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THE IMMIGRATION OF *Anguilla anguilla* (L.) GLASS EEL IN COASTAL WATERS: QUESTIONS ABOUT THE DETERMINISM OF THE OTOLITH STRUCTURES

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A B S T R A C T. Glass eels were collected in estuarine and marine waters in the Bay of Biscay, in February and March 1992. Otoliths were examined with SEM for age and stages duration estimates. Major differences appear between successive samples of transparent glass eels (VB pigmentation stage): up to the „transition zone" the structures were similar, but the 1992 samples showed an additional marginal zone in most of the sagittae, even in transparent glass eels collected in deeper (40-60 m) offshore (60 km) waters. The ecological meaning of these final structures is complicated by: i) unknown determinism of the transition zone and ii) absence of a readable microstructure inside the marginal zone which excludes any back calculation.

Key words: GLASS EEL, COASTAL WATERS, OTOLITH STRUCTURE, DETERMINISM

INTRODUCTION

The SEM examination of eel larvae otoliths allowed Lecomte and Yahyaoui (1989) to distinguish 4 or 5 different concentric zones. These were taken to represent the successive larval stages from birth to the end of metamorphosis into elvers, then young yellow eels. Tsukamoto (1990) and Tzeng (1990) gave a very similar description of the otoliths of larval *Anguilla japonica*. The three first zones were considered to represent:

- the period from birth to the first food intake;
- the pelagic leptocephalus life;
- the oceanic metamorphosis, up to the transparent glass eel (pigmentation stage VB, according to Elie et al. 1982).

The fourth zone is the Liew's (1974) „transition zone". It is 5 μm wide zone, delineated by two deep grooves. Michaud et al. (1988) considered this structure as being the mark of a change to freshwater habitat in *Anguilla rostrata*.

TABLE 1

Sampling and observations of glass eel from the Vilaine estuary and the marine coastal area

Areas	Dates	Observations			
		pigmentation	biometry	otolith	age
estuary	from 02.07.92 to 03.24.92	681	633	25	13
marine coastal	from 01.31.92 to 03.27.92	39	27	17	10

On this basis, Lecomte and Yahyaoui (1989) assumed that: i) the internal groove was possibly the mark of the entrance into the estuarine waters (pigmentation stages VB-VIAO), and ii) the external groove was linked to the end of the starving period, when glass eel got pigmented (stages VIA3-VIA4). As a consequence, the following marginal growth zone should be encountered in elvers or young yellow eels in freshwaters, or at least in coastal waters with lower salinities. This point was to be checked in *Anguilla anguilla* transparent glass eel caught at the same time in estuarine and marine sectors.

MATERIALS AND METHOD

SAMPLING PROCESS (TAB. 1, FIG. 1)

Four samples (681 individuals) were taken from professional glass eel catches in the Vilaine estuary (Bay of Biscay, France) in February and March 1992. At the same period, three scientific cruises were carried out off this estuary, to make a general survey of the local ichthyoplancton, from the coast to the depth of about 100 m. A new suprabenthic gear, called „Zébulon" (Désaunay et al. 1991) was used to catch fish larvae within the last meter above the sea bottom. This provided 39 glass eels caught at distances between 10 and 80 km off the estuary.

BIOLOGICAL EXAMINATION

Glass eels were observed just after having been killed by an addition of tobacco into the water. Length and weight were registered as well as the pigmentation stage

