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Executive summary

This Report summarizes the presentations, discussions and recommendations of the 2010 session of the ICES Study Group on International Ex-post evaluation on Eels which took place in Vincennes, France, hosted by the Onema, from 10 to 12 May 2010. This study group was chaired by Laurent Beaulaton (France) and involved 15 people from 10 countries.

This study group is intended to design, test, analyse and report on a method of scientific ex-post evaluation of applied management measure at the stock-wide level. This report is the first step towards that objective and mainly focuses on designing the appropriate framework and the methods for eel ex-post evaluation and reviewing available data.

A pragmatic framework to ex-post evaluate at the stock-wide level eel management measures has been designed including an overview of potential ex-post evaluation tests, an adaptation to the eel case of the classical ICES precautionary diagram and a framework to compile lower scale stock indicators into stock-wide stock indicators. Available methods to assess the required stock indicators and the available data have been reviewed.

Future work will be dedicated to testing the feasibility, sensitivity and robustness of this framework so that the study group will be able to make recommendations on the best ex-post evaluation method for 2012 and data collection and development needed after 2012.

1 Introduction

At the 97th Statutory Meeting of ICES (2009) it was decided that:

2009/2/SSGEF20: The Study Group on International Ex-post evaluation on Eels (SGIPEE), chaired by Laurent Beaulaton, France, will be established and will meet in Vincennes, France, 10–12 May 2010 and in 2011 [to be announced] to:

a) Review stock assessment and ex-post evaluation methods available for species of eels, and those used by ICES Expert Groups on other species, that could be successfully applied to eels at the stock-wide level in 2012;

b) Adapt methods for stock-wide ex-post evaluation of *Anguilla anguilla* and apply them to data collated by WGEEL at its annual meetings; (this may include aggregation of EMU ex-post evaluation);

c) Analyze sensitivity of the selected methods to stock improvement or deterioration using simulated data;

d) Submit recommendations to WGEEL on: the best available ex-post evaluation method for 2012; gaps in data or knowledge that need to be filled before 2012; and methods that should be developed and data that should be collected after 2012 for the next stock-wide evaluation.

SGIPEE will report by 15 July 2010 and by DATE 2011 (via SSGEF) for the attention of WGEEL, WGRECORDS and SCICOM.

Fifteen people from ten countries attended the meeting (see Annex 1).

An EU Regulation for the Recovery of the Eel Stock (EC 1100/2007) was adopted in 2007. It required Member States to set up an eel management plan by the end of 2008 (article 2). They will report to the Commission by 30 June 2012 (article 9.1) and the Commission will present to the European Parliament and Council, not later than 31 December 2013, a report with a statistical and scientific evaluation of the outcome of the implementation of the Eel Management Plans.

A scientific evaluation of the outcome of the implementation of eel management plans is planned is article 9 of the EU regulation. It is beyond the capacity of the WGEEL in its annual meetings to develop the method of this evaluation. DGMARE have funded a pilot study to estimate silver eel biomass at the local level but neglected to include a stock-wide ex-post evaluation mechanism in the project. This SG is aimed at filling this gap.

This first meeting of the SG is thus the first step to develop a method of scientific ex-post evaluation at the stock-wide level of the outcome of eel management measures. We covered the ToR a and part of ToR b during the meeting. The remaining terms of reference will be addressed in the 2011 meeting and by correspondence in-between the meetings.

The structure of this report does not strictly follow the order of the Terms of Reference for the meeting, because different aspects of subjects were covered under different headings, and a rearrangement of the Sections by subject was adopted. The meeting was organized in three subgroups using the agenda in Annex 2. The subgroups under the heading “Ex-post evaluation concept”, “stock assessment method” and “data needs for international eel stock assessment” addressed the Terms of Reference as follows:

- **Chapter 2** presents ex-post evaluation from a conceptual point of view, reviews the concept of reference points (ToR a), and adapts the methods to the case of the European eel in a comprehensive framework at the stock-wide level. This framework provides a method for aggregating stock indicators from geographical units (e.g. eel management unit, river basin district or country) (ToR b).
- **Chapter 3** reviews stock assessment methods applied to eel and to other species that can be applied to lower-level scales in order to provide the required stock indicators for applying the ex-post evaluation framework developed in chapter 2 (ToR a). The most appropriate methods are selected and, where necessary, adaptations of those methods are advocated to be fully in accordance with what is needed for this framework (ToR b).
- **Chapter 4** reviews the data that are already or that will be soon available. These data are compared with the data required for methods selected in chapter 3 (ToR b).
- **Chapter 5** reviews the main achievements and proposes a work plan to complete SGIPEE (ToR b, c and d).

2 Ex-post evaluation[1] concept

2.1 Introduction to ex-post evaluation

Ex-post evaluation is the evaluation of the efficacy of management measures, conducted at sufficient time after measure implementation, so to ensure their consequences on the stock are visible.

A conceptual diagram of the ex-post evaluation process is given in Figure 2.1. On the left side, from top to bottom, the general **objective** (i.e. eel stock recovery) is translated into the **target/limit** (i.e. getting an amount of spawner escapement equal to the 40% of pristine levels) that is further indicated through **reference points** commonly used in stock assessment (e.g. stock biomass, mortality rates etc.). On the right side, it is shown that a given **management** (e.g. reduce fishing mortality) affects **stock status** (e.g. increasing the percentage of large individuals) and that changes induced in the stock status can be detected by appropriate **monitoring**. Ideally, ex-post evaluation would compare actual **stock status** and previously declared **targets/limit** in order to evaluate the efficacy of adopted measures and accordingly adjust future **management**. Actually, monitoring data are used to determine indicators that are compared with reference points and hence provide an **assessment** of management efficacy. Such assessment should provide decision makers with information necessary to post-evaluate past management and consider possible adjustments.

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[1] The wording "Ex-post evalution" seems to be more widely used than "post evaluation". In this report, we will adhere to this.

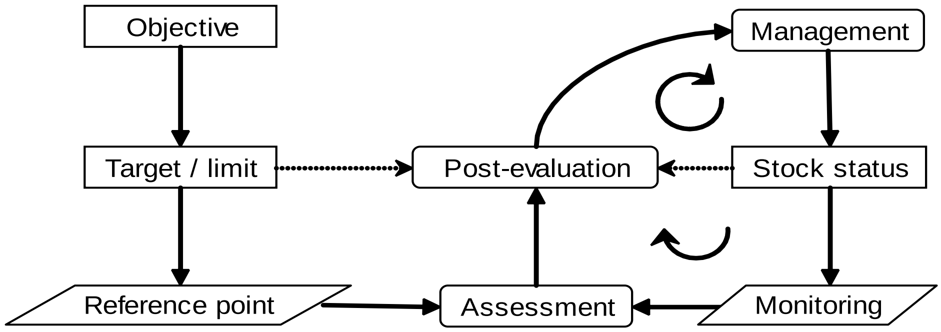

Figure 2.1. A conceptual view on the ex-post evaluation process, and the role of stock assessment. To ex-post evaluate whether the objective has been achieved by the implemented management, the stock status should be compared to the predefined targets/limits (dotted arrows). However, the actual status of the stock is not directly known. Monitoring data (samples) are used to derive indicators of the stock status (assessment), which are compared to reference points corresponding to the targets/limits (solid arrows). (Source: Dekker 2010)

The Eel Regulation sets a long term general objective ("the protection and sustainable use of the stock of European eel"), but delegates the local management, the implementation of protective measures, the monitoring, and the local ex-post evaluation to its Member States (EU 2007; Dekker, 2009). Eel management plans (EMPs) have been submitted by Member States in 2008/2009 and an ex-post evaluation of EMPs is required every 3 years, the first in 2012.

Due to the panmixia of the eel (i.e. local silver eel production contributes an unknown fraction to the entire European eel spawning stock, which in turn generates new glass eel recruitment), the efficacy of a single EMP cannot be ex-post evaluated without considering the overall efficacy of all EMPs. Thus, Member States will have to set **reference points** for their own EMP(s), to which the state of the local stock and efficacy of their actions can be compared.

2.2 The spatial scale for ex-post evaluation

There are two general approaches for international ex-post evaluation and assessment of the eel stock. The first is to conduct a central assessment with data from all areas/EMU's (spatial lumping of data); the second consists of regional stock assessment and the post-hoc summing up of indicators.

2.2.1 Lumping regional data into a central assessment

The first approach would require the typical data for stock assessment from all areas, and additional information for all other anthropogenic impacts. The data could fill an "impact-by-age-data-matrix". This would be an enormous task, but in principal, it would be possible. However, the results of such an approach would be very difficult to interpret. As growth differs greatly throughout the distribution area, there is no common age-length-key. Impacts on a certain age class will therefore have different meaning depending on geographical region. In the "central assessment" approach, for instance, fishing mortality at age 8 is a single estimate for the whole stock. In practice, it would be the assembly of fishing on rather young animals below the minimum legal size in the Baltic and fishing on very old animals in the Mediterranean. Because of this mixing, the relation between mortality (by age) and management measures is completely lost. Similar constraints hold for the maturation pattern.

In principal, the spatial-lumping approach could provide an effective quantitative analysis of the overall state of the stock. However, the interpretation of the results and the link to management measures make it difficult. In addition, the enormous data requirement would be a big problem. Therefore, spatial lumping is not recommended.

2.2.2 Post-hoc integration of regional stock indicators

In the second approach, relevant stock parameters, such as silver eel escapement, are calculated or estimated on a lower geographical scale (e. g. RBD, EMU, regional, national). On this geographical scale, there ought to also be information available on lifetime mortality, separately for the respective anthropogenic impacts.

