decline are likely multiple, including climate factors affecting ocean circulation (Knights 2003) and anthropogenic factors such as water pollution conducting to the accumulation of pollutants in eel such as heavy metals and PAH metabolites (Wariaghli et al 2013; 2015), habitat reduction, and overfishing (Castonguay et al 1994; Elie 1998; Dekker 2004; Lafaille et al 2005). In this context, a better knowledge of eel biology can lead to significant improvements in current management plans of Moroccan eels (Edeline 2006). Therefore, it is very important to study the growth of eels in the mouth of Martil river (Moroccan Mediterranean coast), where no study has been undertaken.

Material and Method

Study site. Martil river (35°37' N, 5°17'W) is located in the north of Morocco at the Mediterranean coast (Figure 1).

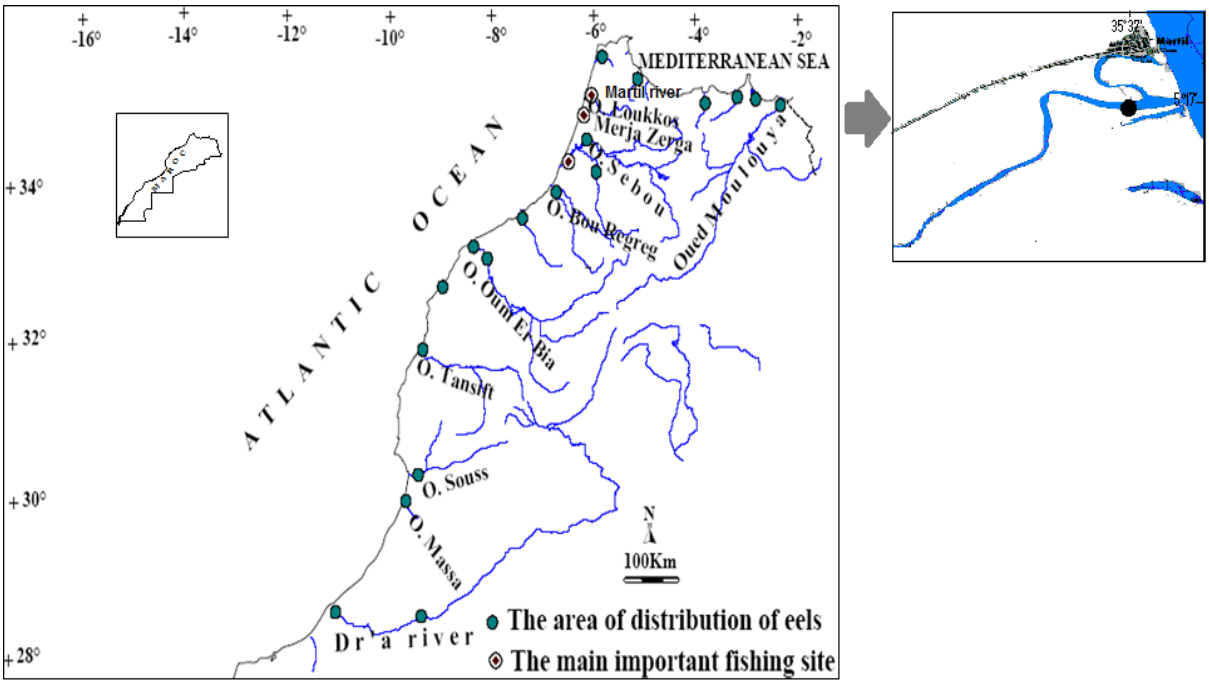

Figure 1. Location of sampling site of eels in Martil River.

The Martil watershed is draining a surface area of 1,220 km^2 and it is 22 Km long. The average annual flow is estimated to be at 19.2 m^3/s (Stitou 2002). During the periods of low water flow, Martil River is maintained by calcareous's dorsal sources, most of them are at altitudes between 140 and 1,090 m (Amraoui 1988).

The plain of Martil is represented by detrital materials with lateral and vertical variations of lithological facies. It has a surface area of 60 km^2 that goes all the way to Tetouan, Morocco. Their composition is sand and silt alluvium of the Quaternary recent. This region is known by its Mediterranean climate which is characterized by a hot and dry summer and a cold winter sometimes cold (Thauvin 1971).

Capture and examination of eels. Eels (n=100) were caught from Martil river in 2003. Fishing for eels was undertaken by fishermen using fyke nets. They were then kept at a low temperature and transported (4°C) to the laboratory, where standard length (cm) and body weight (g) data were recorded.

