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GROWTH OF EUROPEAN EEL IN A TURKISH RIVER AT THE SOUTH-EASTERN LIMIT OF ITS DISTRIBUTION

Şükran. Yalçin-Özdilek*, Aysun. Gümüş†, Willem. Dekker**

*Çanakkale Onsekiz Mart University, Education Faculty, Anafartalar Campus, 17100 Çanakkale, Turkey.
†19 Mayıs University, Faculty of Science and Letters, Biology Department, 55139 Kurupelit Samsun, Turkey.
**Netherlands Institute for Fisheries Research PO Box 68, 1970 AB Ijmuiden, the Netherlands
Corresponding Author: Dr. Şükran Yalçın-Özdilek Çanakkale Onsekiz Mart University, Education Faculty, Anafartalar Campus, 17100 Çanakkale Turkey
Tel. 90 286 217 13 03, Fax. 90 286 212 07 51, Email: yalcin.ozdilek@gmail.com

Abstract: European eel, *Anguilla anguilla* L., has a wide distribution from polar to arid climates. The growth and sex in eels from the River Asi, which is in the most arid region of the species distribution, and at a temperature of 21-27 ºC close to the experimentally determined optimum for the eel were examined. A total of 315 European eels were collected between January 1997 –May 1998 and April 2003. Growth was fast, with a high asymptotic length. Temperature is the main factor driving to growth; apparently, growth does not cease during the hot, arid summer. Since these fastest growing stocks will be of major significance for overall dynamics of the whole population, further studies of these southern eels will be required.

Key words: *Anguilla anguilla,* Asi River, European eel, growth, temperature, Turkey

Introduction

European eel, *Anguilla anguilla* L., is distributed in Northern and Western Europe, and along all the coast of the Mediterranean Sea (Dekker 2003). The eastern tip of its distribution is in the River Asi (called the Orontes in Syria), which originates in Lebanon, and drains into the Mediterranean near Antakya in Turkey. The European eel is found in Turkish rivers and streams, draining into the Mediterranean, the Aegean Sea and part of the Black Sea (Geldiay and Balık 1996; İkiz et al., 1998; Koca 2001). Within the River Asi, it constitutes the most important commercial species, used for local consumption or export. Most research on eel has focused on the European part of its distribution area (Tesch 2003). Climate in the River Asi (and most of the Asian and African distribution) differs from that in Europe, in that temperatures are considerably higher, and precipitation is largely restricted to the winter months (Hatay Directorate of Agriculture 2000). The average water temperature in the River Asi is close to the optimum for eel growth (Seymour 1984), but no field studies have been published to corroborate the temperature relation. The onset of maturation in eel (silvering) is primarily related to their length, and not their age (Vøllestad 1992). Consequently, one would expect silvering of fast growing eels to occur at a younger age. Due to a shorter life cycle, the optimal temperature regions might play a prime role in the overall population dynamics.

Over the past decades, the abundance of the eel population has decreased dramatically (Yalçın and Küçük 2002; Dekker 2000a; Moriarty and Dekker 1997; Dekker 2004a). Russel and Potter (2003) stated that the biology and population dynamics of European eel is poorly understood. Therefore, monitoring and research on eel stocks throughout Europe and the biology of this species should be investigated. There are many studies on growth of eel in fresh waters (for example; Aprahamian 1986, 1988, 2000; Carpenter

1983; Husein 1981; Naismith and Knights 1988; Barak and Mason 1992; Berg 1990; Nagiec and Bahnsawy 1990; Gordo and Jorge 1991), but the ecology and biology of eel in Turkish waters has received comparatively little attention. Information on the seasonality of silver eel migration, the size of migrating stocks in Turkey and distribution, catching devices and nutritional value (Oray 1987; İkiz et al., 1998; Küçük 1997) has been published. The knowledge about age and growth of this species within and between stocks may be important for future studies focusing on such as sexual maturation, fecundity, recruitment, migration, and etcetera. The Asi population is a part of whole eel population and when one tries to assess of age and growth data of eel populations in different regions in order to use in the management of eel, this extreme locality can not be ignored. Unfortunately, there is no record about the growth of eel in this area. The current paper presents data on the age and growth of eel in the River Asi, and compares these to the results reported from non-arid regions. These data can be useful for improving the management of the whole eel population.