The relevant stock parameters (spawner escapement, lifetime anthropogenic mortality, relative spawner per recruit; see below) will then be summed for the whole area to provide information on total 'potential'[2] spawner stock biomass.

From the information on spawner biomass and on the lifetime anthropogenic impact, a "precautionary diagram" (see section 2.4) can be developed for each geographical unit and for the total stock.

This approach of regional stock assessment and post-hoc summing up of indicators for total stock assessment appears to be more pragmatic then the "central assessment" described above. Most of the necessary monitoring structures and data should be available at the EMU level, and the interpretation of the results is easier. As an alternative or as an addition there is the possibility to combine biologically similar areas for the assessment (e.g. international RBD's, which at the moment are not treated as one unit).

2.2.3 Local versus global reference points

Biological as well as management characteristics of the eel stock vary greatly throughout the distribution area. The results of the assessments for single geographical units (RBD's, EMU's, countries) may be very different, some reaching the targets/limits, while others may not. Consequently, the question arises how the picture of the total stock is to be evaluated. Is the sum or average of all areas an adequate indicator for the whole population, even though some areas might defect, or should all areas conform? For example, several countries or regions could achieve a very good state of their local stock whereas a few others have high levels of anthropogenic impacts and, consequently low spawner escapement. If under such a scenario the total spawner escapement for the whole stock (or the European part of the stock) would be above the target/limit (40% of pristine), there could be a tendency to evaluate the overall state as positive. However, this evaluation would only be correct, if all regional eel stocks contribute equally to the reproduction. Yet at present, there is no scientific evidence for or against this assumption. Of the total European glass eel, 76% are thought to recruit to the area around the Bay of Biscay, and Dekker (2000b) therefore hypothesised that only the Biscay area might constitute a self-sustaining population, with 24% of the total recruitment scattered over the rest of the continent. On the other hand, nearly half the reported landings are derived from the Mediterranean, at temperatures in accordance with the species' preference, and Dekker (2003a) there-

[2] Note that this is the potential spawner biomass based on the amount of silver eel emigrating towards the spawning grounds but the actual spawning numbers will likely be reduced by mortality during the oceanic migration.

fore hypothesized that the distribution north of the Mediterranean might constitute only an accidental diaspora. Not knowing which part of the continental stock actually reproduces, a focus on the sum or average over the whole continent thus runs the risk of under-rating an essential area. Well-managed, but non-reproducing areas might compensate for badly-managed, but reproducing areas in the international sum or average, which would result in false-positive stock indicators. Therefore, the precautionary approach dictates that, until the true identity of the reproducing stock is known, for each (regional) part of the population the biological reference point (40% of pristine biomass) has to be achieved, which is in accordance with EU Council Regulation 1100/2007.

2.3 Stock indicators, reference points and ex-post evaluation tests

2.3.1 Definition

The relationship between the size of the spawning stock and the resulting abundance of offspring called the "stock-recruitment-relationship". It is generally assumed that at low stock abundance, the number of offspring is proportional to the size of the spawning stock, while at high stock abundance, compensatory mechanisms limit the numbers of offspring by some density dependent process. Several mathematical models have been used to describe the shape of stock-recruitment relationships (i.e. Beverton and Holt 1957, Ricker, 1954, Shepherd, 1982) but these all take a similar shape at low stock-abundance, only differing in the upper ranges of stock size, which is of little concern for depleted stocks such as the eel. The Beverton and Holt type of stock-recruitment relationship reads:

$$R = \frac{\alpha B}{\beta + B}$$

where R is recruitment strength, B is spawning stock biomass, and α and β are (unknown) parameters.

The ecology of eels makes it difficult to demonstrate a stock-recruitment relationship. The identity of the reproducing (part of the) stock is unknown, and the size of the spawning stock is unquantified. Additionally, recruitment trends apparently differ between regions (ICES, 2009). However, the precautionary approach requires that such a relationship should be assumed to exist for the eel until demonstrated otherwise (ICES, 2002). Note that in the case that another type of stock recruitment curve applies, in particular if recruitment falls more rapidly than the spawning stock (the depensatory effect which was explored by Dekker, 2004), the theoretical basis presented here should be reconsidered.

To 'close' or complete the life cycle, there is another relationship which links the abundance of the offspring to the survival of the spawning stock, called "recruitment-stock relationship" (see explanation in ICES, 2008). This relationship depends upon natural (**M**) and anthropogenic (**A**) mortality accumulated over the lifespan in continental waters. Anthropogenic mortality **A** encompasses the fishery and the other sources of mortalities induced by human activities. Usually, no density effects are taken into account in the recruitment-stock relationship, i.e. the relationship is assumed to be linear (Figure 2.2). The basis for a more complex relationship, including compensatory effects such as density dependence, is similar but complicates the formulae. The intersection between both curves gives the equilibrium point of the population dynamic.

When only natural mortality is considered (i.e. **A**=0), the biomass at the intersection point corresponds to the pristine biomass (**B_0**), that is the biomass which is produced when there are no anthropogenic impacts.

However, exploitation that leaves 30% of the virgin spawning stock biomass is generally considered a reasonable target for sustainable escapement. Due to the uncertainties in eel biology and management[3], ICES (2002) proposed a limit reference point of 50% for the escapement of silver eels from the continent in comparison to pristine conditions. This is higher than the escapement level of at least 40% pristine set by the EU Regulation.

The reasoning using a stock-recruitment-relationship, in which density dependent processes in the oceanic phase restrict the number of offspring produced, is based on (partial) compensation of the effect of a declining spawning stock (due to human activities) by an increasing survival rate of the offspring.

The Eel Regulation has fixed a limit in biomass (**B_{lim}**) at 40% of the pristine biomass (B_0). Below this limit, there is a higher risk that the stock suffers from reduced productivity, and recovery to an improved status is likely to be slow and will depend on effective conservation measures (ICES 2004b page 1–12). The anthropogenic mortality associated with the recruitment-stock relationship that intersects the stock-recruitment relationship at **B_{lim}** corresponds to the limit reference point in mortality rate (**A_{lim}**). Mortality above this limit is associated with a high risk of reduced reproduction and therefore, effective conservation measures are required.

Spawning biomass and anthropogenic mortality can only be estimated with a certain degree of uncertainty (see Chapter 3). To allow for this uncertainty and keep the true risk low that spawning biomass indeed falls below **B_{lim}**, the estimated spawning biomass should be kept above a higher level than **B_{lim}**. Therefore, an extra 'buffer zone' is defined by setting a spawning biomass reference point **B_{pa}** above **B_{lim}**, i.e. a precautionary biomass reference point (ICES, 2004b page 1-12). Because **B_{pa}** is a mechanism for managing the risk of the stock falling below **B_{lim}**, the distance between these reference points depends on the uncertainty in the data derived from the assessment techniques. This distance will be related to the uncertainty of the assessment and the amount of risk society is prepared to take in order to balance the recovery of the stock with socio-economic considerations.

Similarly, to be certain that fishing mortality is below **A_{lim}**, anthropogenic mortality should in practice be kept below a lower level **A_{pa}** that also allows for uncertainty. When fishing mortality is estimated to be above **A_{pa}**, management action should be taken to reduce it to **A_{pa}**. Such advice is given even if the spawning biomass is above **B_{pa}** because anthropogenic mortalities above **A_{pa}** are not sustainable. (ICES 2004b page 1–12).

A target reference level **B_{pa}** for the spawning stock biomass of the eel should be higher than the 50% limit reference point advised by ICES (2002). Given our poor knowledge on the status of the stock, a considerable gap between **B_{lim}** and **B_{pa}** will be required. However, in the absence of a stock-wide assessment of the European eel

[3] The uncertainties in eel biology and management stem from our lack of information or understanding of the biological processes and of the impact of management measures. This is not to be confused with the statistical uncertainty in the estimation of the current stock status or the reference points. The former addresses process error, while the latter addresses measurement errors. Hence, the biomass of 50% is not a precautionary reference point Bpa, but a limit reference point Blim, to which the statistical uncertainty margin needs to be added to derive Bpa.

stock (other than the Procrustean assessment of Dekker, 2000b), no precision level or $\mathbf{B}_{pa}$ can be specified (ICES, 2007).

Interim targets/limits, in terms of biomass $\mathbf{B}_{interim}$ or mortality $\mathbf{A}_{interim}$, do not represent biological reference points, but pragmatic intermediate goals defined by politically determined ambition levels and time frames. Indeed, achieving the objective defined by the European Regulation through management actions will take a very long time (at least 80 years for a full recovery, Åström & Dekker, 2007). And therefore, it becomes hard to apply this long term reference point in practical management terms. So, short term, interim targets based on management units need to be defined in connection with management measures (ICES, 2008).

Stock assessment based on data before implementation of management actions (i.e. before the eel management plan) and after management actions (i.e. at time of post evaluation) will inform on spawning biomass before ($\mathbf{B}_{pre}$) and after ($\mathbf{B}_{post}$) management, and on anthropogenic mortality before ($\mathbf{A}_{pre}$) and after ($\mathbf{A}_{post}$) management when recruitment was low $\mathbf{R}_{low}$ compared to pristine conditions.

Finally $\mathbf{B}_{best}$ is the spawning biomass corresponding to recent low recruitment that would result if there is only natural mortality. It corresponds to the maximum value that $\mathbf{B}_{post}$ can achieve (in absence of restocking), corresponding to $\mathbf{A}$=0.

