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RESEARCH ARTICLE

Mean age and migration patterns of *Anguilla anguilla* (L.) glass eels from three French estuaries (Somme, Vilaine and Adour Rivers)

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Abstract. Glass eels were sampled, according to the 1991 EIFAC Working Party recommendation (Anon., 1991), in three estuaries, about 800 km apart along the French coast. Only preliminary data are presented here for the peak of immigration in February – March 1992. Biometrics, otolith structure and estimates of larval duration lead to several assumptions on the early life dynamics. Results show that: i) the body size, the otolith development and the mean age are not correlated with the latitude; ii) the migration over the continental shelf is not reflected in the otolith proportionally to the shorter distance from the shelf edge to the estuary; iii) marginal structures of the otolith could be related to the delay before entering freshwater.

Keywords: glass eel, migration, age, otolith structure, river estuaries

Introduction

Following the preliminary data presented by Lecomte (1991) on the age and recruitment of glass eels, *Anguilla anguilla* (L.), on the Eastern Atlantic coasts, from Morocco to the British Isles, the Working Party on Eel (Anon., 1991) proposed to organize a cooperative group on eel recruitment, based on a coordinated sampling programme for glass eels. Hence, the sampling of glass eels in several sites along the French coast was performed from the autumn 1991 onwards. The common hypothesis to be checked was: due to the fishing seasons and the dates of immigration of glass eels, the elvers occur in later periods at higher latitudes. Hence, it was assumed that a longer time was necessary to complete the larval migration to northern regions, leading to differences in body length and otolith structures.

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Materials and method

This scheme was tested at a 800 km range from the South of the Bay of Biscay, in the estuary of the Adour (43° 30' N/1° 30' W), down the estuarine dam of the Vilaine (47° 30' N/2° 20' W) and the first sluice of the river Somme (50° 10' N/1° 40' E) (Fig. 1). The complete series included:

- 7 samples (November 1991 – April 1992) from the Adour estuary totalling 990 individuals;
- 25 samples (September 1991 – December 1992) from the Vilaine estuary totalling 4497 individuals;

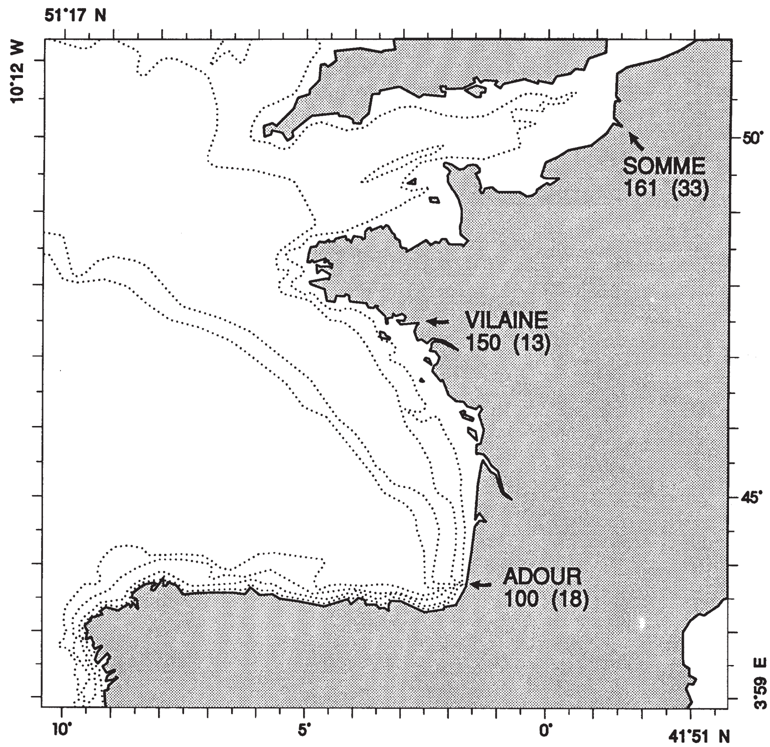

Figure 1. Location of the three sampling sites and sample size. n: number of glass eels, (n): number of otoliths.

- 3 samples (February, March and April 1992) from the Somme estuary totalling 526 individuals.

The peaks of migration observed through the fisheries were respectively February (Adour), February-March (Vilaine), and March-April (Somme). Only „peak samples" have been considered in the present paper (Fig. 1, Tab. 1), totalling 411 individuals.

Pigmentation stages were determined according to Elie at al. (1982) and to Grellier et al. (1991). Stages VB glass eels were selected for biometry and otolith examination. Samples from Vilaine and Adour were observed in freshly killed individuals whereas those from Somme were immediately preserved in 70° alcohol. Their measured length was transformed into fresh values using a correction of +1.28 mm (Guérault, pers. com.).