Materials and methods

Study Area

The River Asi (called Orontes in Syria) drains the northern Levant. From its source in Central Lebanon, the River Asi flows north into Syria, and then bends westward into the southern tip of Turkey, where it drains into the Mediterranean Sea at Hatay (36o02'N-35o57'E) (Figure 1).

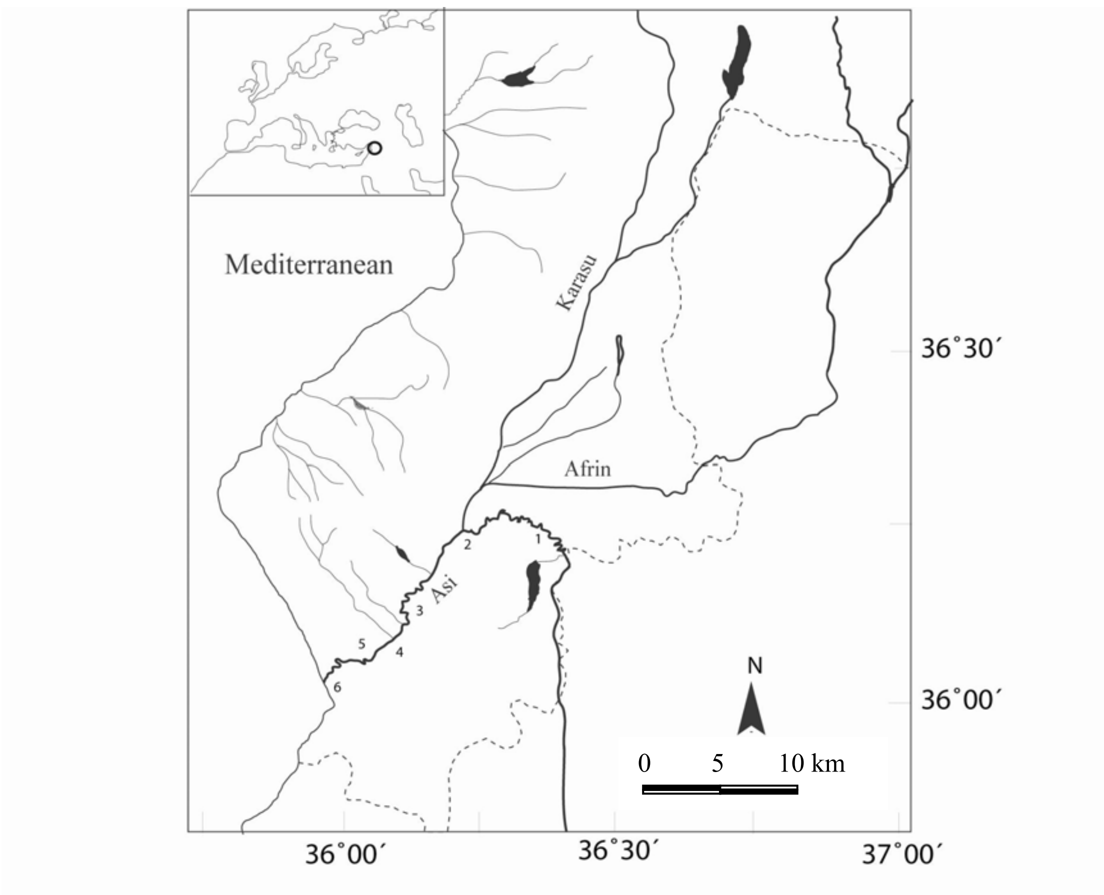

Figure 1. The map shows the area from where the specimens were collected. 1. Demirköprü 2. Güzelburç 3. Aşağıokçular 4. Şeyhhasan 5. Tavlaköyü 6. Samandağ

The river is about 380 km in length (of which 94 km in Turkey), the width and depth of the river change according to season. In the rainy season the depth of the river may increase over 2.5 m at a width of 35-45 m, while in the hot and arid summer, water depth becomes less than 1 m, with the river bed often drying up completely. Annual precipitation is approximately 400-800 mm, but rainfall is restricted to the months October to May, where the water temperatures of about 21 oC. For the remainder of the year, precipitation is less than 50 mm in total, with July and August water temperatures above 27 oC (Hatay Directorate of Agriculture 2000).