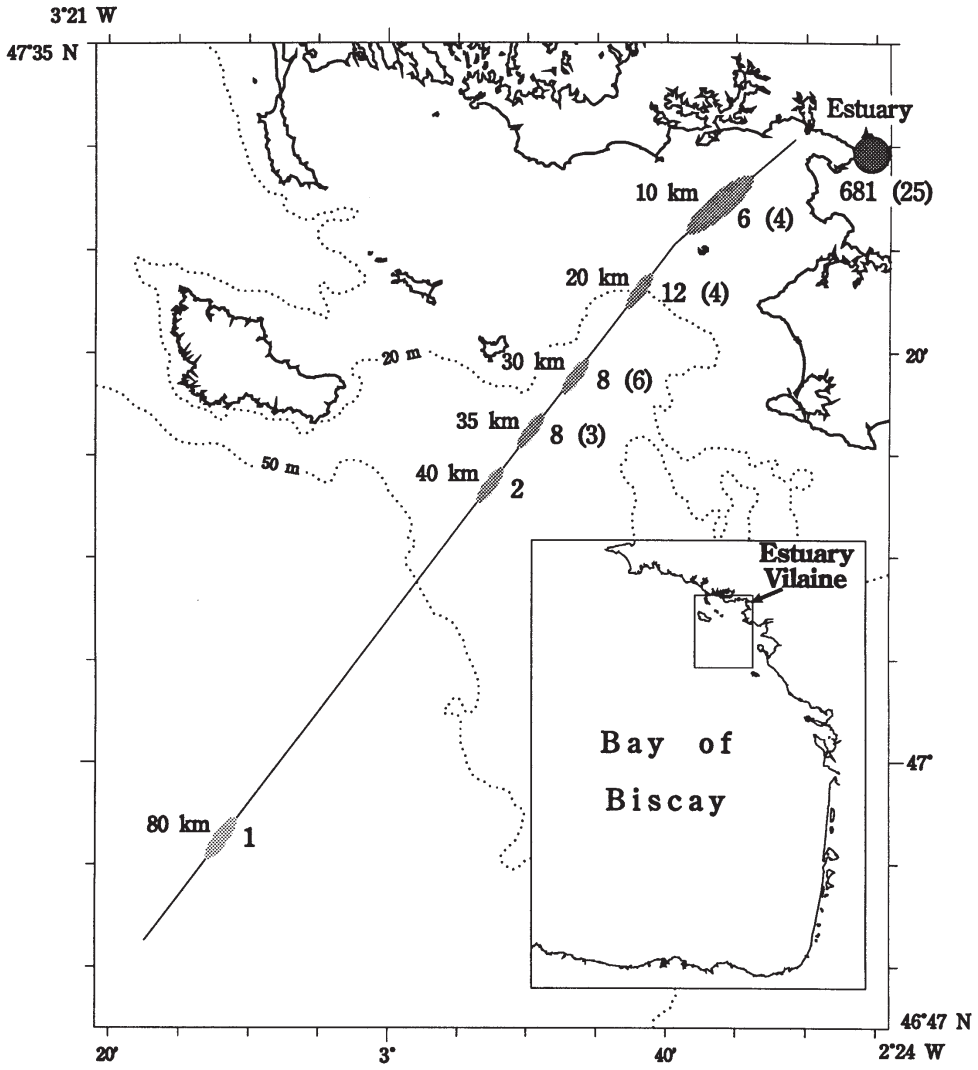

Fig. 1. Location of catches of glass eel in the coastal zone in February-March 1992. Distance from the estuary (km), n (n): number of individuals caught and aged

according to Elie et al. (1982) and Grellier et al. (1991). Samples were preserved in 70% ethanol. Subsamples of the estuarine individuals, totalling 25 VB glass eels, and 17 individuals of the marine ones were examined for the otoliths according to Lecomte and Yahyaoui (1989) method.

RESULTS

EXTERNAL FEATURES (FIG. 2)

For the whole samples, the characteristic pigmentation stage is the stage VB, with a weak number of chromatophores forming the cerebral spot and the developing caudal spot. Only less than 7% more advanced individuals were found in the estuary where glass eels were hardly longer than offshore (69.71±3.62 mm vs 65.48±3.6 mm).

OTOLITH ZONING (TAB. 3, FIG. 3)

In order to use a simplified terminology, various structures which were identified and measured are described as follows:

Five zones (1 to 5) are used. According to the presence of external zones 4 and 5 in these transparent VB glass eel the otoliths are typed as „type 3" (without external zone), „type 4" if the 4th zone is present, and „type 5" if the last 5th zone is observed. In our samples, 52% of the estuarine otoliths and 59% of the marine ones were of type 3.