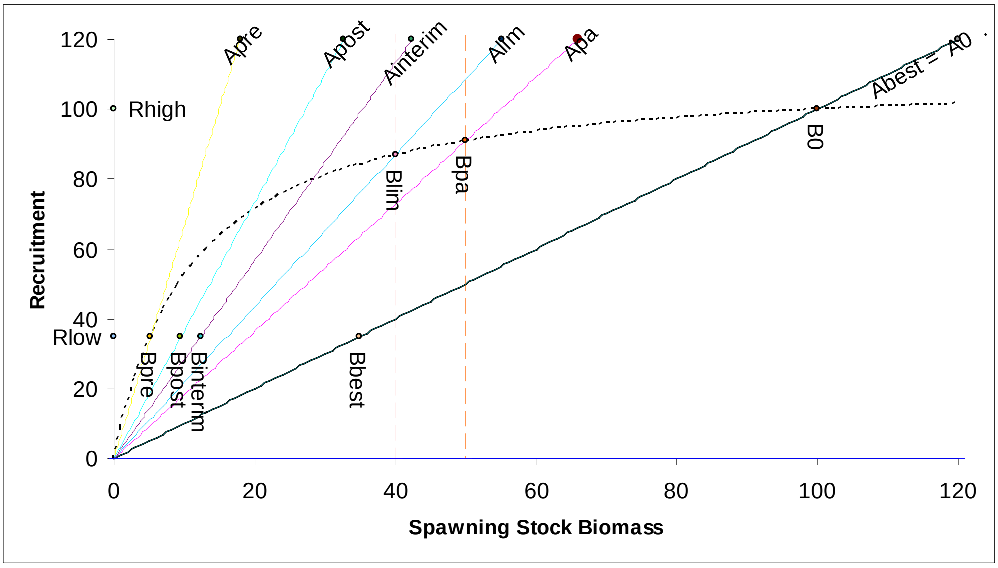

Figure 2.2. A theoretical example of a Beverton & Holt (1957) stock-recruitment relationship (solid line). On the horizontal axis, the parental spawning stock size; the vertical axis shows the number of resulting progeny. The broken lines indicate the reverse relationship: the dependence of the parental spawning stock (horizontal) on the number of recruits (vertical) from which it was derived. In the pristine state (no anthropogenic mortality, A=0), the natural spawning stock reaches B_0 (which is here set at 100 %). The limit on anthropogenic mortalities A_{lim} is set so that the corresponding spawning stock biomass B_{lim} is achieved at 40% of the pristine state B_0, while recruitment R_{high} is close to the pristine 100%.

The different values for ex-post evaluation are summarized in Table 2.1. $\mathbf{A}_{pre}$, $\mathbf{B}_{pre}$, $\mathbf{A}_{post}$, $\mathbf{B}_{post}$ are the output of stock assessment process; the others are calculated or fixed by the EU regulation and managers.

Table 2.1. Terminology for Biomass B and Anthropogenic mortalities A, for high and low recruitment R, including observed/observable states (plain text) and calculated/chosen reference points (italics), for a range of mortality levels. Pre- and post indicate the periods before and after protective management measures have been taken.

	Mortality	Biomass	
Situation		Recent recruitment R_{low}	Pristine (historical) recruitment Rhigh
No anthropogenic impacts	$\mathbf{A}_0=0$	$\boldsymbol{B}_{best}$	$\boldsymbol{B}_0$
Target / limit on impacts	$\boldsymbol{A}_{lim}$		$\boldsymbol{B}_{lim}$
Safe target /limit, data uncertainty	$\boldsymbol{A}_{pa}$		$\boldsymbol{B}_{pa}$
Interim target/limit	$\boldsymbol{A}_{interim}$	$\boldsymbol{B}_{interim}$	
Before management measures	$\mathbf{A}_{post}$	$\mathbf{B}_{post}$	
After management measures	$\mathbf{A}_{pre}$	$\mathbf{B}_{pre}$	

2.3.2 Ex-post evaluation tests

ICES (2009) suggested ex-post evaluation was based on (i), the difference on stock before and after intervention, and (ii) the difference between the mortality rate before and after intervention, and (iii) also the difference between mortality rate and a threshold where recruitment decline is expected to stop.

Following Dekker (2010), we propose a generalisation of this approach (Table 2.2) by systematically comparing on the one hand all possible combinations of biomasses and on the other hand all combinations of anthropogenic mortalities. Ex-post evaluation might address the questions formulated in Table 2.2. There is no one-to-one correspondence between biomass tests and apparently corresponding mortality tests. Mortality tests are generally less restrictive than the corresponding biomass tests. Each test is associated with a pragmatic question for managers. Tests results will be summarized in the Precautionary Diagram presented in section 2.5.

Table 2.2. Schematic overview of potential ex-post evaluation tests, based on biomass or anthropogenic mortalities, detecting trends or testing against specific set-points.

Note that the tests are ordered on mortalities (from low to high ambition), and thus the biomass tests might out of order (in particular: the maximum achievable is often less demanding than the long-term goal, $\mathbf{B_{best}} < \mathbf{B_{lim}}$).

	Trend	Interim target/limit	Long-term targ./limit	Maximum achievable
Biomass **B**	$\mathbf{B}_{post} > \mathbf{B}_{pre}$ An increasing trend in the biomass of silver eels escaping?	$\mathbf{B}_{post} \geq \mathbf{B}_{interim}$ Has the biomass increased to the level set as interim target/limit?	$\mathbf{B}_{post} \geq \mathbf{B}_{lim}$ Has the biomass increased to the level set as long-term target/limit?	$\mathbf{B}_{post} \ll \mathbf{B}_{best}$ How far is current biomass below the maximum achievable? (†)
Anthropogenic mortality **A**	$\mathbf{A}_{post} \leq \mathbf{A}_{pre}$ A decreasing trend in anthropogenic mortalities?	$\mathbf{A}_{post} \leq \mathbf{A}_{interim}$ Has mortality decreased below the interim target/limit?	$\mathbf{A}_{post} \leq \mathbf{A}_{lim}$ Has mortality decreased below the long-term target/limit?	$\mathbf{A}_{post} \approx \mathbf{A}_{0}$ Is the minimum anthropogenic impact achieved?

(†) Note that restocking of eel purchased abroad may boost biomass, compensate for anthropogenic mortalities, and in doing so, may disrupt any of the relations shown here. Restocking will be discussed in section 2.5.3.

2.4 The Precautionary diagrams used by ICES

The Eel Regulation sets a limit reference for biomass as a percentage (40%) of the pristine biomass, and leaves it up to the Member States to determine actual reference points for the part of the stock within their territory. Effectively, the limit of the Regulation being formulated as a percentage, this condenses to a limit mortality, unless density dependence is to be taken into account (note that we interpret restocking as a negative mortality here, see section 2.5.3 below). Depending on the type of reference point chosen, either the current state or the target is hard to quantify. In order to get the best of both approaches, we will develop indicators for both biomass and mortality, and develop a suitable presentation form in section 2.5.

In its advice on fisheries management, ICES (2004b) applies a 'traffic light' colouring scheme, signalling the status of the stock and the impact of exploitation. The information on the stock status and the reference points are summarised in a so-called Precautionary Diagram (Figure 2.3), summarizing the criteria and status. This diagram presents the status of the stock (horizontal, low versus high spawning stock biomass determining whether the stock has achieved full reproductive potential) and the impact of fishing (vertical, low versus high fishing mortality determining whether the exploitation is sustainable or not).

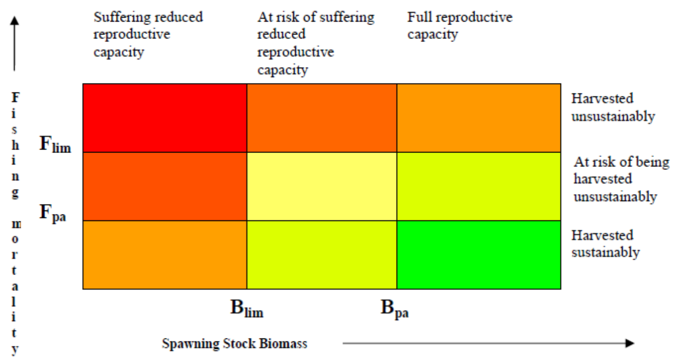

Figure 2.3. In its scientific advice on fish stock management, ICES applies a standard terminology to qualify the status of the stock (horizontal) and the impact made by fishing (vertical). Source: ICES 2004b (diagram p. 1–7).

2.5 A Modification of the Precautionary Diagram

2.5.1 The inadequacy of the traditional Precautionary Diagram for eel

The ICES Precautionary Diagram presupposes a stock status in the neighbourhood of the reference points, which unfortunately does not happen for the eel stock. For the eel, the stock is (assumed to be) suffering from reduced reproductive capacity, and anthropogenic impacts are (assumed to be) outside safe biological limits (ICES, 1999). Applying the Precautionary Diagram in an actual case study on eel (Dekker, 2010) results in a diagram with all data points arranged in a narrow vertical strip along the y-axis, which does not provide a useful presentation of the stock status. Below, we suggest a modification of the Precautionary Diagram to suit the eel case. In this modified diagram, the spawning stock is plotted on a logarithmic scale, while the annual fishing mortality is replaced by the %SPR (%SPR is known as either percentage-spawner-per-recruit or spawner-potential-ratio). In comparison to the standard Precautionary Diagram, the focus in this Modified Precautionary Diagram has shifted from the unreachable limits/targets towards the current situation, while the far-out targets/limits are shown in the far-out lower-right corner. As in the standard diagram, the horizontal axis quantifies the status of the stock. The vertical axis quantifies the anthropogenic impacts, as opposed to only fishing impacts in the standard diagram, but the axis scaling has changed from an (exponential) annual mortality rate to a percentage spawner per recruit.

