Point sampling the abundance of European eel (Anguilla anguilla) in freshwater areas

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Point sampling the abundance of European eel (*Anguilla anguilla*) in freshwater areas

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With 2 figures

Abstract: The European eel population is in decline. Urgent management actions are required. To monitor their effect, we developed a fast sampling method, applicable in shallow rivers and tributaries. We compared the Carle & Strub estimator from 35 double pass electric fishing samples with Point Abundance Sampling by Electrofishing or PASE (24 point samples on average by section) which we adapted for the eel. The correlation between both methods was highly significant ($r^2 = 94\%$, $p < 0.001$) for densities lower than 150 eels $\cdot$ 100 m^{-2}. PASE, being a cheaper sampling method, thus constitutes an efficient and cost-effective method for evaluating management actions and further biological studies.

Key words: *Anguilla*, stock, monitoring, electrofishing, methodology.

Introduction

The population of the European eel (*Anguilla anguilla* L.) has declined throughout its distribution range (MORIARTY & DEKKER 1997, LOBON-CERVIA 1999, DEKKER 2003). ICES (1998) recommended the implementation of a stock recovery plan, with measures addressing all inland water life stages. Several studies have attempted to estimate the size of the stocks, using methods based on fishery surveys or commercial landings data (ARDIZZONE & CORSI 1985, FEUNTEUN et al. 1998, DEKKER 2000 a). Among the many sampling methods used to assess population density (gillnets, poisoning, hydro-

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acoustics, electrofishing, etc.; see BROSSE et al. 2001), the most common technique is the depletion sample or survey removal data (COWX 1983) associated with electrofishing (COWX & LAMARQUE 1990, LAMBERT et al. 1994). However, this method is biased, imprecise (ZALEWSKI 1985, COWX 1983), time consuming and expensive in both manpower and equipment (LOBON-CERVIA & UTRILLA 1993, PRÉVOST & BAGLINIÈRE 1995). Moreover, the eel population is scattered among a multitude of streams, and each of these streams may be considered to have an independent eel population, depending on local accessibility and mortality factors (DEKKER 2000b). Monitoring eel stocks may therefore require a large number of sampling points. Since data from a large number of small random samples provide more precise estimates and are more statistically robust than those from a small number of large samples (BLONDEL et al. 1970, COPP 1990), a new sampling methodology should be proposed.

Several authors have proposed 'light techniques' to determine fish stock density, especially for salmonids (STRANGE et al. 1989, BÜTTIKER 1992, LOBON-CERVIA & UTRILLA 1993). One of the most common methods, in freshwater research, is the Point Abundance Sampling by Electrofishing (PASE) technique (NELVA et al. 1979). This rapid and cheap method provides reproducible and quantitative samples, and hence permits temporal and spatial comparisons, within and between stations (COPP 1989). We have adapted the PASE technique to the eel and propose a rapid method for estimating freshwater eel stocks in shallow rivers tributaries. This new method is validated by comparison with the standard depletion method.

Materials and methods

Study site

Samplings were conducted on tributaries of the Vilaine, in slow-flowing lowland streams, with macrophytes, and a fine gravel substrate. The Vilaine watershed covers 10 400 km², covering 1/3 of Brittany (N. W. of France). The mainly schist geology is associated with impermeable soils and causes considerable variations in river flow, with severe floods in winter and low water in summer. Most of the streams have been degraded through hydraulic re-profiling. Modification of landscape and loss of plant cover on the border of streams due to intensive agriculture have created considerable silt loads. The sampling points consisted of narrow (mean width = 3.7 m, sd = 1.66) and shallow (mean depth = 0.26 m, sd = 0.12) sectors. The habitats consisted of 15 % pools (slow-deep), 35 % glides (slow to fast-non-turbulent) and 50 % riffles (shallow and fast-turbulent).

Sampling procedures

Electrofishing was conducted in stream sections 30 m long, with a surface area about 120 m² (mean = 122 m², sd = 31.8). 35 river sections were sampled in September from

1998 to 2001. A 'Heron' apparatus was used and delivered direct current (150 to 365 V and 0.8 to 6 A).

Eels were caught during two consecutive electrofishing passes using a modified Point Abundance Sampling by Electrofishing (PASE) technique (NELVA et al. 1979). Upon arrival at each point, the anode was immediately placed on the bottom of the stream and was kept turning in an area of $1 \, m^2$ for at least 30 seconds. This duration corresponded to the minimum time for obtaining a response from the eels present near to the anode (see FEUNTEUN 1994). Fish were then collected with several fine-mesh dipnets. A total of 829 points were sampled (23.7 ± 6 per river section). Electrofishing was conducted in an upstream direction to prevent the 'contamination' of downstream samples.