The swim bladder was removed and macroscopically examined for the presence of adult and pre-adult *Anguillicoloides crassus* (lumen worms). The prevalence and the mean intensity were calculated according to Bush et al (1997).

Otolith extraction and measures. Sagittae otoliths (the biggest otolith for eel) are extracted by a longitudinal incision at the posterior part of eel's head, washed with water and then kept dry. The otoliths (sagittae) are measured using a stereomicroscope with a camera and Motic Images Plus, specific software to perform various measurements on the otolith. Thus, we measured the otoliths along the large antero-posterior axis (D in mm) of the otolith and along the dorso-ventral axis (d in mm) of the sagittae (Yahyaoui et al 2004).

Results

Size. The histogram of eel's size (Figure 2) is almost unimodal showing a good distribution of the eel size. Eel's size classes can be divided into three groups: the first group of eels is less than or equal to 300 mm, the second one is between 300 and 650 mm (the most represented) and the last one is between 650 and 700 mm. The average size of this population is 456.7±100.67 mm.

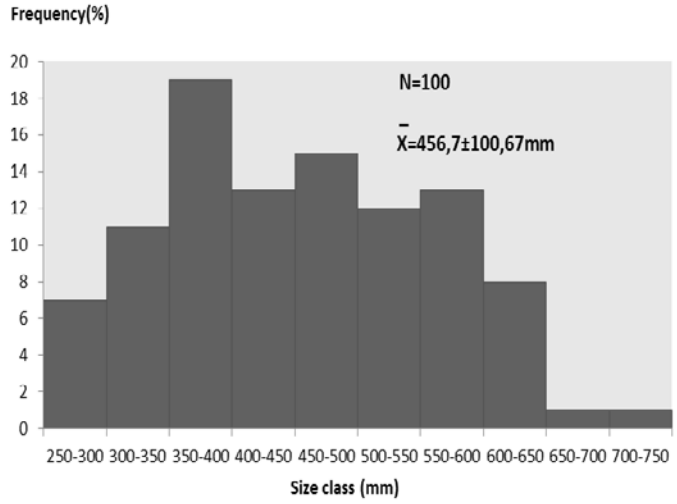

Figure 2. Distribution of size classes of eels in Martil River.

Relationship between size and weight. To study this relation, the exponential equation $P = a. L^b$ is most often used:
P: the weight in g;
a: is a constant that represents the fatness of the fish;
b: represents the allometric rate;
L: represents the total length of the fish in cm.
The correlation equation obtained is: $P = 5.10^{-4} L^{3.31}$ and the coefficient of correlation is 0.97.

We noticed also, that the rate of allometry is b> 3, which means that the weight increases faster than the cube of the length. Thus, the population studied has a higher allometry (Figure 3).

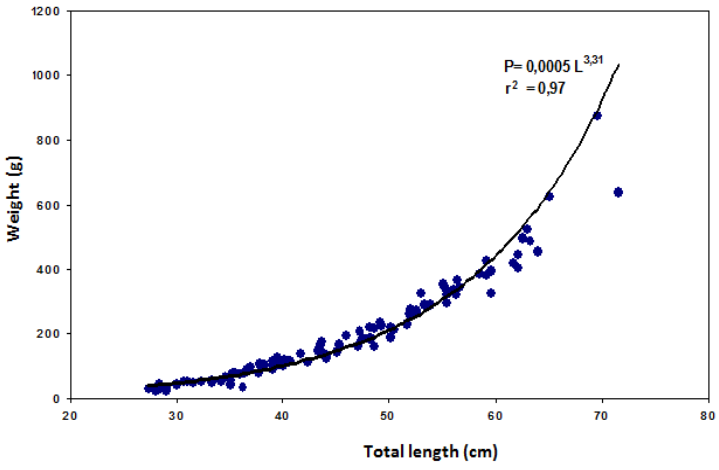

Figure 3. Relationship between weight and size of eels in Martil River.

Otolithometry. The two parameters (d and D) are interdependent. The growth of the otolith along the ventro-dorsal axis (d) and along the antero-posterior axis (D) follows a linear regression: d=aD+b.
For these eels caught from the mouth Martil River, the regression of equation is:
d = 0.46 D + 0.47. The correlation coefficient is high, in order of 0.85.
The linear regression equations used in this study model the relationship between the large diameter of the otolith (D in mm) and the small diameter of the otolith (d in mm) as well as the size of the eel (L in cm) are: D = a L + b and d = a L + b.
The equations obtained are as follows:

D = 0.05 L + 0.6, the correlation coefficient equal to 0.74
d = 0.02 L + 0.57, the correlation coefficient equal to 0.76

Relatively significant correlation coefficients were obtained in the population of eels in the mouth of Martil River (Figure 4 and Figure 5).