Considering the horizontal biomass axis, below we will focus on the comparison between Eel Management Units and on the integration of EMU-specific estimates into stock indicators for larger geographical areas, ultimately for the whole population. To allow comparison between EMUs, and to incorporate various geographical scales in a single plot, the horizontal biomass level will not be plotted in absolute quantities (tons), but as the percentages of the pristine escapement (biomass), %**B**.

Considering the vertical axis, the standard Precautionary Diagram quantifies the fishing mortality F as a *per annum* mortality rate. Other anthropogenic mortality H (including potential effects of pollution, habitat loss, migration barriers and hydropower mortality) can be added, summing up to total anthropogenic mortality A=F+H. However, the implicit assumption in the standard Precautionary Diagram is that annual fishing mortality is an adequate indicator of fishing impacts. This excludes the evaluation of changes in size selectivity and minimal legal size and the evaluation of major changes in growth rates (as for instance might be achieved by within-river trap and transport of recruits or fish passes). More importantly, the vertical axis of the standard diagram shows no relationship to stock abundance, and therefore does not adequately quantify anthropogenic impacts in cases where density dependent mortality occurs. Density dependence might be a factor contributing to dispersal within rivers, to growth, mortality and to sex differentiation (see ICES, 2003 for an overview). Density dependence plays a key role in the assessment of the continental stock, and has been the central argument justifying the intensive fishery on glass eel around the Bay of Biscay (Moriarty & Dekker, 1997).

2.5.2 The relation between %SPR and mortality

In the Modified Precautionary Diagram, the annual fishing mortality has therefore been replaced by percentage-spawner-per-recruit %SPR, that is, the current spawner escapement $\mathbf{B}_{post}$ as a percentage of the (expected) spawner escapement $\mathbf{B}_{best}$ if no anthropogenic impacts would have occurred.

In density independent cases, %SPR is related to anthropogenic impacts: spawner escapement number N (not biomass) is

$$N_t = \sum_a S_a \times R_{t-a} \exp^{-\sum_{i=0}^{a} M_{t-a+i,i} + A_{t-a+i,i}}$$

$$= \sum_a S_a \times R_{t-a} \exp^{-\sum_{i=0}^{a} M_{t-a+i,i}} \times \exp^{-\sum_{i=0}^{a} A_{t-a+i,i}}$$

Where N_t the number of silver eel escaping in year t

S_a the fraction of eels of age a silvering

R_t the recruitment in year t, in numbers

$M_{t,a}$ natural mortality in year t at age group a, as an annual mortality rate

$A_{t,a}$ anthropogenic mortality in year t at age group a, as an annual mortality rate.

The (expected) spawner escapement $N_{t,\ best}$ if no anthropogenic impacts would have occurred, equals

$$N_{t,best} = \sum_a S_a \times R_{t-a} \exp^{-\sum_{i=0}^{a} M_{t-a+i,i}}$$

Silvering usually occurs over a range of age-groups, but to simplify the derivation, we will assume here a knife-edge silvering pattern, in which all animals silver at the same age. In this simplified case, the summation sign drops out, and *a* becomes the age at silvering.

For the density-<u>in</u>dependent case, %SPR expressed in numbers[4] thus equals

$$\%SPR_t = \frac{N_t}{N_{t,best}} = \exp^{-\sum_{i=0}^{a} A_{t-a+i,i}}$$

and hence

[4] %SPR is most frequently expressed in terms of biomasses, but for low-fertility fish such as sharks, it is more commonly defined in terms of numbers. Although eels definitely do not pass the low-fertility criterion, we will use the number-based definition here.

$$\sum_{i=0}^{a} A_{t-a+i,i} = -\ln(\%SPR_t), \text{ or for short: } \sum_{lifetime} A = -\ln(\%SPR),$$

where *lifetime* is considered to cover the whole continental life span, up to and including the silver eel phase, the anthropogenic mortalities in the silver eel phase.

For a %SPR based on biomass rather than on numbers, the relationship between %SPR and mortality is much more complex, but numerical simulation indicates that the relationship comes close to that specified above.

The above derivation is based on a knife-edge silvering pattern, which is not realistic. If silvering occurs over a range of length/age-groups, the above relationships hold, if the lifetime mortality is weighted by the number of eels silvering per length/age-group. Though calculations might be a bit more complex, the relationship between (weighted) lifetime mortality and %SPR remains unchanged.

In density dependent cases, natural mortality declines when anthropogenic impact increases, resulting in a buffering of total mortality, and hence a more stable stock abundance than in the density-independent case. The interaction between natural and anthropogenic impacts complicates the simple relation between $\sum_{lifetime} A$ and %SPR shown above. Without going into greater detail on stock assessment and density dependence here, this will necessitate a more complex assessment procedure. In all density-dependent cases, $\mathbf{B}_{post}$ will be closer to $\mathbf{B}_{best}$ than if no density dependence would have occurred. Using a more complex assessment, the value of $\mathbf{B}_{post}$ and $\mathbf{B}_{best}$ must be estimable, and hence %SPR can be determined.

2.5.3 Restocking

Unlike for most other exploited fish stocks, local management measures for eel might include positive impacts, such as local restocking of eel purchased outside the area of the management unit. Glass eel caught in regions of high abundance (predominantly the Bay of Biscay; Moriarty & Dekker, 1997, Dekker, 2000b, 2003a) are transported to regions of low abundance, within the same river, to nearby areas, regions or countries, , or historically even to waters outside the natural distribution area (Dekker, 2003a). Although the successful contribution of restocked eels to the spawning stock has been questioned (ICES, 1999, 2009), the Eel Regulation promotes restocking as one management measure within a suite of potential measures. Restocking potentially increases the local escapement of silver eels (in numbers and biomass), and is therefore considered a positive impact (or benefit) on the stock, in contrast to the negative impacts (fishing, hydropower related mortality, habitat loss, etc), which all reduce the escapement. As a consequence, actual escapement $\mathbf{B}_{post}$ might conceivably exceed the natural escapement $\mathbf{B}_{best}$, as for instance in unexploited natural waters that are restocked for stock restoration purposes. In this case, %SPR will reach a value above 100% and total anthropogenic impact will be positive. If this happens, the (Modified) Precautionary Diagram can easily be adapted to allow for net positive impacts, below the horizontal axis.

Restocking will only contribute to the spawner escapement after the young eels have grown to the silvering size. This requires between 3 years for male silver eels in the Mediterranean and up to nearly 20 years on average for females in the Baltic. Consequently, a proper judgement on the (positive and negative) impacts of the combination of management measures might require a medium term projection, covering nearly one whole life-span. In order to allow for an assessment of the current (positive or negative?) as well as the expected (positive) impacts, plotting the current stock indicators as well as the medium term projection in one Modified Precautionary Diagram is advocated. Since all recruitment year classes are already known at the time of the assessment, this does not require an estimate of future year classes based on a (assumed) stock-recruitment relationship.

Long-term projections, including new year classes will be required to estimate the time-schedule of the recovery process (c.f. Art 2.9 of the Eel Regulation). To this end, a relationship between spawner escapement and recruitment has to be quantified. Since it is unlikely that eels home to the river/region/country of where their parents grew, such a relationship cannot be derived for individual rivers/regions/countries. For the stock-wide assessment, the relationship between spawner escapement and recruitment implicitly assumed in the Eel Regulation does not correspond with the tentative relationship based on historical data (Dekker, 2004, 2010). Further analysis is required.

2.5.4 An example of the Modified Precautionary Diagram

An example of the Modified Precautionary Diagram is shown in Figure 2.4, in which the data for Lake Ijsselmeer (the Netherlands) have been plotted (Dekker, 2010.).

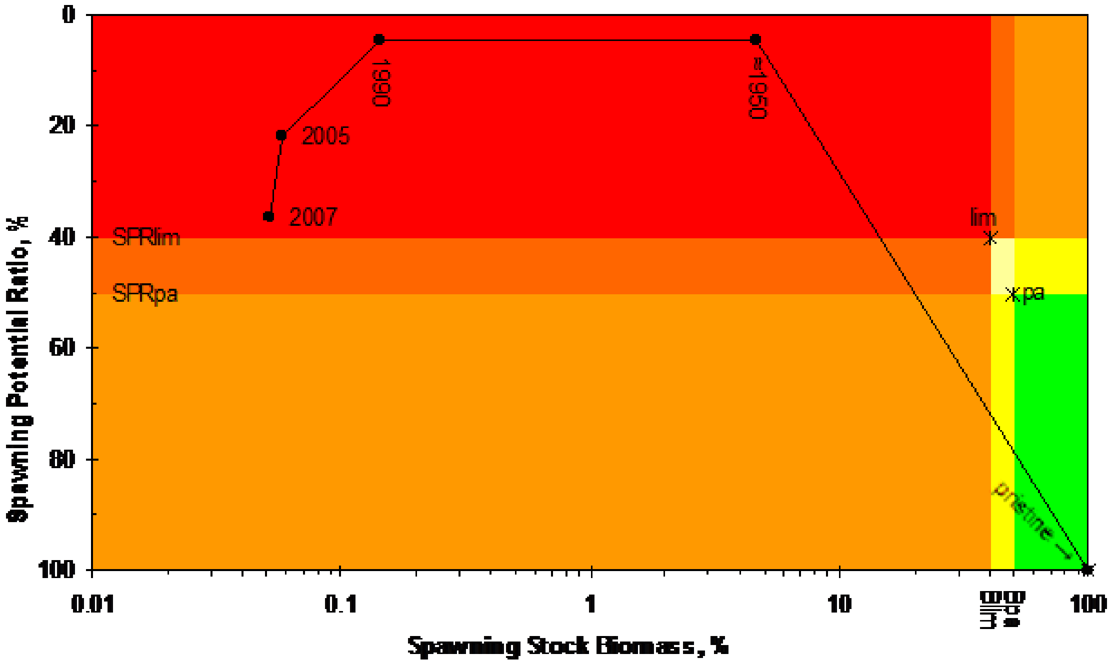

Figure 2.4. Modified Precautionary Diagram for Lake IJsselmeer eel stock, indicating the biological reference points and the historical trajectory. (Source: Dekker 2010. Data from the Dutch EMP, Dekker *et al.*, 2008 and supplemented by expert estimates. Bpa is set at 1.25*B_{lim} , and %SPR_{pa} at %SPR_{lim}*1.25)