Sampling Procedure

A total of 293 specimens were collected from six localities between January 1997 and May 1998 (Figure 1) and an additional 22 specimens were caught in April 2003, using traditional fishing equipment of the local fishermen. At Demirköprü, drift nets were used, elsewhere fyke nets. The drift net consists of a rectangular frame with a 10 m long net, hung under a bridge; stretched mesh size ranges from 40 mm in the front to 10 mm in the cod-end of the net.

Individual length and weight was measured to the nearest cm and g, respectively. Sexes were determined in 124 individuals (female=90, male=34) by macroscopic examination (Sinha and Jones 1966). Otoliths of 240 eels were collected and stored dry (EIFAC/FAO 1988), and later on examined immersed in alcohol at 20-fold magnification, using reflected light against a dark background. Ages were determined from the number of alternating opaque and hyaline zones along the longitudinal axis. The listed ages refer to the number of years spent in fresh water.

Growth rates were derived from the von Bertalanffy growth equations ($L_t = L_\infty [1-e^{-k(t-t_0)}]$) and ($Wt = W_\infty [1-e^{-k(t-t_0)}]^n$) (Bagenal and Tesch 1978) fitted to the individual observations for both sexes. The weight-length relationship; $W=aL^b$, was applied, where W is body weight (g), L is total length (cm) and a and b are constants (Weatherley 1972). Length frequencies of male and female individuals were compared by Mann Whitney U-test for any significant difference. Pauly and Munro (1984)'s growth performance index (or phi-prime index) was computed from the equation: $\varphi' = \log_{10} K + 2 \log_{10} L_\infty$.

Results

The recorded minimum and maximum lengths were 6.5 and 92.0 cm. The age determination was undertaken an eel in the range of 24.9-88.4 cm total length. The mean total length with standard deviation in males and females were measured as 40.0 cm ± 7.4 and 53.7 cm ± 11.9, respectively and the mean total weight with standard deviation in males and females were measured as 146.7 g ± 93.8 and 392.4 g ± 284.3, respectively. Males were significantly smaller and lighter than females (Figure 2; Mann Whitney U-test; $N=124$, $z=-5.823$, $P<0.001$ for length; $N=124$, $z=-5.666$, $P<0.001$ for weight).

Sex was successfully determined in 121 eels and overall the male to female ratio was 0.43; at Demirköprü, (site 1) about 50 km from the river mouth, it was 0.24, and at Samandağ (site 6), in the estuary, it was 1.0.

Otolith reading indicated age ranged from 1 to 18 years. Modal age was 3 (26 %) in females, 2 (39 %) in males, and 3 (38 %) in combined specimens, including unsexed ones. Ring deposition was extremely vague in some of the otoliths, necessitating the exclusion of 1.8 % of the otoliths. In the other samples annuli were well in contrast and regularly deposited. False annuli, that are incomplete rings, were rarely observed. The low frequency of false annuli for European eel of Mediterranean estuaries was also reported by Mounaix (1991) and Panfili and Ximenes (1994).

The von Bertalanffy growth equations fitted to measurements of 68 females and 28 males, and a total of 240 eels of mixed sexes (Table 1, Figure 3). Only one each specimen were caught at the ages of 9, 10, 11 and 18. Therefore, the growth equation was calculated using only first 8 age groups specimens. The maximum length of specimen used for calculation is only 68.8 cm total length. Females grow faster than males (higher value for k) and attain a larger maximum length (L∞). The weight-length regression showed a high correlation coefficient and calculated as W = 0.0007L3.27 (n = 315, r2 = 0.96), W = 0.001L3.20 (n = 90, r2 = 0.95) and W = 0.001L3.17 (n = 34) r2 = 0.90) for all samples, females, and males, respectively

Table 1. The growth parameters calculated from von Bertalanffy equation.

