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Assessment of eel stock status in Garonne and Dordogne water bodies by analysing length structures

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Summary
We analysed length structure of European eel (*Anguilla anguilla*) stocks with a simple size-structured model including a linear trend of recruitment, a linear growth curve, a negative exponential mortality and a silvering process based on a gamma function. Eels shorter than 30 cm were excluded from the analysis in order to limit effect of sex determinism, colonization process and gear selectivity. The data sets used in this study were obtained from Water Framework Directive (WFD) survey and sampling that can be assimilated to Data Collection Regulation (DCR) survey in the Garonne and Dordogne basin covering seven “WFD water bodies” (from downstream estuary to upstream tributaries). Even if the calibration remained very sensitive to parameter boundaries, this approach allowed calculation of percentages of silver eels per settled yellow eels in each water bodies. The resulting percentages obtained for each water body matched our knowledge of the corresponding anthropogenic pressure levels. The information about eel stock status provided by the present analysis urges to implement management actions in freshwater estuary compartment. This analysis also showed that the trend in mean length of silver eels between compartments can be inversed only by changing mortality and growth. This result explained why longest eels are presently produced upstream where mortality rate is the lowest even though in putative pristine conditions, they would be produced in the estuary.

Keywords: Anguilla anguilla, length structure, silvering, growth, mortality

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1. Introduction

European eel (*Anguilla anguilla*) is a catadromous semelparous long-lived fish. All available information indicates that its stock is at a historical minimum and continues to decline (ICES, 2006a). Management plan are urgently requested. Two types of target, in terms of biomass or of mortality, are usually used in fishery science (Mace et al., 1993; Caddy et al., 2004). In case of eel stock, the first one is a long-term objective (ICES, 2006b). At the contrary, mortality target, expressed as percentage of spawner per recruit, can be useful to design eel management plans.

Length structures are easily recorded in field survey and give information on the mortality level (Gulland, 1969).

We proposed a length-structured model to analyse eel length structures. We applied this model to several datasets corresponding to different ecological and management contexts met in the Gironde system. We then calculated the percentage of silver eels per settled yellow eels (%SPY), which is a part percentage of spawner per recruit. We finally outlined the difference between features and statistics of the maturation process.

2. Material and method

2.1. Material

The data sets used in this study were obtained from Water Framework Directive (WFD) survey (Lepage et al., 2005) and sampling that can be assimilated to Data Collection Regulation (DCR) survey in the Garonne and Dordogne basin (Dekker, 2005). Seven "WFD water bodies" were covered, from brackish estuary to upstream tributaries (Table 1). Mesh size of commercials pots is 10 mm nod to nod for commercial pots, stretched mesh size is 20 mm for beam trawl. Eels in tributaries were electro-fished during 38 operations in 2002.

Table 1: List of data sets

# data set	Data sources	"WFD Water bodies"	Ecological zone	Gear	Year of sampling	Number of eels measured
1	WFD	Downstream Gironde	Polyhaline estuary	Beam trawl	2005	40
2		Middle Gironde	Mesohaline estuary	Beam trawl	2005	61
3		Upstream Gironde	Oligohaline estuary	Beam trawl	2005	29
4	DCR like	Upstream Gironde	Oligohaline estuary	Commercial pots	2005	112
5		Downstream Garonne + Dordogne	Freshwater estuary	Commercial pots	2005	807
6		Upstream Garonne	Mainstream river	Commercial pots	2005	274
7	RHP	Tributaries	rivers	Electro-fishing	2002	626

2.2. Model presentation

ELSA (Eels Length Structure Analysis) is a length-structured model including an exponential trend of recruitment, a linear growth, a negative exponential mortality and a silvering process based on a gamma function.

The main feature of ELSA is to not integrate effects of sex determinism, colonization process and gear selectivity on length structure. Sex determinism in eel is influenced by environmental and social conditions (Oliveira et al., 2002). Eels shorter than 22 cm are histologically considered undifferentiated and sex orientation is definitely fixed for eel longer

then 35 cm {Colombo, 1996 #60). Telemetry tracking of eel longer than 30 cm demonstrate that individuals adopt a homing behaviour (Baras et al., 1998; Lamothe et al., 2000; Aoyama et al., 2002; Jellyman et al., 2003) except when they change home-site in responses to different factors (lack of food, insecurity) as suggested by Baras et al. (1998) or Daverat and Tomas (2006). The L_{50} of 20 mm stretched mesh size is about 30 cm (Adam, 1997).
Silver eel shorter than 30 cm for males and shorter than 50 cm are rare (Durif, 2003).
Therefore a minimal length $L_{\min} = 30 \text{ cm}$ seems to be a good compromise to be able to analyse length structure by only considering growth, silvery and mortality.