The otoliths were removed from a random subsample according to Lecomte and Yahyaoui (1989) method. The structure of the otoliths was described in reference to the pattern in Fig. 2, leading to the classification in three types of otoliths.

Daily rings (validated in *Anguilla japonica* larvae by Umezawa et al. 1989 and by Tsukamoto et al. 1989) were counted and their increments were measured in both zones 2 (*leptocephalus*) and 3 (*metamorphosis*), on the radius nearer to the apex.

Results

Comparative outline of samples from the three estuaries

A brief description of samples can be given based on the stage of pigmentation, the mean body size and the otolith structure to tackle the question: in what way glass eels entering the estuaries during the peak season may differ? Table 1 shows that VB „true glass eels" (Boetius and Boetius 1989) always dominated although a relatively lower value of 81% was found in the Adour sample. Sizes of glass eels and otoliths

Table 1
Characteristics of samples and otoliths from the three estuaries. LT: glass eel length. Type 3, 4, 5 refers to otolith structures. R: is the mean radius

Estuary	Adour	Vilaine	Somme
dates	18 February 1992	7 February 1992	15 March 1992
Biometry nb ind.	100	150	161
nb VB	81 (81%)	147 (98%)	136 (85%)
LT mm	67.62	70.97	66.67
(sd)	(3.4)	(3.5)	(3.2)
Otolith subsample	18	13	33
Type 3	5 (28%)	9 (69%)	27 (82%)
Type 4	5 (28%)	2 (15%)	3 (9%)
Type 5	8 (44%)	2 (15%)	3 (9%)
R µm	158.2	161.6	149.8
(sd)	(14.5)	(13.7)	(14.6)

Table 2
Mean width (R_i, µm), mean age (Ji, days) and mean daily increment (D_i, $\mu m.d^{-1}$) for larval stages (R_2 = leptocephalus, R_3 = glass eel before transition zone, $R_4 + R_5$ = transition and growth zone on the otolith margin)

	Adour	Vilaine	Somme
Otolith subsample	18	13	33
R_2+R_3 µm	153.6	159.7	148.6
J_2+J_3 days	315.0	272.1	317.6
D_{2+3} $\mu m.\ d^{-1}$	0.49	0.59	0.47
R_2	93.9	86.9	91.0
J_2	195.4	171.7	202.4
D_2	0.48	0.51	0.45
R_3	59.7	72.9	57.6
J_3	119.6	100.4	115.2
D_3	0.50	0.73	0.50
R_4+R_5 µm	4.6	1.9	1.2

were higher in the Vilaine, (by 3-4 mm in body length and 3.4-11.8 µm in radius width) than at other sites. The most „developed" otoliths (types 4 and 5) were more numerous in the South (Adour: 72%) than in Vilaine (30%) and Somme (only 18%).

As a consequence, no relationship could be established between the body or the otolith size and the structural evolution of the otoliths. Therefore, both processes of somatic growth and internal structures are not dependent. Moreover, the between sites variability relies on the presence of marginal zones 4 and 5 in the otoliths.

Comparative duration of larval phases

The second question was: Regarding the duration of larval stages up to the transition zone 4 and the mean otolith growth rate for each stage, is there any difference in the migration patterns?

The glass eels from the Vilaine estuary exhibited a lower oceanic age (272 days vs about 316 d.) in both stages (172 d.vs about 200 d for J2; 100 d vs 117 d. for J3) and higher growth rates of the otolith in both stages (Tab. 2). This would mean that the three coastal samples did not belong to the same „flux" across the