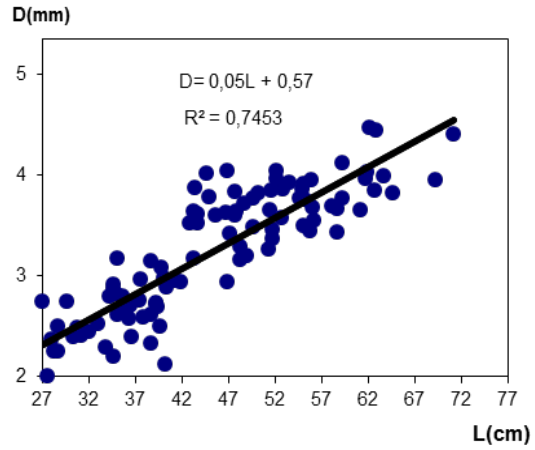

Figure 4. Relationship between large diameter (D) (mm) of eel's sagittal otolith and the total length (cm) of eels in Martil river.

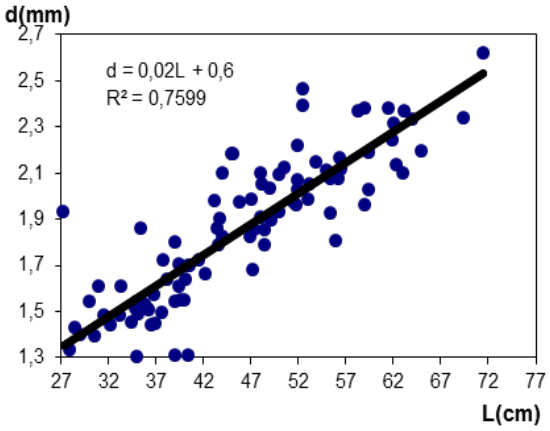

Figure 5. Relationship between small diameter (mm) of eel's sagittal otolith (mm) and the total length (cm) of eels in Martil river.

Distribution of size classes according to sexes. Among the 100 eels examined, we observed the predominance of female over male eels. Indeed, they represent 100% of eels that measure 45 cm in size.

Parasitology

Prevalence and the degree of infestation. The results of epidemiological analysis showed an infestation of eels by *A. crassus* caught in the mouth of Martil river. Of the 100 eels examined, 52 eels are infested by this parasite.

256 nematodes were found in their swim bladder. Hence the prevalence is 52% (Figure 6); half of this eel population is infested.

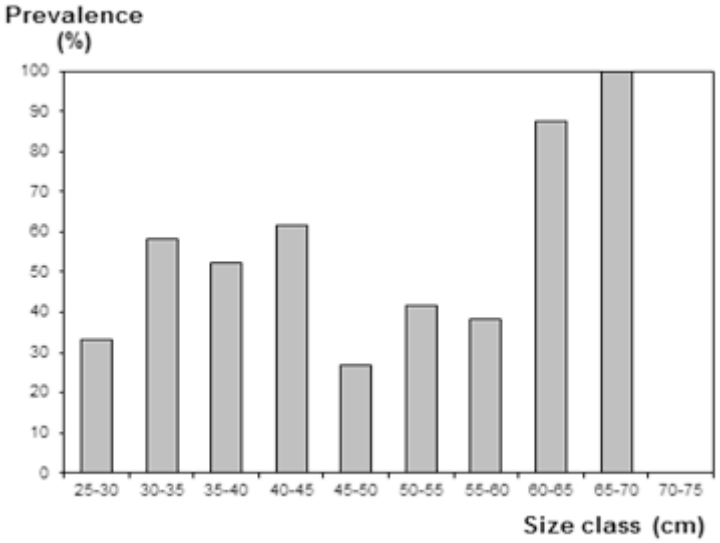

Figure 6. Prevalence of *Anguillicoloides crassus* according eel size classes.

The degree of infestation calculated is 5.09 parasites per parasitized eel while the abundance reaches 2.65; an average of about 3 parasites per eel.

The majority of the population is infested, with an average of 6 parasites per eel. The degree of infestation or the average parasite intensity shows fluctuations within different size classes. The maximum number of parasites that is of the order of 9 parasites is observed in size eels (55-60 cm).

Discussion

Growth and allometry. Growth is certainly the best-known aspect of fish biology, and the variability of growth (individual or annual) within populations is also considerable (Philippart 1975). The potential for variations, i.e. adaptation, of linear and weight growth are related to several factors, the extreme lability of the diet is among the main factors that contribute to the remarkable ability to adapt to trophic conditions.