- **Zone 1** is the part from the core to the assumed first feeding ring. Its average diameter was about 18 to 20 μm.
- **Zone 2**, from the first feeding to the deepest groove of the diffuse mark which is supposed to represent the begining of metamorphosis of leptocephali when arriving above the shelf edge. The overall mean width of this zone was slightly less in the estuary (88.4±11.1 μm) than in the marine individuals (97.5±8.6 μm). The daily increments were counted in this zone; this allowed to estimate the

TABLE 2

Larval life stage duration estimated for zone 2 (leptocephalus) and zone 3 (glass eel) and total age estimated without accounting for zones 1, 4 and 5

		zone 2	zone 3	zone 4+5	total age
Estuary	type 3 otolith n=13	167	104	0	271 days
	all the otolith n=25	175	92	?	>267
Coastal area	type 3 otolith n=10	189	94	0	284 days
	all the otolith n=17	190	93	?	>283

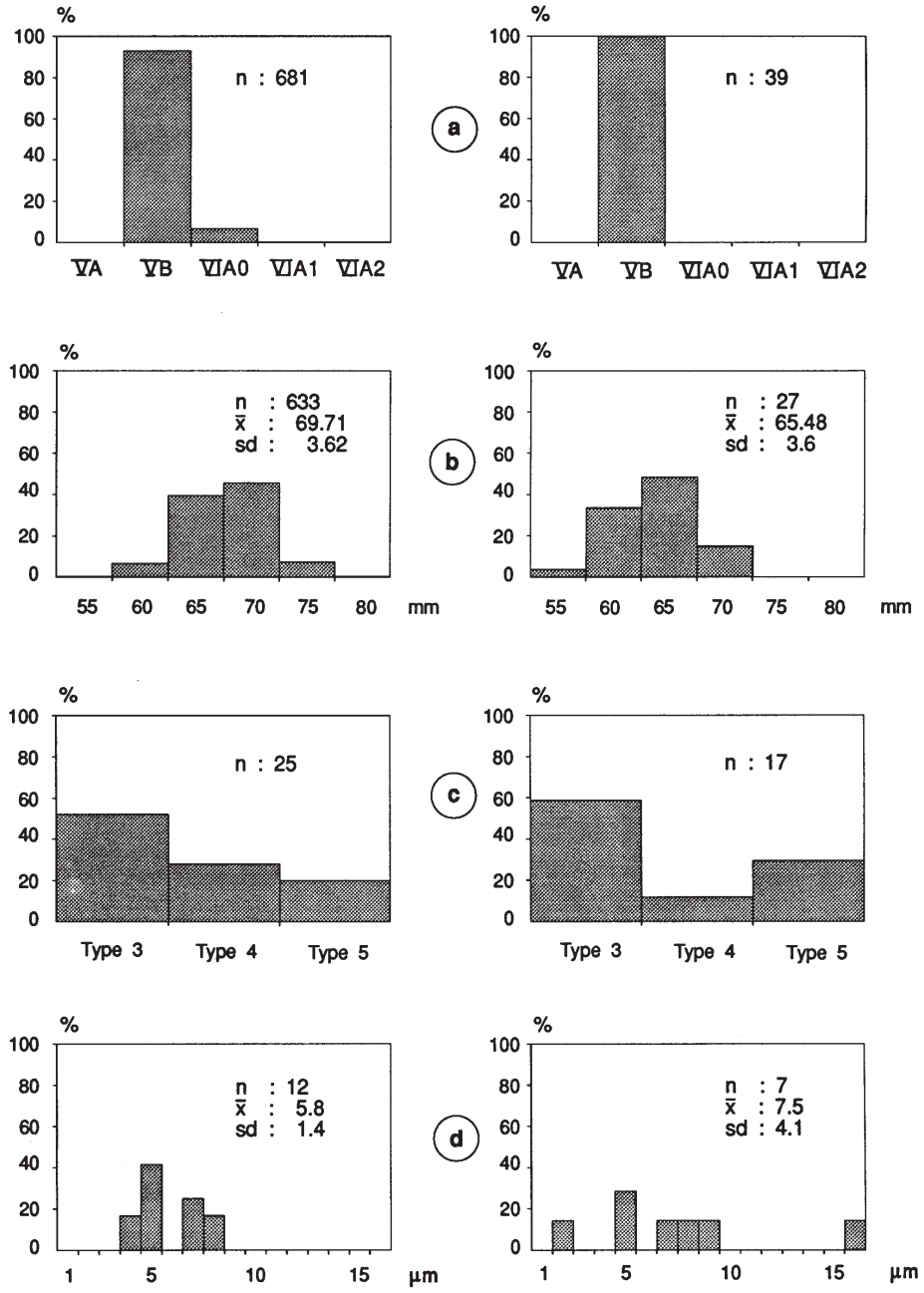

Fig. 2. Comparaison of samples from estuary (left) and the marine zone (right), a: pigmentation stage, b: total length, c: otolith frequency, d: external zones 4-5 width

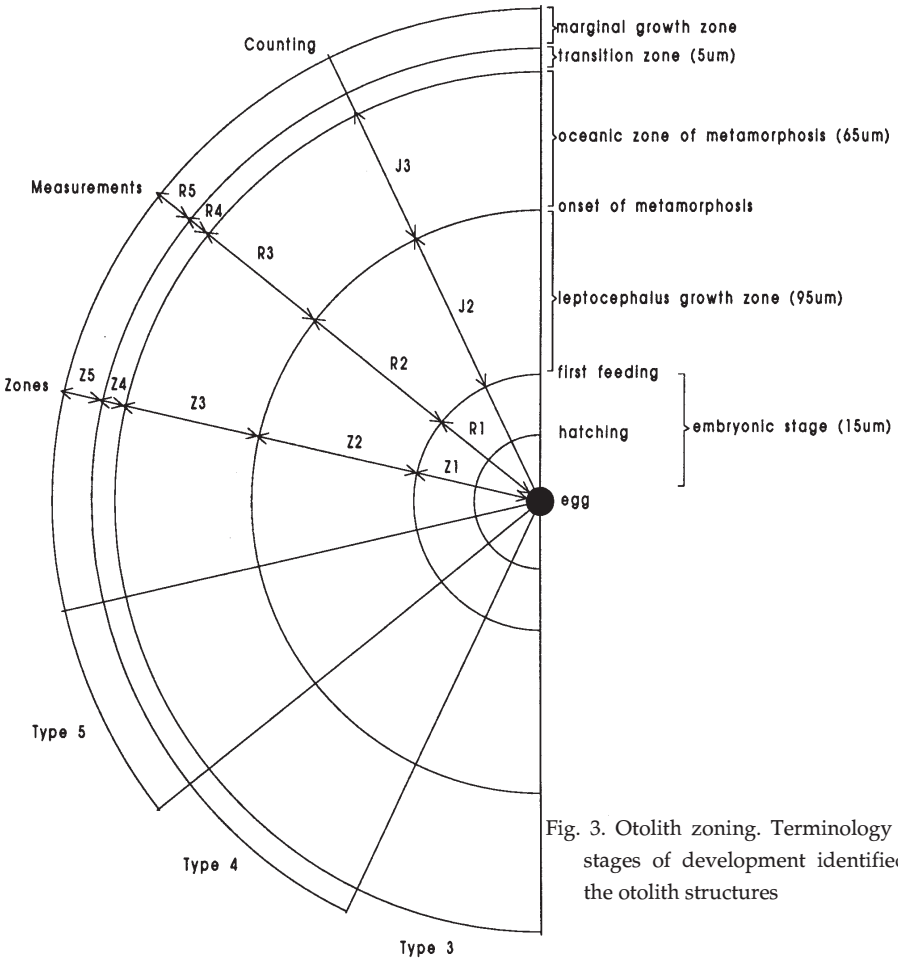

Fig. 3. Otolith zoning. Terminology and stages of development identified in the otolith structures

duration of the leptocephalus stage. No significant difference appeared in respect of the location; the mean duration varied from 174.7 days (estuary) to 189.9 days (marine sample).