Growth

We considered different growth curves between sexes (Holmgren et al., 1996; Davey et al., 2005). We simply used a linear relationship as assumed by Sinha (1967), Barak and Mason (1992) Aprahamian (2000) for European eel, by Chisnall and Haynes (1991) and Jellyman (1997) for New Zealander eels, by Walsh et al. (2006) for Australian fish. Growth equations for females and males were written as follows:

$$L^f(a) = L_0 + g^f a$$
$$L^m(a) = L_0 + g^m a$$

with g^f and g^m the linear growth rates for female and male, L_0 the mean length of glass eels, and a the age of fish.

In the Gironde system, female growth rates were estimated to 6.7 cm year^{-1} in brackish estuary, 5.2 cm year^{-1} in freshwater estuary and 4.7 cm year^{-1} in river (Lamaison, 2005). No estimation for male were available.

Mortality

Survival rate was simply modelled with a decreasing exponential function (Beverton et al., 1957; Gulland, 1969) as follows:

$$N^f(L) = R^f_{L\min} e^{-\frac{(M+H)}{g^f}(L-L_{\min})}$$
$$N^m(L) = R^m_{L\min} e^{-\frac{(M+H)}{g^m}(L-L_{\min})}$$

where $N^f(L)$, $N^m(L)$ are the number of females and males of length L, $R^f_{L\min}$, $R^m_{L\min}$ the recruitment in $L_{\min}$ long female and male, M and H the natural and anthropogenic mortality rates in year^{-1}, constant for both sexes.

With $M^{*f} = \frac{M}{g^f}$, $H^{*f} = \frac{H}{g^f}$, the size-based mortality rates (Xiao, 2006) for females and growth rate ratio $g^{f/m} = \frac{g^f}{g^m}$, the previous equations became:

$$N^f(L) = R^f_{L\min} e^{-\left(M^{*f} + H^{*f}\right)(L-L_{\min})}$$
$$N^m(L) = R^m_{L\min} e^{-\left(M^{*f} + H^{*f}\right)g^{f/m}(L-L_{\min})}$$

Recruitment variability

We supposed an exponential evolution of recruitment according to time with the current recruitment R_0 as reference.

$$R = R_0 e^{rt}$$

where r is the evolution rate of recruitment (a negative value corresponds to a decreasing recruitment).

The number of $L_{\min}$ length fish corresponded to the glass eels recruitment recorded $\frac{L_{\min} - L_0}{g}$ years before and which has survived until $L_{\min}$ is:

$$R^f_{L\min}(L) = \alpha^f R_0 e^{-r\left(\frac{L - L\min}{g^f}\right)}$$

$$R^m_{L\min}(L) = \left(1 - \alpha^f\right) R_0 e^{-r\left(\frac{L - L_{\min}}{g^m}\right)}$$

where α^f is the proportion of females in the $L_{\min}$ length yellow eels recruitment.

With $r^{*f} = \frac{r}{g^f}$, previous equations became

$$R^f_{L\min}(L) = \alpha^f R_0 e^{-r^{*f}(L - L\min)}$$

$$R^m_{L\min}(L) = \left(1 - \alpha^f\right) R_0 e^{-r^{*f} g^{f/m} (L - L\min)}$$

Silvering

We considered silvering as a change from yellow stage to silver stage depending only on length. We assumed that the proportion of fish that have silvered before length L follows a gamma cumulative distribution function of length $\Gamma(L \mid \mu, \sigma)$ with mean μ and standard deviation σ. This type of function, unlike logistic curve usually used (De Leo et al., 1995), allows dissymmetry.