2.5.5 Integration of disaggregated assessments into a higher level assessment

The local/regional/national stock assessments, using the Modified Precautionary Diagram presented above, can be used to derive an integrated assessment for larger geographical areas (from individual rivers to RBDs or EMUS, from RBDs/EMUs to countries, from EMUs/countries to geographical regions, ultimately to a stock-wide assessment). The merging of disaggregated assessments into a single, higher level assessment for spawner escapement biomass simply adds up the biomasses of the lower level assessments, both for the current escapement and for the biomass reference points (limit/target/pristine). For the anthropogenic impact, we use the average of %SPR values, weighted by the (expected) spawner escapement $\mathbf{B}_{best}$ if no anthropogenic impacts would have occurred. As an example, consider the integration of two management units, here labelled as a northern and a southern unit. The %SPR of these two units combined equals:

$$\%SPR_{post} = \frac{B_{post}/R_x}{B_{best}/R_x}$$

where R_x refers to the recruitment from which the actual spawner escapement was derived. We will not define R_x more accurately here, since it occurs in nominator and denominator of the above equation, and therefore cancels out, whatever its exact nature. Thus

$$\begin{aligned}
\%SPR_{post} &= \frac{B_{post}}{B_{best}} \\
&= \frac{B_{south,post} + B_{north,post}}{B_{south,best} + B_{north,best}} \\
&= \frac{\frac{B_{south,post}}{B_{south,best}} \times B_{south,best} + \frac{B_{north,post}}{B_{north,best}} \times B_{north,best}}{B_{south,best} + B_{north,best}} \\
&= \frac{\%SPR_{south} \times B_{south,best} + \%SPR_{north} \times B_{north,best}}{B_{south,best} + B_{north,best}}
\end{aligned}$$

which exactly matches the average %SPR weighted by $\mathbf{B}_{best}$.

2.5.6 An example of spatial integration of stock indicators in a Modified Precautionary Diagram

Stock indicators for local eel stocks are currently available for only a very small number of case studies. Several of the EMPs submitted to the EU provide part of the requested information, but estimates of the current impact (enabling the derivation of $\mathbf{B}_{best}$) are frequently missing. The assessment of current stock indicators has received little review; the review by ICES focused on the distance between the current and the pristine state, with only a minor focus on the current anthropogenic impacts. Hence, we prefer to exemplify the above technique using artificial data.

This artificial example is plotted in Figure 2.5, below. This example shows area 1 with a sustainable impact, and a biomass slightly below $\mathbf{B}_{lim}$; area 2 having a low biomass despite a sustainable impact; areas 3 and 4 are too small to influence the over-all position of the stock; and areas 5 and 6 having an impact above the limit. The overall indicator (sum or av.) shows that the stock is below $\mathbf{B}_{lim}$, and noting that the impact is too high on average, no recovery can be expected.

Figure 2.5, plotting all areas and their sum, provides a direct visual presentation of the overall status of the stock, and an indication of the variation between areas. This allows for the identification of problem areas, which themselves will need further inspection to find the cause for their problem. For the sum/average, no direct relationship between the status and the impacts can be derived from this plot, which is in agreement with the analysis given in section 2.2.

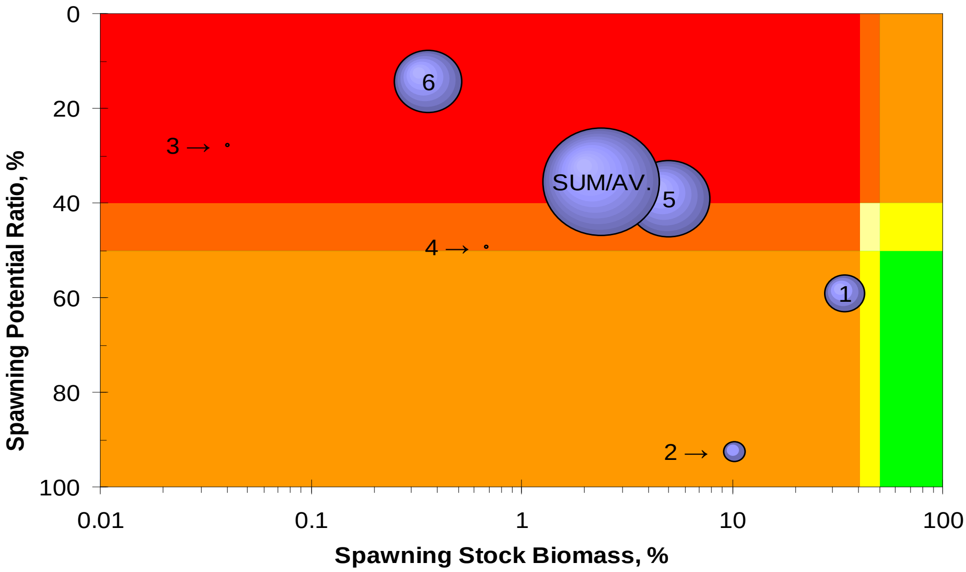

Figure 2.5. Modified Precautionary Diagram for an artificial data set. For 6 areas, the stock status is shown, and the sum/average of those six is added. For each, the size of the bubble is proportional to B_{best}, the best achievable spawner escapement given the recent recruitment.

2.5.7 In conclusion: data requirements

Summing up, the international stock assessment can be based on lower-level stock assessments, if those lower-level assessments supply the following estimates:

a) $\mathbf{B}_{post}$, the biomass of the escapement in the assessment year;

b) $\mathbf{B}_0$, the biomass of the escapement in the pristine state. Alternatively, one could specify $\mathbf{B}_{lim}$, the 40% limit of $\mathbf{B}_0$, as set in the Eel Regulation;

c) $\mathbf{B}_{best}$, the estimated biomass in the assessment year, based on the recently observed recruitment, but assuming no anthropogenic impacts have occurred (neither positive nor negative impacts).

The ratio of items a) and b) determine the horizontal position for the lower-level assessment on the Modified Precautionary Diagram. The ratio of items a) and c) determine the vertical position. Item c) is the weighting factor for the lower-level assessment in deriving integrated stock indicators.

The estimation of $\mathbf{B}_{best}$ will require an estimate of **A** for density-independent cases, and a more complex analysis for density-dependent cases.

For quality insurance reasons, the assessment should report the methods used and the values of all indicators derived (Table 2.1, Table 2.2).

3 Stock assessment methods

The stock assessment methodology developed in the previous chapter requires estimates of $\mathbf{B}_{post}$, $\mathbf{B}_{best}$, $\mathbf{B}_0$ and/or $\mathbf{B}_{lim}$, along with estimates of uncertainty (confidence intervals) for these estimated values. The estimation of $\mathbf{B}_{best}$ will require the summation of all anthropogenic mortalities ($\sum\mathbf{A}$) for density-independent cases, and a more complex analysis for density-dependent cases. Recruitment time series are also required to derive $\mathbf{B}_0$ from $\mathbf{B}_{post}$ in the absence of historical data. The following sections focus on the methods potentially available in the various geographical units to provide an assessment of these estimates, and how they could be used together to make the best use of the existing information.

3.1 The potential applicability of commonly used fisheries stock assessment methods

We considered some of the most commonly used stock assessment methods (SAMs) from marine fisheries applied by ICES assessment working groups and reviewed for the Working Group on Methods of Fish Stock Assessments (WGMG, in prep), to consider whether these could be used to estimate the required parameters. Broadly speaking, most SAMs are used to assess non-migratory, 'standing' stocks which are heavily fished (thus where fishing mortality is the dominant component of total mortality), and where natural mortality is assumed to be known and relatively low in comparison with anthropogenic mortalities. Few of the commonly used SAMs estimate anthropogenic mortalities other than fishing mortality (e.g. ICES multi-species VPA, SWAM, Knights *et al*. 2001 model). Thus, these models could not be used for silver eel escapement mortality due to our requirement to estimate other anthropogenic mortalities, e.g. entrainment in hydro-electric power stations. Therefore, we assessed the usefulness of these methods for estimating the biomass and mortality at the yellow and silver eel stages and for specific circumstances where fishing is the dominant anthropogenic mortality.

The most commonly used SAMs are (statistical) catch-at-age models such as extended survivor analysis (XSA) or Integrated catch-at-age analysis (ICA). These catch-at-age models all use an age-based virtual population analysis (VPA) as the main part of the model and therefore require catch-at-age information. In a VPA, the total size of year-classes that have disappeared out of the exploited stock can be estimated under the assumption that almost all fish are eventually caught. Therefore, these methods require time-series of catch data that are preferably at least as long as the mean life-span of the species. Typically, the estimated numbers-at-age and year-class sizes are correlated with survey tuning indices and recruitment indices arising from scientific surveys, in order to improve estimates of year-classes that are still in the fishery. Biomass is estimated by multiplying estimated numbers-at-age with weight-at-length relationships derived from biological sampling of the catches.