– **Zone 3** is completed by the first groove of the transition double ring. It is taken as the oceanic part of metamorphosis and, thus, covers the main duration of the glass eel migration accross the continental shelf. Width and increment counting gave similar results for the both sectors: 67±15.8 μm and 92 days in the estuary; 65.9±13.1 μm and 93 days offshore.
– **Zone 4**, the so called „transition zone", is a very characteristic structure, with a constant width of 5 μm, in which it is yet difficult to identify clear incre-

ments. Respectively 28% and 12% of the estuarine and marine otoliths had their edge inside this zone.

– **Zone 5** had not been clearly identified in the previous studies of glass eel in the Bay of Biscay. It is nevertheless observed in 20% and 29% of the estuarine and marine very little pigmented individuals. It appears as a homogeneous zone, and no increment can be seen, even with SEM. The former hypothesis led to the statement that only young estuarine elvers could present this „marginal growth zone". The mean width of this zone is 5.8±1.4 μm for the estuarine glass eel and 7.5±4.1 μm for the marine ones.

As no obvious discrepancy could be established between the two sectors regarding either the total size of the otoliths, the typing of the otoliths, or the width of additional zones 4 and 5, it was assumed that these additional zones could be formed through a process which did not affet development of the pigmentation.

LARVAL LIFE AND AGE ESTIMATE

The mean duration of the total larval life can be approximated counting the daily increments in zones 2 and 3 in all individuals, whatever their otolith type. This is an underestimation of the total larval life for which one should take into account the first period before the first food intake and, when necessary, the time corresponding to the last zones 4 and 5. Thus, the minimum mean values vary between 267 days for the estuarine individuals and 283 days for those from the coastal zone. Regarding the absolute age which can be used for any back calculation, type 3 otoliths give mean values from 271 days (estuary) to 284 days (coastal area).

DISCUSSION

Previous studies of glass eel in the Bay of Biscay assumed that the development of pigmentation and the otolith microstructure grew in parallel (Lecomte and Yahyaoui 1989, Guérault et al. 1991), particularly in the case of glass eel entering the estuarine waters. Indeed, this could be confirmed by 1990 samples in which 89% of the VB glass eel had type 3 otoliths. Converesely, the recent results show that 74% of VB glass eels caught in the estuary from September 1991 to September 1992 exhibit type 4 otoliths (26,7%) or type 5 otoliths (47.2%).

The present results demonstrate that the previous hypothesis for *Anguilla rostrata* glass eel (Michaud et al. 1990) cannot be applied to *Anguilla anguilla* from the Bay of Biscay. There is no direct relation between the pigmentation stage and the setting of the „transistion zone" (zone 4). This discrepancy had not been detected in 1990 samples (Guérault et al. 1991) because of the dominance of type 3 otoliths. Moreover, transparent VB glass eel from the marine area, up to 35 km from the estuary, exhibit the so called „transition zone". It is very unlikely that about half of the glass eels could have already experienced the freshwater habitat and then drifted back to the marine deep waters. Neverteheless, uncertainties can be evocated for parts of the eel population which inhabits coastal marine sectors, at a distance from any river discharge, or even in brackish ponds on oceanic islands. The question to answer now is where and when this very characteristic structure settles. Because it is a constant 5 μm narrow zone, we can guess that it may be formed within a very short time, compared with the mean daily increments of the preceding period (0.7 $\mu m \times d^{-1}$). A new tool should be tested to tackle this point; the accuracy of the microchemical probe would perhaps fit this goal (Tzeng & Tsai 1993).

The time when the „transition zone" is formed can no more be matched with the entrance of eel into freshwaters, nor with the end of the metamorphosis, which should be contemporary to complete pigmentation and the new food intake. A possible ecological meaning of the zone 4 could refer to the duration of glass eel migration on the continental shelf. In 1990 samples, most of glass eel had no transition zone and the mean duration on the shelf was about 60 days, whereas in 1992 samples the increase of both zone 4 frequency and migration duration (96 days) appeared to be a new figure. Consequently, one can propose a hypothesis of a physiological limit of the starving period accross the continental shelf. The last zones 4 and 5 in the otoliths would then be the sign of exhaustion of the energetic reserves and the entrance into an extra period of physiological resistance.