The population of the mouth of Martil river is composed mainly of medium to large-sized individuals (P = 207.1 g and L = 45.67 cm). In Moulouya, Yahyaoui (1991) found values comparable to those of the mouth of Martil river (L = 45.55 cm and P = 210.09 g). Similarly, in the same site (Moulouya estuary) El Hilali (1998) recorded mean size and weight values respectively of L = 44.4 cm and P = 167.58 g. The same author also, found in Sebou river eels of average size of 20.63 cm and average weight of 20.64 g. This shows that the population of the Mediterranean eel is characterized by individuals of weight and size generally higher than those of the Moroccan Atlantic (Sebou), this could be related to the distance to the spawning area (Sargasso Sea).

Silver eel (*A. anguilla*) have to swim a huge distance (5000-6000 km) to attend their spawning area (Sargasso Sea). Eels require high energy reserves and low cost of transport. So, it could be hypothesized that long term swimming capacity is a major prerequisite for eel reproduction (Lecomte-Finiger 1983).

In the context of weight- length relationship, we observed that there is a strong correlation between these two parameters. This relationship is exponential of type: $P = a L^b$. The allometric growth rate (b) of the population of Martil River is greater than 3 (b = 3.31), which means that the weight growth is proportionally faster than the linear growth in this population. This was confirmed by many studies that have always found that the allometric growth rate greater than 3. Yahyaoui et al (2004) found in Rhin River an allometric rate of 3.11, El Hilali (1998) noticed a rate of 3.09 at Moulouya, 3.39 at Sebou and 3.03 at Laou rivers in Morocco.

Otolithometry. Sagittal otolith of eels changes shape and increases in size during fish growth (Yahyaoui 1991). Sagittae growth is achieved by successive centrifugal addition

of concentric layers of organic (calcium carbonate) and inorganic material around its nucleus (nucleus). Several authors have shown that the relationship between the size of the large diameter (D) and the small diameter (d) of the otolith and the total length of the eel is summarized in these equations: D = aL + b and d = aL + b.

Indeed, the growth of these two parameters D and d follows the total length of the fish. The present study has shown that there is a strong correlation between the size of the otolith and the total length of the fish with a coefficient of 0.74 for a large diameter and 0.76 for a small diameter. El Hilali (1998) noticed in the Moulouya River (Morocco) correlation coefficients close to ours (0.71 for D - L and 0.69 for d - L).

For the relationship of weight and otolith diameters, there is a weak correlation between these two parameters, suggesting that weight gain is not parallel to otolith growth. In other words, the heaviest individuals are not necessarily the oldest.

Parasitology. In addition, we found out that the eels of Martil River were heavily infested by *A. crassus* (present study). The recorded prevalence is 52%, compared to 55% in Moulouya River (Lachheb 1997) and 48% in the Rhine (Yahyaoui et al 2004); on the Atlantic coast the prevalence in Sebou River was 55.36% (El Hilali et al 2004).

The Mediterranean and Atlantic sites show a strong infestation with this nematode. According to El Hilali (1998) and Wariaghli & Yahyaoui (2018), the introduction of this parasite into Moroccan freshwater is probably due to the importation of alevin from three carp species originating from Bulgaria and Hungary to control the eutrophication of dam lakes and against invasive vegetation of irrigation canals, since carp are potential paratenic hosts of this nematode, migratory birds may also be a cause of the parasite's dissemination. The degree of eel infestation in Martil River is 5.09 and the abundance is 2.65.

For the distribution of these parasites within the size classes of their hosts, we notice that medium-sized individuals are generally the most attacked (eel start their silvering stage), this in relation with their diet and their nutrition which increases with their age, at this stage. Eels need to accumulate more energy reserves on one hand, for their growth and on the other hand, to prepare to perform downstream migration. Generally, the probability of an eel being infested depends on several factors, such as salinity, temperature and life expectancy of the parasite. Indeed, the chances that a parasite will be able to survive in freshwaters decrease if the temperature and salinity of these waters are high (El Hilali et al 2004).

Conclusions. This study show that eels in the mouth of Martil River have a positive allometry (b>3). However, the health status of eels is affected; almost half of them (52%) are infested by *A. crassus*. Silver eel (>60 cm) of eel samples are totally infested, that could compromise their migration to their spawning area (Sargasso Sea). The present work consisted on a preliminary field study and need further investigations to evaluate the degree of infestation in this species (*A. anguilla*) of great economical and ecological interest in Moroccan waters (estuaries, lagoon and freshwater), since these areas sustain eel stocks.

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