These models would only be useful in assessing local eel stocks in cases where the major determinant of mortality is fishing. Also, they would have to be adapted in order to incorporate silver eel emigration. There are few eel fisheries where age is routinely measured, although this is a requirement of the EU Data Collection Framework (DCF), for which eel has recently been included. Length sampling of the catch is more common. Eels are notoriously difficult to age from otoliths and though methodologies and validation procedures have been improved and standardised through the ICES WKAREA, the intensive resource requirements of eel otolith analysis, high variability in growth rates between individuals and uncertainties inherent in estimating length-at-age are such that modeling based on year-classes or age-cohorts are not as applicable as they are to other fishes.

Length-based Virtual Population Analysis (LVPA) models have also been developed, but are less routinely applied. These LPVA models use length-structured data, and growth is handled as a state transition matrix in-between annual intervals. See Lassen

& Madley (2001) for a general discussion of LPVA methods, and Berg (1989) and Dekker (2006) for examples of LVPA applied to an eel fishery.

Stage-based models such as Dekker (2000)'s Procrustean model, Knights *et al.,* (2001) or Lambert (2008) SED models have also been developed to cope with situations where the best information available is little more than information per stage. Although informative in the situation where landings per stage are the best information available, the results of these models remain crude, and these approaches would benefit from considering both temporal and spatial processes, when the data will become available.

The following section provides an evaluation of the methods applied to eel. The migration stages, i.e. the glass eel and silver eel stages have to be treated separately from the yellow eel stage.

3.2 Assessment of stock and mortality

3.2.1 Methods based on catching or counting silver eels

Silver eel escapement can be estimated directly from catching or counting eels. The EIFAC/ICES Working Group on Eels reviewed these methods in 2008 (ICES, 2008). The following text develops from this review, and adds consideration of the major practical issues associated with deploying these methods at geographical scales appropriate for basin district or national assessments.

3.2.1.1 Traps

Wolf traps, or related systems, or use of winged nets deployed for research purposes can provide precise estimates of migrating eel population dynamics and under some circumstances, all silver eels can be counted and weighed. However, this is usually only possible in smaller river systems where the gear can fish the entire width of the channel and where discharge patterns allow for silver eel trapping throughout the migration season. Examples of this type of silver eel escapement estimation include the studies undertaken on the Norwegian River Imsa (Vollestad & Jonsson, 1988), the French Rivers Frémur (Feunteun *et al.*, 2000) and Oir (Acou *et al.*, 2009) or the Burrishoole (Poole *et al.*, 1990).

There are several issues with applying this method for eel stock assessment that mean it is not widely suitable. Given that the trap is required to fish the entire river width, there are likely to be relatively few suitable sites. There are exceptionally high resource requirements associated with installing and maintaining traps. Full and accurate measures of silver eel escapement require that the trap operates throughout the entire period when emigrating fish are passing the site, and that they are all captured. However, the capture efficiency of the trap may often be reduced by varying flow conditions. Further and given the considerable size range of silver eels in some basins which may vary from 35 to 100+ cm length, the trap design may not be suitable to catch eels across the whole size range – i.e. is size selective. This is often the case with commercial gears (see below), especially where the fishery is controlled by a minimum size limit for the catch. In such circumstances, the catch may not accurately represent the full run.

3.2.1.2 Fisheries-based

Commercial silver eel fisheries can, depending on their location and scale, provide good opportunities for direct estimation of the numbers and biomass of escaping silver eels, provided that it is possible to determine the efficiency (proportion of run or local stock that is captured) of the eel capture systems involved (see 3.2.1.4). Examples of such investigations, of population dynamics and seasonal patterns of seaward migrating eels, include those undertaken on the River Loire, River Shannon and Corrib, River Bann (Lough Neagh outlet), the River Imsa, and the Baltic basin (Vollestad and Jonsson, 1988; Feunteun *et al*., 2000; Allen *et al*., 2006; WGEEL Baltic sea; McCarthy *et al*., 2008). Catch and effort data from closely monitored fisheries in enclosed waterbodies such as Lake IJsselmeer (Netherlands) (Dekker, 2000c) and Lough Neagh (Northern Ireland: Rosell *et al*., 2005) allow detailed assessments of eel production. However, such large and discrete eel fisheries constitute only about 5% of the continental fisheries, with the remainder consisting of very small and disparate fisheries in comparison (Dekker, 2000a).

As with scientific monitoring studies, difficulties can occur when the fishing season does not cover the full migration period or when there is significant eel production downstream of the fishery area. Furthermore, eel management plans may include silver eel fisheries management such as legal size limits and/or reduced fishing seasons that will prevent the monitoring of the complete migration. Use of mark/recapture (M/R) methods for estimation of fishery capture efficiency allows for an estimation of the numbers and biomass of migrating eels at the fishing sites.

3.2.1.3 Fish Counters

Counters and various acoustic technologies can allow for the estimation of silver eel escapement in locations where eel capture is not possible. McCarthy *et al*., (2008) used hydroacoustic methods to investigate variations in numbers of silver eels migrating downstream in the headrace canal of the Ardnacrusha hydropower plant in the River Shannon, Ireland. Resistivity counters have been trialled for counting emigrating silver eel in the UK (J. Hateley, pers. comm.), as have high-frequency multi-beam sonar (Didson) in the UK and the Netherlands (J. Hateley and W. Dekker[5], pers. comm.). The Didson is not suitable for deployment in rivers >15 m width and with a depth <1m, and the main constraint at sites of appropriate dimensions is that the site must have a suitable profile with minimum or little shadowing of the beam.

Such eel counts, and linked data on size frequencies of the migrating eels, are only possible in locations where other fish species (with target strengths in the same range as the silver eels) are not also migrating downstream at the same time as eels. Work is in progress in Ireland, UK, Poland, Sweden and other European countries that should lead to improved sampling protocols and to more widespread use of this method for estimation of eel escapement rates.

3.2.1.4 General issues with these approaches

Few fisheries or in-river traps are operated at the mouth of the study basin, and therefore they miss any silver eel produced from the habitats further downstream. This is especially a problem when the study basin includes the estuary or even coastal waters. Given the practical and logistical difficulties associated with methods relying solely on capture of silver eels, not least the ability to catch the eels in a manner that is representative of the entire run, there are relatively few places across Europe where this method could be adopted. When one considers the requirements for a suite of methods appropriate to the diverse range of habitats across Europe, therefore, it is apparent that we must rely on a modelling approach.

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[5] **http://www.imares.wur.nl/NL/onderzoek/faciliteiten/didson/**

Where catch efficiency is not 100%, mark-recapture methods could be employed to estimate capture efficiency of the trap, based on the proportion of marked eels that are recaptured. The total catch is then raised by this efficiency to estimate the size of the run. A comprehensive measure of capture efficiency would incorporate the varying effects of river condition and fish size. Note therefore that M/R requires a model-based approach to raise the catch to the whole population based on estimates of capture efficiencies: all the methods require some form of model-based approach to raise catches in account of device selectivity/efficiency and/or accounting for downstream parts of the basin.

A further limitation of these direct approaches, as it relates to this project and European assessment and management of eel, is their inability to provide a measure of potential 'pristine' silver eel production in the absence of data from the appropriate historic period. Although such historic data exist and have been used for a small number of river basins, e.g. Burrishoole (Ireland: Western District EMP), Neagh/Bann (UK N. Ireland: Neagh/Bann EMP), the approach cannot be used to back-calculate from present to historic production. Thus, while a new direct approach might be deployed in a river basin, it can only provide an estimate of silver eel production from now onwards, assuming constant conditions. Predictions of future biomass in response to management actions require an estimate of cumulative lifetime mortality (**A**), which the user can "switch on or off" depending on the selected scenario. Thus, we are reliant on models of eel production to estimate pristine and future levels.

3.2.2 Silver eel output derived from yellow eel data

In the places where no fishery occurs estimates of silver eel escapement ($\mathbf{B}_{post}$ and $\mathbf{B}_{best}$) will have to be derived from the yellow eel stage, and more specifically from fishery independent surveys, such as electrofishing or fyke net sampling.

3.2.2.1 Silver eel output based on pre-migrant status.

The use of proxy indicators from sedentary eels and habitat population models has been applied in experimental studies to estimate silver eel escapement (Feunteun *et al.*, 2000; Aprahamian *et al.*, 2007; Lobon-Cervia & Iglesias, 2008). A number of morphological characteristics have been identified that indicate pre-migrant status of eel, i.e. that they should be expected to emigrate as silver eels in the next migrant season (Feunteun *et al.*, 2000; Durif *et al.*, 2005). It is possible therefore to estimate silver eel production from a watercourse based on the numbers of such pre-migrant eels (Feunteun *et al.*, 2000; Acou *et al.*, 2009).

3.2.2.2 Silver eel outputs based on yellow eel data and GIS approaches.

At a wider geographical level, the EDA (Eel Density Analysis, Hoffmann, 2008; French EMP) model is being developed using the GIS layer of the CCM (the European-based river network). The principle is the same as in the previous case: estimates of numbers and biomass of silver eels are derived from yellow eel surveys. Most countries conduct a sampling programme to estimate the ecological status of freshwater and transitional waters as part of their responsibilities towards the European Water Framework Directive (WFD). These sampling programmes provide a good coverage of the river and lakes drainage network.

The EDA concept uses a modelling tool based on a geolocalized river network to: (1) relate observed yellow eel densities or yellow eel catch per unit effort (CPUE) from experimental samplings to different parameters - sampling methods, environmental conditions (e.g. distance to the sea, relative distance, temperature, Strahler stream order, elevation and slope), anthropogenic conditions (obstacles, fisheries, land use) and time (year trends); (2) calculate the yellow eel density in each reach of river network by applying the statistical model calibrated in step 1; (3) calculate the overall yellow eel stock abundance by multiplying these densities by the wetted surface area of the reaches and by summing them; (4) calculate a potential silver eel escapement by converting the yellow eel stock estimated in step 3 into silver eel stock; and, (5) when silver eel mortalities (fisheries, turbines) are known (or estimated) they can be used to assess the silver eel escapement.