Using conditional probability theory, the proportion $\gamma(L_1, L_2)$ of fish silvering between length L_1 and L_2 $(> L_1)$ was calculated by

$$\gamma(L_1, L_2) = 1 - \frac{1 - \Gamma(L_2)}{1 - \Gamma(L_1)}$$

Computation of length structure of yellow and silver eel

Numbers of female $Y^f(L)$ and male $Y^m(L)$ yellow eels of length L were calculated combining recruitment, survival and cumulative silvering equation for each sex:

$$Y^f(L) = \alpha^f R_0 e^{-\left(r^{*f} + M^{*f} + H^{*f}\right)(L - L\min)} \frac{1 - \Gamma^f\left(L \mid \mu^f, \sigma^f\right)}{1 - \Gamma^f\left(L_{\min} \mid \mu^f, \sigma^f\right)}$$

$$Y^m(L)=\left(1-\alpha^f\right)R_0 e^{-g^{f/m}\left(r^{*f}+M^{*f}+H^{*f}\right)(L-L\min)}\frac{1-\Gamma^m\left(L\mid\mu^m,\sigma^m\right)}{1-\Gamma^m\left(L_{\min}\mid\mu^m,\sigma^m\right)}$$

Numbers of female $S^f(L)$ and male $S^m(L)$ silver eels of length L were calculated considering the proportion of yellow eels of length $L-1$ which survive until L and mature between $L-1$ and L:

$$S^f(L)=Y^f(L-1)e^{-\left(M^{*f}+H^{*f}\right)}\gamma^f(L-1,L)$$
$$S^m(L)=Y^m(L-1)e^{-\left(M^{*f}+H^{*f}\right)g^{f/m}}\gamma^m(L-1,L)$$

Computation of the percentage of silver eels per settled yellow eels (%SPY)

The percentage of silver eels per settled yellow eels %SPY is a part of the eel mortality management target expressed in percentage of spawner per recruit. %SPY for females, males and both sexes were calculated with the ratio of simulated production of silver eel by the production of silver eel when anthropogenic mortality rate is null.

$$\%SPY^f=100\frac{\sum_L S^f\left(L\mid H^{*f},\ldots\right)}{\sum_L S^f\left(L\mid H^{*f}=0,\ldots\right)}$$
$$\%SPY^m=100\frac{\sum_L S^m\left(L\mid H^{*f},\ldots\right)}{\sum_L S^m\left(L\mid H^{*f}=0,\ldots\right)}$$
$$\%SPR=100\frac{\sum_L\left(S^f\left(L\mid H^{*f},\ldots\right)+S^m\left(L\mid H^{*f},\ldots\right)\right)}{\sum_L\left(S^f\left(L\mid H^{*f}=0,\ldots\right)+S^m\left(L\mid H^{*f}=0,\ldots\right)\right)}$$

2.3. Calibration

We derived the expected value of parameters by minimizing the following square deviation

$$\sum_l\left(\bar{\pi}(l)-\hat{\pi}(l)\right)^2$$

where $\bar{\pi}$ is the observed size structure of yellow eels and $\hat{\pi}$ the size structure calculate with the model

$$\hat{\pi}(l)=\frac{\sum_{k=L\min}^{l}Y^f(k)+Y^m(k)}{\sum_{k=L\min}^{L\max}Y^f(k)+Y^m(k)}$$

Equations to compute Y^f and Y^m show that r^{*f}, M^{*f} and H^{*f} cannot be estimated separately. We then fixed the natural mortality rate to the value proposed by Dekker (2000a), i.e. 0.138 year^{-1} and the recruitment trend to -0.0649 year^{-1} according to the time series of capture per unit effort of the Gironde glass eels fisheries (Beaulaton et al., in press).

It was not possible to fit all the last seven parameters, α^f, H^{*f}, $g^{f/m}$, μ^f, σ^f, μ^m and σ^m at the same time because optimization of the objective function was sensitive to initial value of the parameters. We therefore fixed the mean silvering parameter of female and male, μ^f and μ^m, to the mean length of silver eels reviewed by Vollestad's (1992), *i.e.* 62 cm for females and 41 cm for male. We arbitrary fixed σ^f and σ^m to 10 and 5 cm to take into account the higher variability in length at maturity observed for females (Vollestad, 1992; Bevacqua et al., in press). At last, we fixed the growth rate ratio $g^{f/m}$ to 1.8, the median obtained with from our review of annual growth rate for both sexes between 30 and 45 cm (Table 2) .