This sampling design requires the presence of at least three people: the first with the electroshocker, the second with the dipnet and the third on the bank to note the results. The first pass was used to evaluate the mean density of eel by PASE (expressed as number per sampling point).

Secondly, a standardised depletion method (LAMBERT et al. 1994, FEUNTEUN et al. 1998) was used to estimate eel density (expressed as number $\cdot \, 100 \, m^{-2}$) from the CARLE & STRUB (1978) estimator with two consecutive electrofishing passes. The Carle & Strub estimator was the method that produced the more statistically reliable estimates (COWX 1983), especially for eels (i.e., LAMBERT et al. 1994, FEUNTEUN et al. 1998).

All eels caught were measured (total length, to the nearest mm), kept in tanks and released inside the sampled area immediately after the second pass.

Analysis

The mean abundance per sampling point (expressed as number of eel by sampling point) was modelled from the CARLE & STRUB density estimator (expressed as number $\cdot \, 100 \, m^{-2}$) by linear regression. This regression modelling was carried out in three steps. First, a model calibration was performed using data from the Vilaine. Second, the model was tested using a 'leave-one-out' cross validation (Jacknife procedure; EFRON 1983) to assess the prediction capabilities of the linear regression. This procedure was appropriate because the data set was quite small and/or each sample was likely to have 'unique information' relevant to the regression model (RUMELHART et al. 1986). Thirdly, the validation of our results was performed using an independent data matrix in order to determine the predictive quality of the model. We used 9 samples from the Arguenon River (northern Brittany) where a similar sampling was conducted.

All determination coefficients were used to quantify the ability of the model to produce the right answer. The Fisher F value was used to test the model significance (r^2) and t-tests were used to test the significance of the slope. A Kolmogorov-Smirnov one sample test (Lillefors option) was used to test the residual normal distribution.

Size selectiveness

PASE is known to be size-selective (COPP 1989) and especially the probability of capture by electrofishing could differ according to eel size classes (NAISMITH & KNIGHTS 1990, LAMBERT et al. 1994). The relative abundance of different fish size classes, col-

lected using the two sampling passes in the Vilaine River, were compared using a Kolmogorov-Smirnov two-sample test.

Results

A total of 1350 eels were collected. Eel densities estimated by the CARLE & STRUB method ranged between 0.43 eels $\cdot$ 100 m^{-2} and 208 eels $\cdot$ 100 m^{-2} (mean $\pm$ sd = 46.9 $\pm$ 57.3 eels $\cdot$ 100 m^{-2}). With the PASE method, eel densities ranged between 0.05 eels per sampling point and 4.13 eels per sampling point (mean $\pm$ sd = 1.23 $\pm$ 1.31 eels per sampling point). However, only two eel density data points were higher than 150 eels $\cdot$ 100 m^{-2}. Consequently, analyses were made only using densities of < 150 eels $\cdot$ 100 m^{-2}.

Using linear regression we could predict eel density (Carle & Strub – expressed as number $\cdot$ 100 m^{-2}) according to mean abundance per sampling point (Point Sampling – expressed as number per sampling point):

$$Carle \ \& \ Strub = 35.088 \pm 1.666 \times Point \ Sampling$$

The model provided good predictions of eel densities in the Vilaine river (training data set, $r^2 = 0.94$, p < 0.001; testing data set, $r^2 = 0.94$, p < 0.001) and the Arguenon river (validation data set, $r^2 = 0.94$, p < 0.001) (Fig. 1).

Total eel length ranged from 70 mm to 800 mm (mean $\pm$ sd = 219 $\pm$ 119 mm). There was no significant difference (Kolmogorov-Smirnov two-sample test, KS = 0.047, p = 0.631) in eel size distribution between eel sampling during the first and the second pass (Fig. 2).
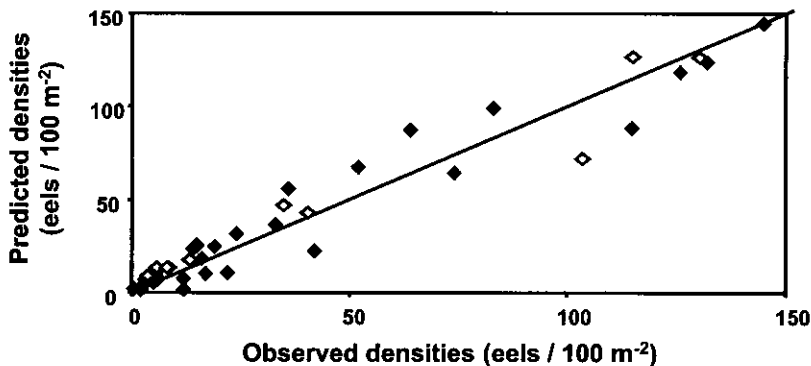

