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Short communication

Using length–frequency analysis to determine the age of *Anguilla anguilla* (L.)

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Introduction

The European eel (*Anguilla anguilla*) is on the brink of extinction (Dekker, 2003). The population has declined markedly in recent decades, and current recruitment is < 10%, possibly even as low as 1% of the level recorded in the early 1980s. Urgent action is required to halt or at least slow the decline of this species; the loss of this resource would not only have a considerable socioeconomic impact on the European fishing communities, it would also have grave ecological and heritage implications (Baisez and Laffaille, 2005). Since 2007, the European eel has been included in Appendix-II of the Convention on International Trade in Endangered Species (CITES). To counteract the socioeconomic threat of this loss to the fishery, the European Union has adopted an action plan for the reconstitution of eel stock (Council Regulation EC 1100 ⁄ 2007, Council of the European Union 2007). To implement such management programs, the dynamics of the populations must be understood, including knowledge of the age structure. The attributes and validity of the various methods to determine the age of eels have been widely debated (see for example, Vollestad et al., 1988; Mallawa and Lecomte-Finiger, 1992; Rigaud et al., 2008). Otolith reading is the most widely used method to collect age data on eels; however, this entails sacrificing numerous individuals, particularly undesirable given the present status of the stock. Non-lethal methods of age determination are certainly preferable. One such method developed by Bhattacharya (1967) uses length histograms to analyse the demographic structures of the population. In the present study, we compared results of a population age structure by means of otolith interpretation and by length–frequency analysis.

Materials and methods

The eels used in the present study were caught in the Frémur watershed in north-western France between 1995 and 2010. The Frémur is representative of many small coastal catchments in the Biscay region. Its catchment area is about 60 km^2, which comprises some 45 km of waterways including 17 km of the main stream. Despite its small size, the Frémur contains a wide range of habitats from high-velocity streams to lentic waters, including 5 ha of running waters (streams) and 70 ha of still waters (man-made ponds and reservoirs).

A total of 7920 eels (ranging in size from 56 to 854 mm) were collected from existing eel ladders and by electrofishing in waterways within the catchment. Individual eel lengths (total length in mm) were then used to construct length–frequency histograms using class-intervals of 10, 15 and 20 mm, with the 10 mm class giving the best polynomial decompositions. These were adjusted using the Bhattacharya (1967) method, which fits normal distributions to each modal-class of the length–frequency histograms. Mean size and standard deviations for each age group were then determined using the FISAT II software (Gayanilo and Pauly, 1997).

To obtain an estimate of age, a subsample of 1183 eels (size ranges 69–783 mm) were sacrificed and the sagittal otoliths extracted. One sagittal otolith from each fish was embedded in methacrylate resin, then ground and polished until the nucleus was exposed. This exposed surface was then etched with 5% EDTA (Mounaix, 1993; Robinet et al., 2003; Laffaille et al., 2006) whereby each otolith was examined with a scanning electron microscope (JSM-6301F; JEOL, Tokyo, Japan). Two readers interpreted the resulting images, with both readers analysing the same 300 otoliths as a control to ensure consistency.

An ANOVA with a Tukey post-test was used to compare the mean size-at-age grouping obtained by the length frequency and otolith methodology.

Results and discussion

The mean length-at-age relationships obtained by the length-frequency and otolith ageing methodologies were significantly different (ANOVA: $F = 5415.3$, $P < 0.0001$). However, for each age, the length difference obtained by otolith interpretation and length-frequency analysis was generally very small (mean difference ± SD: 5.22 mm ± 3.83; Fig. 1). Mean lengths for the 0+ group obtained by the two methodologies (102 mm vs 106 mm, respectively) were the only ones to show a significant difference (Tukey post-test: $P < 0.05$). Examining the records in more detail, we found that the statistical difference between the mean sizes obtained by the two methodologies for the 0+ age group could be explained in that individuals used for otolith interpretation were essentially those collected from eel ladders, whereas those used in the length–frequency analysis were obtained by electrofishing in the river. Individuals from the eel ladders were smaller than those of the same age group in the river, because the sampling periods were different. Indeed, individuals from the eel ladder were in the middle of their growth period (April, May and June) whereas river stocks were from the end of this growth period (September). Consequently, and in light of similar results obtained in a separate study by Gordo and Jorge (1991), we concluded that it is possible to use the length–frequency analysis