Table 2: Growth rate between 30 and 45 cm for females and males from various catchments within Europe

Habitat	Stage [(1)]	Site	Data [(2)]	g^f (cm y^{-1})	g^m (cm y^{-1})	$g^{f/m}$	ref
Brackish estuary	y	Guadalquivir (Spain)	obs	7.7	2.7	2.85	(Fernandez-Delgado et al., 1989)
Brackish lagoon	y	Elbe (Germany)	obs	3.5	3.5	0.99	(Ehrenbaum et al., 1913)
	y	Alster (Germany)	obs	5.8	4.2	1.39	(Ehrenbaum et al., 1913)
	s	Comacchio (Italy)	obs	5.0	2.7	1.89	(Rossi et al., 1976)
	s	Valli Nueva (Italy)	obs	10.2	3.7	2.79	(Rossi et al., 1976)
	y	Arcachon (France)	vBm	5.0	3.1	1.60	(Lee, 1979)
	s	Lesina (Italy)	vBm	10.4	3.7	2.78	(Rossi et al., 1980)
	s	Varano (Italy)	vBm	10.6	3.9	2.72	(Rossi et al., 1980)
	y + s	Sardinia (Italy)	vBm	11.3	4.3	2.66	(Rossi et al., 1984)
	y + s	Comacchio 74-76 (Italy)	vBm	8.1	3.1	2.63	(Rossi et al., 1987)
	y + s	Comacchio 82-83 (Italy)	vBm	9.5	2.0	4.79	(Rossi et al., 1987)
	y	Comacchio 89-90 (Italy)	vBm	9.0	2.6	3.40	(De Leo et al., 1995)
	y	Camargue (France)	vBm	14.3	9.1	1.58	(Melià et al., 2006)
Freshwater river	s	Pont de Rousty (France)	obs	5.5	3.6	1.51	(Frost, 1945)
	y	Ffraw (England)	obs	4.1	4.0	1.01	(Sinha et al., 1967)
	y	Rhyd-hir (England)	obs	2.4	1.3	1.79	(Sinha et al., 1967)
	y	Glaslyn (England)	obs	2.3	2.7	0.88	(Sinha et al., 1967)
	s	Burrishoole (Irland)	vBm	1.5	1.0	1.53	(Poole et al., 1996)
Freshwater lake	y + s	Grand Lieu (France)	Gm	6.7	3.7	1.82	(Adam, 1997)

(1) y : yellow ; s : silver
(2) obs : observed; vBm: von Bertalanffy model, Gm : Gompertz model

Only sex ratio (α^f) and antropogenic mortality rate (H^{*f}) were fitted by optimization. We used bootstrap methods (Efron, 1982), as recommended by De Leo et al. (in press), for estimation of confidence intervals. 1000 replicates of sampling with replacement were performed. According to Melià et al. (2006) we used the median instead of the mean to limit the impact of extreme values.

Definition and value of Elsa parameters are gathered in Table 3.

Table 3: List of parameters used in ELSA model

Symbol	Definition	Value	Comment
$L_{\min}$	Minimum length (cm) considered in the analysis	30	Above this limit we suppose that gear selectivity is 100%, fish are settled, sex is fixed

g^f	Female growth rate (cm year^{-1})	6.7 5.2 4.7	in brackish estuary, in freshwater estuary, in river (Lamaison, 2005).
$g^{f/m}$	Ratio of female growth rate g^f and growth rate male	1.8	Reviewed in this document
r	Exponential trend of L_{min} long eels recruitment (year^{-1})	-0.0649	according to the time series of capture per unit effort for the Gironde glass eels fishery (Beaulaton et al., in press)
r^{*f}	Evolution rate of recruitment divided by female growth rate (cm^{-1})	$\frac{r}{g^f}$	To be fitted simultaneously with Z^{*f}
α^f	Proportion of female in recruitment	[0.01 ; 0.99]	To be fitted
R_0	Present recruitment		Not fitted because simplified in the objective function
μ^f	Mean of the female silvering gamma distribution (cm)	62	(Vollestad, 1992)
σ^f	Standard deviation of the female silvering gamma distribution (cm)	10	Pure guess
μ^m	Mean of the male silvering gamma distribution (cm)	41	(Vollestad, 1992)
σ^m	Standard deviation of the male silvering gamma distribution (cm)	5	Pure guess
M	Yearly natural mortality rate (year^{-1})	0.138	(Dekker, 2000a). Constant for time and sex
M^{*f}	Natural mortality rate for female (cm^{-1})	$\frac{M}{g^f}$	
H^{*f}	Instantaneous total mortally rate for female (cm^{-1})	>= 0	To be fitted simultaneously with r^{*f}

3. Results

3.1. Parameters estimation for each data set

Results of calibration are presented in Table 4. The sex ratio was in favour of female except for dataset 3 (oligotrophic estuary - DCR like).