The tool will predict eel densities from a variety of methods (e.g. fyke net cpue, point density estimates, single pass electro-fishing) by treating them as categorical variables in the model. However, this requires calibration according to the bias of the various methods, determined from comparison with eel-specific methods.

The tool can simulate the population in the absence of the impact of anthropogenic factors such as dams and turbines. The assessment of these impacts will, in the vast majority of cases, not be driven by data specific to the location, but will be based on values derived from the literature or mark/recapture experiments. The impact of a yellow eel fishery can be estimated from catch records. The estimate of silver eel (equivalents) can be estimated using the silvering rate and observed or estimated sex ratio. The model can estimate current silver eel escapement in terms of biomass (**B**) and 'pristine' biomass (**B_0** by removing the effects of turbines and fisheries and correcting for the recent European recruitment decline.

3.2.2.3 Uncertainties and sampling biases

Both the pre-migrant and EDA approaches will have to cope with two main sources of uncertainty.

First, the relationship between silver eel migration and pre-migrant number is indeed uncertain. Evidence suggests that some pre-migrants may not emigrate in the year of marking (Feunteun *et al*., 2000) and that studies using this method should be conducted over a number of years, or at the least tested more widely, before using the pre-migrant numbers as a proxy for the silver eel run.

The present version of the EDA model estimates silver eel escapement assuming that a fixed proportion (5%) of the yellow eel stock matures and emigrates each year. This estimate is thus even more crude than the estimation based on estimates of the numbers of pre-migrant silver eels. The EDA estimate could be improved using the length frequency of yellow eels to derive the silvering rate for each sex. As an example, the probability that a yellow eel will mature into a silver eel at length L can be estimated using the relationship of Bevacqua *et al*., (2006):

$$S(L) = S_{\infty} [1 + e^{(\lambda - L)/\eta}]^{-1}$$

Where Y_{∞} is the asymptotic maturation rate, λ is a semi-saturation constant and η is a shape parameter which is inversely proportional to the slope of the curve at $L = \lambda$. The semi-saturation constant (λ) can then be adapted for river specific data.

There is a need to calibrate the EDA model against several silver eel output datasets across Europe, and it is anticipated that this will be achieved in the POSE project.

The second assumption is that the eels sampled during the surveys are representative of the eel population across the river basin, such that the survey results can be raised to the system, typically according to the relative wetted areas. These procedures should be standardized so that methodologies used can provide representative estimates of silver eel production, e.g. sampling at the beginning of the migratory season (late summer in southern latitudes and middle summer in northern latitudes). Several habitat types representative of each catchment should be evaluated in order to allow for extrapolations to the whole catchment. Acou *et al*., (2009) estimated silver eel production from two coastal river systems of western France, the Fremur and Oir, based on 29 surveys covering about 2.3% of the wetted area in the Fremur, and 32 sites in the Oir, accounting for 8% of fluvial habitat, though these were concentrated ina 7.5 km length of river.

Obtaining population density estimates for yellow eels in large water bodies including still waters is often difficult or impossible. Studies suggest that eels are often confined to shoreline margins of still waters because of the presence of cover and food (Jellyman & Chisnall, 1999; Schulze *et al*., 2004), though this is a topic that has received relatively little study. Whilst the presence of eel has also been recorded along the shoreline margins of many lake systems throughout Ireland (Rosell *et al*., 2005; Matthews *et al*., 2001; Moriarty ,1988; Poole, 1994), these findings are commonly associated with seasonality: the shallower waters warm up quickest thereby promoting eel feeding behaviour in these regions. However, commercial fishing experience and scientific survey data have revealed that as water temperatures begin to rise in the summer,eels are more commonly found in the deeper (>9 m) waters (Allen *et al*., 2006; Matthews *et al*., 2003; Poole pers. comm.). Nevertheless, extrapolation of fluvial densities across the entire surface area of still waters may overestimate eel production from some still waters. Conversely, applying a 2.5 m wide shoreline strip of stillwater habitats, such as was suggested for the Fremur, implying that eels were absent from about 95% of the fluvial wetted area (Acou *et al*., 2009), is likely to grossly underestimate eel production in many waters.

The surveys have a significant resource requirement and therefore the numbers and distribution of surveys is often limited. To date we are unaware of any study testing the number and distribution of surveys against the accuracy of their representation of the actual yellow eel population in a river system. Statistical methods are available to aid sampling design (e.g. power analysis), but these must be incorporated with spatial information on habitat diversity and distribution in order to develop statistically robust stratified sampling programmes.

Finally, there is a need to be able to expand the approach (or include addition modules) to take account of eel in the transitional and coastal waters. Data that can be used to feed into these modules may be available from the transitional waters surveys conducted for the WFD and from the coastal demersal fisheries that are undertaken by a number of countries (Dekker, 2009).

3.2.3 Yellow eel fishery-based methods to provide estimates of B and A

In cases where fisheries mortality (F) is considered the most important contributor to the total mortality (Z), and where information on catch-at-age or catch-at-length is available, methods which are conceptually similar to VPA or LVPA, and which account for silver eel escapement, can be used to estimate total mortality and the stock size. This is appropriate where F is the major determinant of Z, but there are few examples of this in eel fisheries (e.g. Lake IJsselmeer, Netherlands; Lough Neagh, Northern Ireland).

We envisage that for many local eel stocks, a recruitment index and information on the length composition of the population will be available from point surveys and/or from fishery data: the latter are often, though not always, required to provide length frequency distributions. In such cases, a general modelling approach to estimating mortality would model the length-frequency distribution given the past variation in recruitment, mortality and growth, and fit this to the observed length-frequencies of the population. The selectivity of the survey and catchability of the local stock will have to be taken into account (see Bevacqua *et al.*, 2007), as well as potential spatial structure in variations of the length distribution across the local stock. Total stock biomass will have to be estimated independently from this, for example by extrapolating abundances from area-specific survey data to the total wetted area. The EDA modelling approach described above is one method to achieve this result.

Combinations of catch and survey data can be used to estimate mortality and biomass. For example, Dunn *et al.*, (2009) used commercial catch-at-length data, length compositions from scientific surveys, biological information on age-, and weight-at-length, maturity ogives, etc. to estimate fisheries mortality and spawning stock biomass for New Zealand longfinned eels in a statistical framework which allowed for ageing misclassification.

If there is no fishery, or the fishery does not have a major impact on the local stock, models will have to be based on the length (or age) structure of the population, determined by scientific surveys. There are some ICES stock assessment methods based on survey data alone, such as the SURBA (VPA-type) model. A methodology similar to SURBA, but based on length-frequencies (thus using an LPVA) could be used for yellow eels, if emigration is incorporated into the model, and natural mortality is known.

The Eel Length Structured Analysis (ELSA; Lambert *et al.*, 2006; Beaulaton, 2008; Lambert, 2009) is specifically designed to assess total mortality (and anthropogenic mortality providing natural mortality is known) using yellow eel length data from fisheries as well as from scientific surveys. It handles the major eel life history processes of sexual differentiation, growth, recruitment variability, natural and anthropogenic mortality, gear selectivity and silvering. However, even if the results obtained seem to be satisfactory, calibration is difficult and the parameters are correlated.

3.2.4 Coupling fishery-based and fishery-independent estimates of B

In many river basins, only some parts of a river basin or EMU are fished, or have sufficient catch statistics to enable a fishery-based stock assessment. In these cases, applying a statistical model derived from fishery-independent surveys will enable the assessor to derive $\mathbf{B}_{\mathbf{post}}$ at the catchment or EMU level (see 3.2.2). If density dependence is neglected, landings can be used to predict $\mathbf{B}_{\mathbf{best}}$, i.e. the silver output that would have occurred in the absence of the fishery. The prediction of biomass will enable to balance the contribution of each part of the basin or of the whole catchment in terms of the total anthropogenic mortality (such as in figure 2.5). The same aggregation can be employed for different river basins at the EMU level.

3.2.5 Modelling the glass eel stage

The anthropogenic impacts at the glass eel stage are primarily either pumping station intakes or glass eel fisheries. The latter takes place only in Spain, Portugal, France, and the United Kingdom, with France having the largest glass eel fishery. A suitable candidate for this estimation is the GEMAC (Glass eel Model to Assess Compliance) model (Beaulaton & Briand, 2007). This model simulates the effect of recruitment, anthropogenic mortality (fishery or pump intake), natural mortality and migration, in one or several areas of an estuary. Daily transformed values of salinity and temperatures are used to calculate a pigmentation time, which then determines the pigmentation stage structure (used as a derivative for age structure) and settlement process.

The model inputs are: temperature; salinity; fishing effort reported as volume filtered daily by the nets; the volume filtered by the turbines; the mortality rate of the glass eel in the intake; the water volume of the fishing area; and, some daily estimations of the actual density of glass eel, which can be measured through experimental sampling, or using of mark-recapture techniques (Briand *et al*., 2006). The model outputs are the % settlement per glass eel recruit, the absolute recruitment, the number of settled glass eels with current or a pristine level of recruitment, the pigmentation stage structure and the catches.

The calibration could be done either once a year, or for each evaluation round of the management plan. The density of glass eel should provide some means to directly ex-post evaluate the effect of management measures. The main strengths of GEMAC are:

- it is data driven;
- the estimation of fishing and intake mortality is quite robust, and the model is not sensitive to parameter variation (Beaulaton & Briand, 2007);
- it was built to assess compliance and will provide the cumulated anthropogenic mortality at the glass eel stage;
- in data rich situations it will provide an escapement target of settled glass eel, and an estimate of glass eel densities, which could be used as an ex-post evaluation criterion;
- in data poor situations, it will be easily adapted to derive proximate criteria and still compute the required cumulated anthropogenic mortality.