	L_∞	W_∞	K	t_0	Phi prime (Ǿ)
Females	73.73	881.65	0.38406	0.486	3.32
Males	63.05	631.22	0.27547	-0.767	3.04
Both	67.57	730.74	0.37377	-0.108	3.23

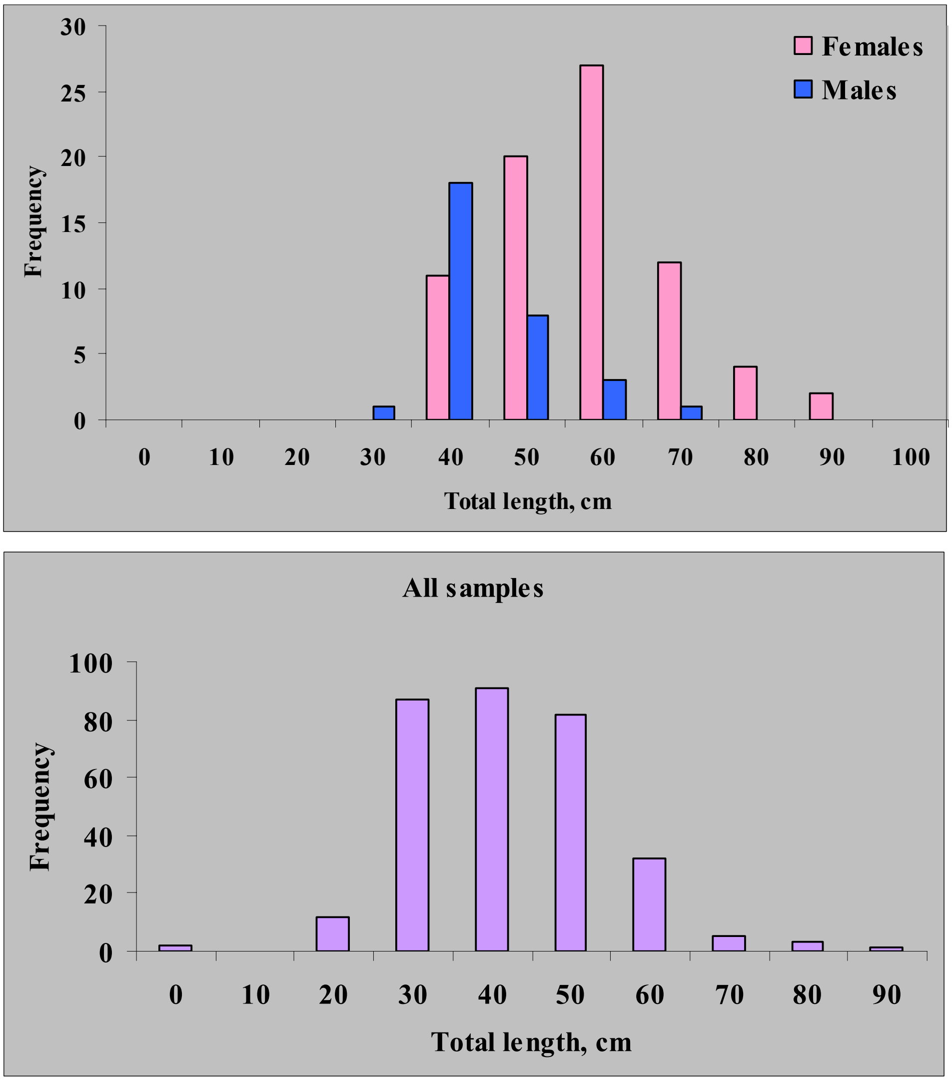

Figure 2. Length frequency distribution of females, males and pooled sexes

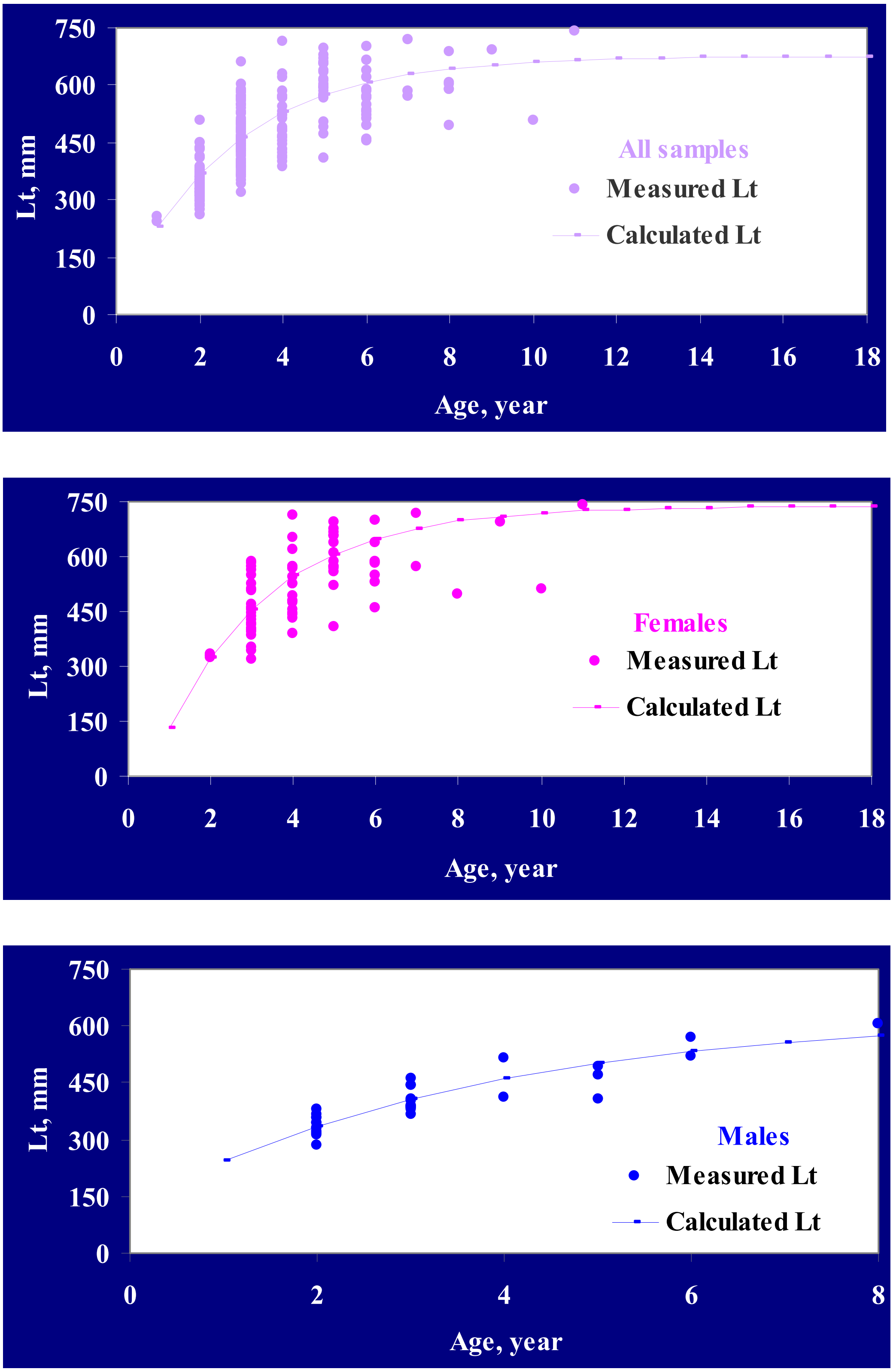

Figure 3. The measured and calculated von Bertalanffy growth curves of European eel collected from the River Asi (Lt represents total length, mm).

Discussion

Eels in the River Asi grow fast and mean growth rate was at about 13 cm per year for the modal age group and 9 cm averaged over all observations. It is believed that this fast growth is a characteristic of the local eel stock, and not an artefact of the sampling procedure. The length composition of the samples lacked eels of smaller sizes (<30 cm), indicating a probable bias in the sampling. However, the mesh size used (10 mm in the cod end, stretched mesh) allows the catch of much smaller eels (see for instance Dekker 2004b, Figure 4), down to 10 cm. Absence of the youngest and smallest eel at the inland sampling locations (about 50 km from the river mouth) seems a much more plausible explanation (Ibbotson et al., 2002).

The numbers of specimens larger than about 60 cm total length were rare in Asi population. This caused to seem low infinitive length in European eel of Asi population. It can be said that the eels over 60 cm in total length were hunted excessively in the river Asi.