Anthropogenic mortality rate was the highest for the dataset 4 (freshwater estuary - DCR like) and lead to a very low %SPY. For datasets 3, 4 and 7 (freshwater estuary, tributaries – RHP), %SPY, estimated to 100%, was explained by the anthropogenic mortality rates close to 0. Medium value of mortality and % SPY were observed for the last three datasets.

Sometimes, confidence interval cannot be calculated because of too many bootstrap results near the boundaries.

Table 4: Results of ELSA calibration on the 7 datasets

Data set	α^f	H^{*f}	$\%SPY$	$\%SPY^f$	$\%SPY^m$
1	0.99 [0.39 ; 0.99]	0.0246 [0.0000 ; 0.0524]	43.6 [20.9 ; 100]	47.4 [20.6 ;100]	63.5 [37.6 ; 100,0]
2	0.99 [0.50; 0.99]	0.0120 [0.000;0.0443]	47.9 [27.3;100.0]	47.7 [27.1;100.0]	64.5 [44.3;100.0]
3	0.99 [0.34 ;0.99]	0.000 -	100.0 [29.2 ; 100.0]	100.0 [29.1 ; 100.0]	100.0 [46.3 ; 100.0]
4	0.11 [0.01 ;0.35]	0.000 [0.0000 ; 0.0002]	100.0 [13.3 ; 100.0]	100.0 [10.0 ; 100.0]	100.0 [24.2 ; 100.0]
5	0.99 -	0.1013 [0.0846 ; 0..1166]	6.3 [4.5 ; 11.3]	6.2 [4.4. 9.8]	18.5 [14.9 ; 24.9]
6	0.99 -	0.0221 [0.0100; 0.0350]	51.4 [35.8; 73.3]	51.2 [35.6; 73.0]	65.9 [52.6 ; 82.1]
7	0.99 [0.51; 0.99]	0 -	100 -	100 -	100 -

3.2. Silvering statistics

We calculated the mean length of silver eels with the values calibrated for each dataset (Table 5) in current and pristine situations, i.e. with and without anthropogenic mortality. With the same silvering process (fixed in this work), for pristine situation, differences of few millimetres were calculated between silver eel mean length in different growth contexts, i.e. with natural mortality in brackish estuary (datasets 1,2,3 and 4), in freshwater estuary (dataset 4) or in rivers (datasets 6 and 7). Adding anthropogenic mortality (current situation) to natural mortality, the mean length of silver eel can be reduced of as much as 7 cm (dataset 5).

Table 5: Mean length (in cm) of silver eels calculated for the 7 datasets

Data set	female		male	
	current	pristine	current	pristine
1	59.2	61.4	40.1	41.0
2	59.7	61.4	40.2	41.0
3	61.4	61.4	41.0	41.0
4	61.4	61.4	41.0	41.0
5	54.0	61.2	38.0	40.9
6	59.2	61.0	40.0	40.8
7	61.0	61.0	40.8	40.8

4. Discussion perspective

4.1. Comparison with other length structure analyses of eel stock

ELSA could be seen as a simplification of the model proposed by De Leo and Gatto (1995): no gear selectivity, an exponential mortality rather a Weibull survival function, a linear growth rather a von Bertalanffy curve. These choices lead to save fives parameters.

We proposed a new formulation of the silvering process, which also saves one parameter per sex and which takes out the ambiguity of De Leo and Gatto formula (an annual rate depending on length for a process only length-dependent). It improves the logistic function usually used in representation of such maturation process (Heino et al., 2002), which gives information on the proportion of fish, which have matured before a length and not the proportion of fish, which mature between two lengths.