REFERENCES

Désaunay Y., Koutsikopoulos C., Porche P & Beillois P. 1991 - Zebulon, a simple suprabenthic gear for ichthyoplankton studies over the continental shelf - Poster. ICES Statutory Meeting CM 1991/L: 52.

Désaunay Y., Guérault D. & Lecomte-Finiger R. 1996 - Variation of the oceanic larval migration of *Anguilla anguilla* (L.) glass eels from a two years study in the Vilaine estuary (France) - Arch. Ryb. Pol. 4(2a):195-210

Elie P., Lecomte-Finiger R., Cantrelle I & Charlon N. 1982 - Définition des limites des différents stades pigmentaires durant la phase civelle d'*Anguilla anguilla* L. - Vie Milieu 32 (3): 145-157.

Grellier P., Huet J. & Désaunay Y. 1991 - Pigmentation stages of *Anguilla anguilla* (L.) glass eels from the estuary of Loire and Vilaine - IFREMER RIDRV - 91.14 - RH/Nantes, France.

Guérault D., Lecomte R., Désaunay Y., Biagianti S., Beillois P. & Grellier P. 1991 - The glass eels arrivals in the Vilaine estuary (Northern Bay of Biscay) through the year 1990: Demographic features and early life history - EIFAC Working Party on Eel, Dublin, Ireland, 28 p.

Lecomte-Finiger R. & Yahyaoui A. 1989 - Otolith microstructure analysis of the early life history of the European Eel *Anguilla anguilla* - EIFAC Working Party on Eel, Porto, Portugal, 6 p.

Liew P.K.L. 1974 - Age determination of the American eels based on the structure of their otoliths - In the Ageing of Fish (T.B. Bagenal Ed.): 124-136.

Michaud M., Dutil J.D. & Dodson J.J. 1988 - Determination of the age of the young American eels *Anguilla rostrata*, in fresh water, based on otolith surface area and microstructure - J. Fish Biol. 32: 179-189.

Tsukamoto K. 1990 - Recruitment mechanism of the Eel *Anguilla japonica* to the Japanese coast - J. Fish Biol. 36: 659-671.

Tzeng W.N. 1990 - Relationship between growth rate and age at recruitment of *Anguilla japonica* elvers in a Taiwan estuary as inferred from growth increments - Marine Biology, 107: 75-81.

Tzeng W.N. & Tsai Y.C. 1993 - Changes in otolith microstructure and microchemistry of young eel, *Anguilla japonica*, during its migration from the ocean to the rivers of Taiwan - Int. Symp. Fish otolith Res. and Appl., Hiton Head, South Carolina, USA, January 1993.

STRESZCZENIE

DOPŁYW WĘGORZYKA SZKLISTEGO (*ANGUILLA ANGUILLA* L.) DO WÓD PRZYBRZEŻNYCH: PROBLEM DETERMINIZMU STRUKTURY OTOLITÓW

Węgorzyka szklistego odławiano w ujściu rzek i w przybrzeżnych wodach Zatoki Biskajskiej w lutym i marcu 1992 roku. Analizowano strukturę otolitów stosując elektronową mikroskopię skaningową i oceniano wiek ryb oraz okres trwania poszczególnych stadiów rozwojowych. Największe różnice stwierdzono między kolrejnymi partiami przezroczystego węgorzyka szklistego (stadium pigmentacji V_B). Aż do obszaru przyujściowego struktura otolitów była podobna lecz w próbach z roku 1992 stwierdzono dodatkowy obszar marginalny w większości *sagittae* nawet jeśli węgorzyki odławiano na większych głębokościach (40-60 m) i dalej od brzegu (60 km). Ekologiczne znaczenie tych dodatkowych struktur jestr trudne do objaśnienia z uwagi na: 1) nieznany determinizm obszaru przejściowego otolitu, 2) brak czytelnych mikrostruktur wewnątrz obszary marginalnego co wyklucza możliwość dokonywania odczytów wstecznych.