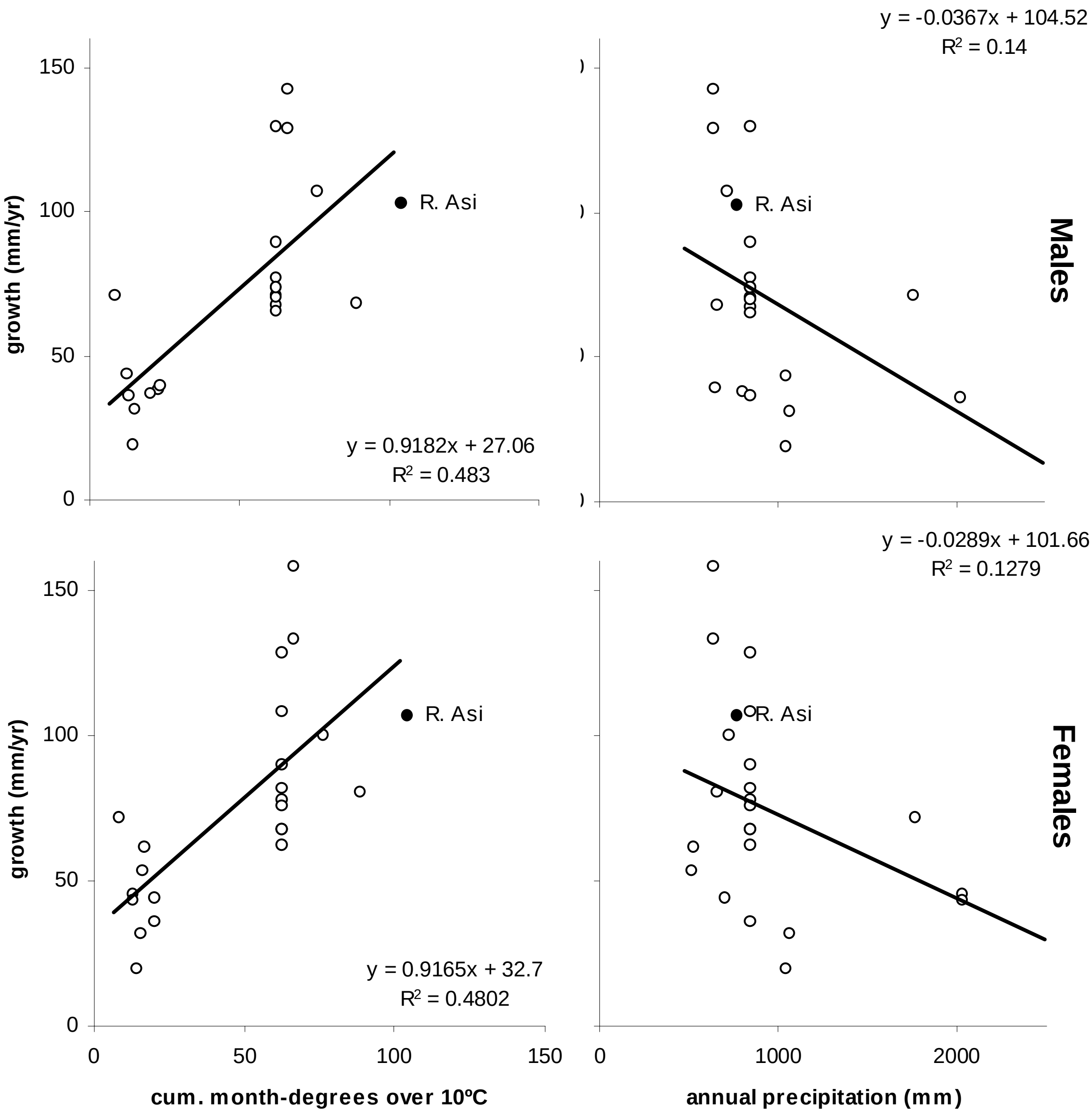

Figure 4. Relationship between growth rate and temperature (left) respectively precipitation (right), for male (top) and female (bottom) eels. Data from Cogley (1994), Vøllestad(1992), and current results. Temperature is given as the annual sum of monthly temperatures above 10ºC (Boetius and Boetius 1967).