Fig. 1. Scatter plot of predicted densities (eel densities estimated by linear regression model) versus observed densities (eel densities estimated by the Carle and Strub method). Black squares = training data set from the Vilaine, white squares = validation data set from the Arguenon. The solid line indicates the diagonal of best prediction (coordinates 1 : 1).
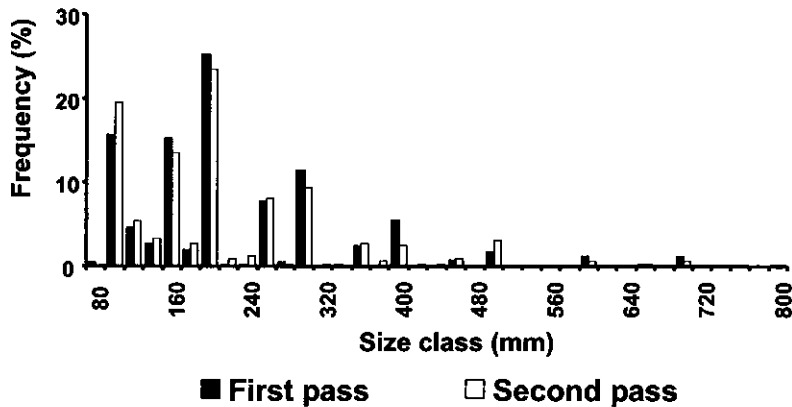
Fig. 2. Eel population structure (percentage frequency of each size class) caught during the first and the second pass.

Discssion

Cowx et al. (2001) recommended that PASE should not be used alone but in conjunction with other sampling methods (for example seine netting) to assess quantitatively the status of the 0-group fish population. However, as long as a sufficient number of samples is taken from a wide range of habitats, the size distributions in catches will be representative of the target population. Moreover, increasing sample size and stratified sampling procedures reduce the variance about mean density estimates (COPP 1989, PERSAT & COPP 1990, COPP & GARNER 1995, PERROW et al. 1996, GARNER 1997). Thus, PASE can be used to produce data pertaining to fish population parameters, such as size structure, density estimates and cohort strengths. Many authors (e. g., COPP 1989, PERSAT & COPP 1990, COPP & GARNER 1995, PERROW et al. 1996, GARNER 1997) have subsequently advocated PASE as an efficient and cost-effective method for assessing fish abundance and population structure. In a large river, PERSAT & COPP (1990) noted that with only 25 point samples, which represent a tiny area within a large stretch of river, a 'stable' image of taxocenose structure can be obtained. However, GARNER (1997) suggested that great care should be taken when interpreting data collected by PASE, and that 50 point samples is the minimum required for reliable estimates of fish density. In our study, we estimated that with 25 point samples per sector, a reliable estimate of eel density index was obtained in shallow streams. Moreover the density index was related to densities calculated from standard electrofishing procedures. The adjustment of such a relation was also emphasized by other authors concerning salmonid populations (STRANGE et al. 1989, BÜTTIKER 1992, LOBON-CERVIA & UTRILLA 1993, PRÉVOST & NIHOUARN 1999).

The validity of this index depends both on the standardization of the unit sampling effort and on the constancy of fish capturability. The standardisation of the sampling protocol (electrofishing in $1\,m^2$ for at least 30 seconds) guarantees the production of a generalized index. Moreover, the use of a single passage avoids the problems of changes in capturability during successive passages (APRAHAMIAN 1986, LOBON-CERVIA & UTRILLA 1993, LAMBERT et al. 1994).

This methodology was effective for predicting densities lower than 150 ind. $100\,m^{-2}$. Higher densities occur rarely and were generally the consequence of the concentration of small eels in sectors of riffles with a high cover of vegetated substratum (LAFFAILLE et al. 2003) or immediately downstream from migration obstructions (FEUNTEUN et al. 1998). It is time and cost effective and provided an unbiased size structure. However, the relation [number of eels per $100\,m^2$ (Carle and Strub estimator) = 35.09 ± 1.67 mean number of eel per sampling point] corresponds to a single type of electroshocker (the 'Heron' working at $150-365\,V$ and $0.8-6\,A$) working in small (mean width = 3.7) and shallow rivers (mean depth = $0.26\,m$). Other similar relations could be developed for use on a wider range of equipment and habitats.

Acknowledgements

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