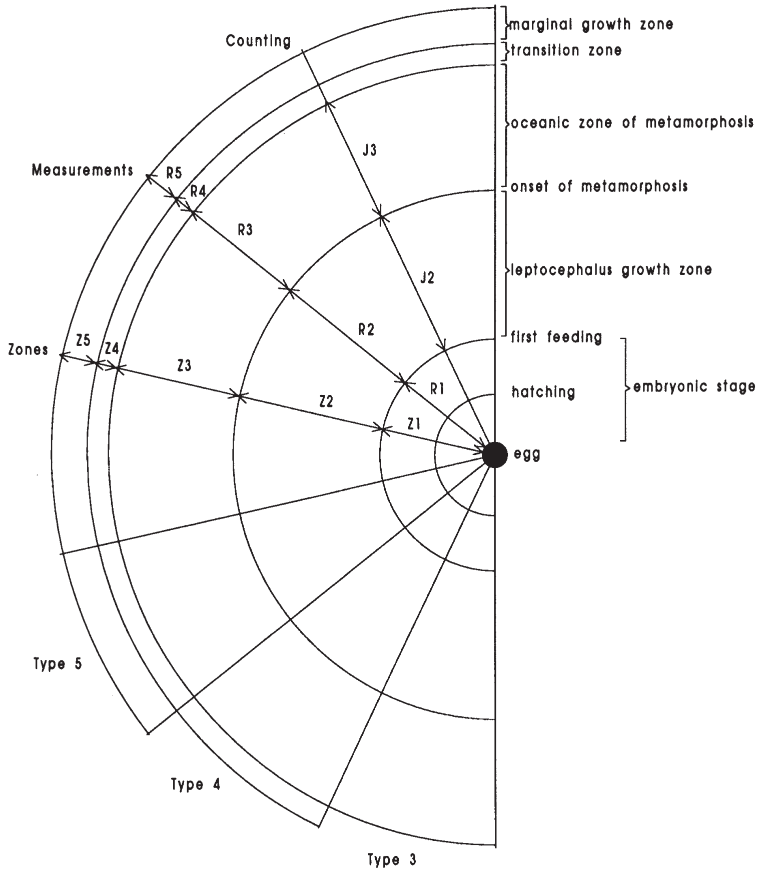

Figure 2. Otolith zoning. Terminology and stages of development identified in the otolith structures.

Atlantic ocean. Larvae reaching the north of Biscay Bay would have experienced a faster circulation in a richer environment. In addition, the radius of the o-tolith appeared a poor index of age and growth: in the Vilaine, R2 was minimum, R3 was maximum but numbers of daily rings J2 and J3 were minimum while growth rates D2 and D3 were maximum.

Discussion

Glass eels arriving at the estuary of the Vilaine differ from the others. This was not expected considering the hypothesis of a latitudinal variation of circulation, larval stage duration or body length (Lecomte 1991, Boetius & Boetius 1989, Bast & Strehlow 1990) and regarding the width of the continental shelf for every location (about 30 km off the Adour, 250 km off the Vilaine, 900 km off the Somme). There was no relationship between the width of the shelf and the metamorphosis stage duration. If we keep the picture of metamorphosing leptocephali over the shelf edge, the migration route towards a given estuary is probably not the shortest possible. The mean circulation in the Eastern Atlantic is still controversial, and seasonal variation of residual current are noticed. Krauss (1986) identified two main regions, one being the North Atlantic Drift system, with a residual current towards the North East, the other being the Subtropical Gyre, with a cyclonic circulation. Bast & Strehlow (1990) gave a good figure of wide distribution of leptocephali from the Azores area towards the European continental shelf. Between these two systems, a variable area, at the latitude of the Bay of Biscay, may be affected by one or the other. Consequently, the distribution of the drifting leptocephali may be affected, resulting in various fluxes of transformed larvae on the shelf. Pingree & Le Can

(1989) outlined the residual currents on the Celtic and Armorican slope and shelf. They demonstrated that, in addition to a poleward current on the slope, various cases existed on given areas of the shelf: a northwesterly current was dominating in the Bay of Biscay, then crossed the Channel, whereas very weak currents characterized the South of Ireland. This favours the migration of glass eels on the Biscay shelf towards the Vilaine region, and is a drawback for the larvae distributed on the Celtic shelf.

In the coastal systems this general circulation is more affected, in the short term, by tidal currents and winds as well as by fluvial discharge. This may explain the fact that the only difference between Adour and Somme glass eels lied on the otolith margin (Zones 4+5) which was wider and more frequent in the former (on the average R4+R5=4.6 µm, in 72% of individuals from Adour vs 1.2 µm and 18% from Somme). This additional structure could be related to the continental „attraction" which consisted of coastal circulation and fluvial discharge, and its size would depend on the delay before entering the estuarine waters. This point had already been stressed by Boetius & Boetius (1989) who compared glass eels from widely distributed sites in Denmark, South West of England and Bay of Biscay. Basing on the differences in biometry and energy reserves, these authors stated that „the time passing their ascent will differ much" and, according to local climate, elvers arriving in unvafourable estuaries may be „forced to stay off-shore, where they are supposed to starve".

Conclusion

Compared with the proposed EIFAC project, these preliminary results bring a limited contribution and the collected samples should be studied before confirming the present data. Considering the possibility of a wider scale sampling, particular attention should be paied to the following points:

- to collect transparent VB glass eels (stage A in Boetius & Boetius 1989) in estuarine brackish waters during and around the local peak of immigration in the same year;
- to collect meteorological data during the last 3-4 months on a regional (n. 10^2 km) scale and the last 3-4 weeks on a local scale;
- to develop cooperative data processing with physical oceanographers at pertinent spatial and temporal scales.

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