The growth observed in the River Asi belongs to the fastest reported in the literature (Fernandez-Delgado et al., 1989; Vøllestad 1992, Fig. 4). The River Asi is the most southern observation site we know of, and probably the warmest and driest in summer (discounting the observation by Penczak and Molinski (1984) of eels at nearly 40 °C at the end of one sunny afternoon, because of the doubtful survival of their eels). Temperature and food supply are the two most often mentioned environmental factors related to the rapid growth (Rasmussen and Therkildsen 1979; Golani et al., 1988; Weatherley 1972). Optimum water temperature (26-27 °C), reported by Seymour (1984) for indoor experiments, actually occurs in the River Asi through summer and autumn. Comparison of the current results to the growth data listed in Vøllestad (1992); Figure 4 indicates, that the rapid growth in the River Asi fits reasonably to the overall relationship between growth and temperature, while the relationship between growth and precipitation rate is weak, and the data for the River Asi in an outlying position, with a fast growth at an average annual precipitation. Since the River Asi fits the general growth-temperature relation, there is no indication that summer dryness limits the growth. Apparently, growth continues during summer; the eel probably migrates into the remaining water pits, where their preys concentrate too, or migrate to deeper and cooler water, where they can sustain their growth rate. Stomach data (Yalçın-Özdilek and Solak 2006) indicate a shift in prey choice during the dry summer months, from fish to insects. However, migration further upstream will cease completely during the dry summer months. This might explain the near absence of the youngest age group in the upriver samples.

When compared to the phi-prime values of northern and southern eel populations, it can be seen that the southern populations grow faster than that of the more northerly ones. For example, while the phi-prime was recorded as 2.42 for females in Burrishoole system (9°55'W, 53°55'N) in Ireland (Poole and Reynolds 1996), it was mentioned as 3.25 for females in Sardina, Italy (Rossi et al., 1988). The phi-prime value in the River Asi (3.32) is more than these showing that the eels in the River Asi grow faster than that in many distribution areas of eel.

In contrast to the general situation (Dekker et al., 1998) that males do not reach a length above 45 cm, we found 7 individual males above that size, with a maximum length of 60.4 cm, as opposed to 68 females of 45 cm length or more. We consider that the high growth rate explains this aberrant large size of males. At a length of ca. 38 cm, the chance to become silver is approx. 50 % (De Leo and Gatto 1995; Dekker 2000b), while we estimate an annual growth of about 13 cm per year at this length. The 50 % not silvering at 38 cm will be over 50 cm one year later; and 25 % will be around 60 cm two year later; etcetera. Consequently, the length frequency is expected to drop by 50 % per 13 cm which matches our findings reasonably well (Figure 2). The extreme size of males observed thus represents a considerable overshoot of the usual silvering length, due to the fast growth.

Sex differentiation of the eel is considered to be related to environmental factors, including distance from the sea, population density, feeding conditions and temperature (Beullens et al., 1997), with population density presumably being the main factor (Sinha and Jones 1966), males dominating the dense, downstream population, and females the upstream regions (Aprahamian 1988; Barak and Mason 1992; Naismith and Knights 1993; ICES 2003). However, only 121 sample of eels' sex were determined, the current study corroborates these findings; females were predominantly found up-river, while males were concentrated in the estuarine region.

The European eel population is in decline; recruitment has been falling by an order of magnitude per generation, while fishing yield, and presumably the continental stock, has gradually declined over several decades (Dekker 2004a). Management measures to protect and restore the stock have been advised (ICES 2002; Starkie 2003). It was shown here, that growth characteristics of the eel in River Asi deviate considerably from those in Western Europe, which might be indicative for deviating characteristics in a larger part of the Mediterranean. The traditional view of the eel, being a slow growing, long-living animal (Moriarty and Dekker 1997) might not apply to the Mediterranean, while the Mediterranean stock contributes significantly to the overall production (Dekker 2003). The shorter life span might alter our view on the population dynamics considerably, especially with respect to (opportunities for) short term restoration of the stock. So far, the Mediterranean stock has been considered only marginally (Dekker 2003) in scientific and management-related initiatives to address the poor state of the stock. Further analysis of the biological characteristics of the Mediterranean eel stocks will be required, to elucidate its contribution to the common eel population.

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