Svedäng approach (1999) is also close to ELSA. It uses a linear growth function and an exponential mortality rate. But it assumes a constant recruitment and silvering rate, equivalent to an instantaneous mortality (Sparre, 1979), similar for all lengths. Cleverly, it uses an unfished equivalent zone to estimate total instantaneous rate of mortality.
Dekker (1996) proposed an adaptation of the virtual population analysis to length structures (LVPA). Growth is also linear but stochastic and silvering rate is integrated in the natural mortality rate. The analysis of eel length structures over several continuous years leads to a backward estimation of the fishing mortality.

4.2. Evaluation of ELSA application on the Gironde system

The calibration of ELSA to actual data remained very sensitive to boundaries and initial values of parameters. In order to limit this problem, we fixed in this work the maximum of parameters, i.e. growth rate and silvering process features. We should go deeper in the mathematical knowledge of the objective function to allow more free parameters. Nevertheless, it is not sure that it will be possible to calibrate all the parameters with only a yellow eels length structure. Moreover, De Leo and Gatto (1995) combined length structures of yellow and silver eels to fit their model. In that case, the application of ELSA in management process will be more limited because silver eels data are not easily available. Because silver eel process seems to be environment-dependant (Bevacqua et al., in press), a specific research is needed to define how to predict silvering features.

The present formulation of ELSA does not permit to evaluate separately the trend of recruitment and the mortality. It obliged us to use glass eels recruitment trend as a proxy of the trend of the number of 30 cm long eels, which settle in a given compartment.

We can compare results from WFD and DCR data for the oligohaline estuary. We obtained the same global mortality (closed to the natural mortally plus the recruitment trend) but a sex ratio completely different. Some macroscopic observations of gonads show a very high proportion of female in all zones (unpublished data). In general, the fitting is better (lower confidence interval) with DCR because of a higher number of data. But application of ELSA with only a few number of fish caught is possible.

Nevertheless, the percentages of silver eels per settled yellow eels obtained for each water body roughly matched our knowledge of the corresponding professional fishing pressure levels (Table 6). Notice that non-professional fisheries exist but are largely unknown. Other anthropogenic impacts are not well known.

Table 6: Fishing effort in the Gironde basin

Ecological zone	Surface (km²)	Professional fishing effort (pot month) (fromGirardin et al., 2004)	Fishing pressure (pot month km^{-2})
Brackish estuary	450	6378	14
Freshwater estuary (Garonne+ Dordogne)	80	6723	112
Upstream Garonne	24	480	20

The maximum value for H^{*f} is 0.1013 cm^{-1}. With the growth rate in the freshwater estuary, the anthropogenic (probably the fishing) mortality rate is estimated to 0.5268 $year^{-1}$. In

brackish estuary (meso- and poly-haline) and mainstream, we found rates from 0.0804 to 0.1648 $year^{-1}$. Svedäng (1999) estimated the fishing mortality from 0.16 to 0.42 $year^{-1}$, according to fishery location. Weeder and Uphoff (2003) without any considerations of silvering found a fishing mortality rate of 0.27 $year^{-1}$ for eel pot fishery in Upper Chesapeake Bay. LVPA application for IJsselmeer fishery leads to estimate a fishing mortality close to 1 $year^{-1}$ with no possible escapement of silver eels rate (Dekker, 2000b).
Notice that all the approaches lead to the same conclusion: yellow eel fishery could locally deplete a stock.

4.3. Differences between silvering features and silvering statistics

Studies on maturation have been usually limited to estimating silvering statistics, i.e. mean total length and/or age at metamorphosis (Rossi et al., 1979; Vollestad et al., 1988; Vollestad, 1992; for review Tesch, 1993; Poole et al., 1996; Svedäng et al., 1996). One should be cautious when interpreting maturation statistics. This analysis showed that mean length of silver eels could be different between compartments only because mortality and in a less extend growth are different. So studies that aim to highlight a phenotypic plasticity in silvering process should take into account the mortality and growth context (this study, Barot et al., 2004).
This result could explain why longest eels are presently produced upstream where mortality rate is the lowest even though in pristine conditions, they would also be produced in the estuary. This point emphases the management priority on lower part of the catchment.

5. Conclusion

We obtained some encouraging results with ELSA model, which uses only a simply yellow eels length structure. We do not presently obtain an accurate evaluation of the stock status but rather information about problems' magnitude. Therefore, more developments are needed to improve the model's reliability before using it without risk in a management process.
Even with some concern about ELSA application, the results provided by the present analysis urges to implement management actions especially in the freshwater estuary.

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