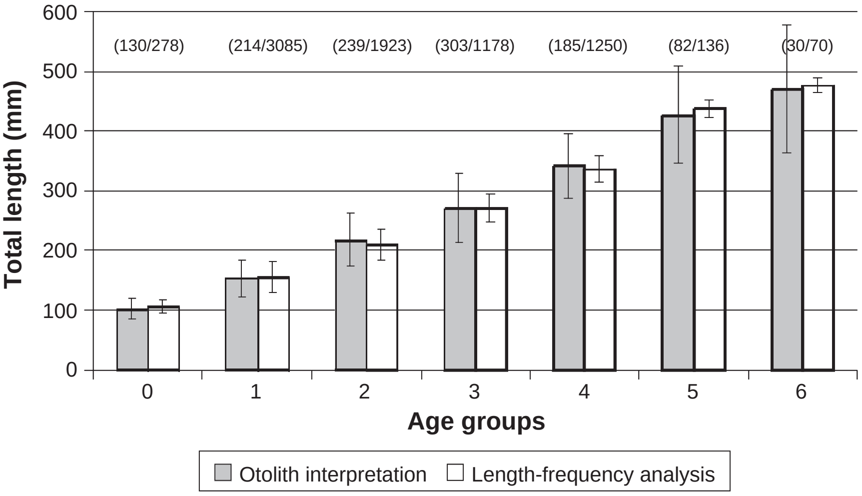

Fig. 1. Relationship between total length (mm; ±SD) and age (in years) of Anguilla anguilla calculated from otolith interpretation and length-frequency analysis. Numbers in brackets = sample size from otolith interpretation and length-frequency analysis

developed by Bhattacharya (1967) to assign size and age structures to the various eel cohorts.

Eel growth varies markedly depending on climate, habitat and sex (Rigaud et al., 2008). In this study we did not distinguish between males and females, which is impossible to do in eels <450 mm without sacrificing the individuals. This is, however, a potential problem because females can grow to a larger size than males. According to Melia et al. (2006), to describe the growth process it should be possible to calibrate three distinct models: undifferentiated eels, males, and females. In the older age groups when growth is reduced and becomes more variable, a reduction in the power of the length-frequency analysis is expected due to overlapping of age-classes. This is not too problematic for small rivers and Mediterranean lagoons where the range in age classes is rather small (Mallawa and Lecomte-Finiger, 1992; Laffaille et al., 2006; Melia et al., 2006). However, the situation may be different in catchments where growth is slower and the period in freshwater or coastal waters is much longer, such as in the Baltic and North Sea catchments.

The number of age groups obtained by otolith interpretation and length analysis examination may also differ because the latter methodology does not include sufficient numbers of large specimens since the older length classes are often rare or even absent from the population. Moreover, since Bhattacharya (1967) method is also subject to constraints (very small class interval and a sufficiently large sample), its precision is poor when applied to small populations. Consequently, for many populations the size-at-age distribution determined by an analysis of size frequency is likely to be narrower (smaller values of standard deviations) than in an otolith interpretation. Conversely, studies using otolith interpretation methods to determine the age of eels require a good knowledge of the methodology, the species, and the environment in which they live (Mounaix, 1993). Otolith interpretation is time-consuming and expensive. Furthermore, it is sometimes difficult to extrapolate otolith interpretation results for the entire population (Mallawa and Lecomte-Finiger, 1992; Mounaix, 1993).

Based on the results of a multitude of completed studies, it is clear that to examine trends in the eel population and determine the success or otherwise of mitigation measures implemented, it is essential to obtain robust population monitoring records over a period of several years, if not decades. The results of the current study indicate that once calibrated, the length-frequency analysis method developed by Bhattacharya (1967) is an effective way of studying an eel population without having to sacrifice additional individuals.

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