The main weaknesses are:

- the pigment stage structure is based on two years of experiments using glass eels in captivity that might not replicate the pigmentation process in the wild;
- the model will use the parameters for settlement and pigmentation as fitted for the Vilaine and the Gironde;
- the model relies on the assumption that the glass eel density is constant within the fishing area;
- there is a large uncertainty about the level of natural mortality at the glass eel stage used in the model (however this is not a highly sensitive parameter in the model).

GEMAC estimates the number of settled eel and, therefore, in the absence of any anthropogenic mortality, silver eel escapement (by number) can be derived by incorporating an estimate of natural mortality, and escapement biomass can be derived by further incorporating an estimate of the typical weight of silver eel.

Another model developed by Prouzet *et al*., (2007) has been used to calculate the recruitment and exploitation rates in an estuary, but it requires that the fishery is concentrated in the downstream part of the estuary (a section on which fishing daily exploitation rates will be calculated) and a calibration based on an intensive set of experimental fisheries.

4 Data needs for international eel stock assessment

4.1 Recruitment Time Series

Analysis of recruitment time series has been the main tool in the past for assessing the overall status of the eel stock. These time series have consisted of a combination of fisheries-dependent and fisheries-independent data on both glass eel and young yellow eel stages. It was cautioned by the EIFAC/ICES Working Group on Eel (WGEEL, 2008) that data discontinuities, particularly related to data from commercial fisheries, can be expected following implementation of EMPs (e.g. management measures affecting fishing effort, season quota, size limits), and CITES restrictions, although at that time it was unknown to what extent this might impact on the data series.

A preliminary review has indicated a total of 47 time series of varying length are available for analysis (Table 4.1).

For the glass eel recruitment series, four have now ceased and 14 are vulnerable to major changes. This means that only 17 of the 35 glass eel series are still available for time series analysis into the future and for bench marking changes in recruitment after 2010. It should be noted that 10 of the 14 vulnerable glass eel series are for the Bay of Biscay and Iberian Atlantic where recruitment is concentrated, with probably only one series remaining unaltered from this area. There is also a paucity of recruitment data for the Mediterranean, with three series remaining, each from commercial fisheries which may change in the future.

The yellow eel time series remain largely unaffected by any changes due to the implementation of management measures: none have closed and only two appear vulnerable. The yellow eel time series are strongly focussed in the Scandinavian area with seven Swedish, one Norwegian and one Danish series. There is also one Belgian and one Irish time series available.

Table 4.1. Numbers of recruitment time series available for historic and future time series analysis, along with those lost, or vulnerable to discontinuity changes.

	TOTAL NUMBER	NUMBER CEASED	NUMBER VULNERABLE TO CHANGES	NUMBER OK FOR HISTORIC ANALYSIS	NUMBER OK FOR FUTURE ANALYSIS
Glass Eel	35	4	14	34	17
Yellow Eel	12	0	2	12	10
Total	47	4	16	46	27

The expected changes to the recruitment time series due to the implementation of management measures, particularly the glass eel time series, has reduced the data available for ex-post evaluation by almost half. This means the provision of scientific advice on changes to the stock based on recruitment series is now vulnerable and it is unlikely that statistical modelling will be able to correct for this.

4.2 Data Requirements by EU, DCF, WFD and CITES

The EIFAC/ICES Working Group on Eel (WGEEL, 2008) provides a list of data required from EU and other international legislative texts (Table 4.2).

It was noted that in almost all cases, these data do not currently exist and therefore new data series will need to be commenced.

Table 4.2. Overview of potential data provisions as required by EC Eel Recovery Regulation (EC EEL), guidance document for preparation of EMPs (GD EC EEL), Data Collection Framework (DCF), Water Framework Directive (WFD) and CITES requirements if international trade exists. Redrawn from EIFAC/ICES WGEEL 2008.

DATA ELEMENT	EC EEL	GD EC EEL	DCF	WFD	CITES
EMU and River Basins	Y	Y		Y	(Y)
List Commercial Fishermen	Y				(Y)
Catch by Recreational Fishers	Y		Y		
List of Primary Sellers	Y				(Y)
Traceability in Trade	Y	Y			Y
Fishing Capacity		Y	Y		(Y)
Silver Eel Escapement	Y	Y			(Y)
Potential Silver Eel Escapement ($B_{pristine}$)	Y				
Fishing Effort by Métier	Y	Y	Y		(Y)
Glass Eel Landings	Y	Y	Y		(Y)
Yellow Eel Landings		Y	Y		(Y)
Silver Eel Landings		Y	Y		(Y)
Catch Composition Length			(+)		
Biological Sampling for Length, Age, Sex, Maturity			+	(Y)	
Recruitment Surveys					
Yellow Eel Surveys				Y	
Silver Eel Surveys		Y			
Hydropower mortality - No. stations		Y		Y	(Y)
Hydropower mortality		Y - if info available			(Y)
Predation Losses		Y - if info available			(Y)
Eel Quality (contaminatants, parasites, pathogens, fat levels)		Y			

Y = required as primary function, (Y) = required as cross-compliance; + = adequately covered; (+) = partially covered but inadequate

An overview of the availability of the data series is given in Table 4.3, revealing several patterns. First, limited data are available for landings by recreational fisheries, traceability of eel catches, hydropower mortality, predation losses or eel quality (contaminants, parasites, fat content). It is also not likely that such data will be widely available in the near future (2012).

Fisheries-dependent data are either available or regular sampling programs are being developed by nearly all countries contributing to SGIPEE. In contrast, some fishery-independent surveys (e.g. yellow eel surveys) are being conducted, but few countries are planning to develop new eel-specific fishery-independent surveys in the near future. This is slightly surprising as in EU countries some fisheries-independent data on eel should become available through WFD fish monitoring obligations. However, the eel is not a target species of the WFD so high quality data on abundance cannot be expected, but basic presence/absence data for eel from a variety of water bodies should become available. Furthermore, eel specific sampling programmes could possibly be integrated in accordance with Water Framework Directive.

It was also surprising that there were some missing estimates of $\mathbf{B}_{\text{pristine}}$ as this should have been reported on by each country in its EMP. This presumably reflects the inability of some countries to estimate $\mathbf{B}_{\mathbf{pristine}}$ in rivers where there are little or no historic or recent data on eels.

Table 4.3: Overview of the availability of data as described in Table 4.1, established in co-operation with SGIPEE or WGEEL members (Table 3.3) during the SGIPEE meeting. 1 = data available, regular program in place; 2 = data will be available in the near future, regular program being developed; 3 = partly available, no regular program, individual *ad hoc* studies; 4 = no data available, no program in the near future; 5 = not applicable.

	DATA ELEMENT	SE	FI	LT	PL	DK	DE	IR[1]	UK	NL	PT	FR	SP	IT
	EMU and River Basins	1	1	1	1	1	1	1	1	1	1	1	1	1
	List Commercial Fishermen	1	1	1	1	1	1	1	1	1	1	1	2	2
	Catch by Recreational Fishers	5	3	2	1	2	3	4	4	2	4	2	2	2
	List of Primary Sellers	1	3	1	1	1	2	1	1	1	1	1	2	2
	Traceability in Trade	4	4	1	1	4	2	5	1	4	4	1	2	2
	Fishing Capacity	1	5	1	1	1	2	1	1	4	5	1	2	2
	Silver Eel Escapement	1	2	2	1	2	1	1	2	2	2	1	1	1
	Potential Silver Eel Escapement (Bpristine)	4	4	1	1	1	1	1	2	1	1	1	1	1
Fisheries Dependent	Fishing Effort by Métier	1	4	1	1	2	2	3	1	2	4	1	2	2
	Landings Glass Eel	5	5	5	5	5	5	1	1	5	1	1	2	2
	Landings Yellow Eel	1	3	1	1	1	2	1	1	2	2	2	2	2
	Landings Silver Eel	1	3	1	1	1	2	1	1	2	2	2	2	2
	Catch Composition Length	2	3	2	1	2	2	3	2	2	4	2	2	2
Fisheries Independent	Biological Sampling for Length, Age, Sex, Maturity	1	1	2	1	2	1	3	3	2	4	2	2	1
	Surveys Recruitment	1	4	2	2	1	1	1	1	1	4	1	2	1
	Surveys Yellow Eel	4	4	2	2	4	4	1	1	2	4	1	1	1
	Surveys Silver Eel	4	4	2	2	4	3	1	1	2	4	2	2	1
	Hydropower mortality Number of stations	1	4	1	2	1		1	1	1	5	2	2	1
	Hydropower mortality	2	4	2	2	2	3	1	4	2	5	3	2	4
	Predations Losses	3	4	3	3	2	3	3	4	3	3	3	2	4
Eel Quality	contaminants	3	3	4	2	4	3	3	2	1	3	2	2	3
	parasites/pathogens	3	3	3	2	4	3	1	2	1	4	2	2	3
	fat levels	3	4	4	2	4	3	3	3	2	4	2	2	3

[1] = Irish fisheries closed but data still available

4.3 Conclusions and recommendation for Chapter 4: data needs for international eel stock assessment

- The absence of any internationally driven requirement to maintain a recruitment data series needs to be corrected and SGIPEE highlights the recommendations of WGEEL 2008 and EU Contract 98/076: Establishment of an international recruitment monitoring system for glass eel.
- Member states could benefit from internationally co-ordinated survey methods that are being developed to estimate catches of selected species like eel, cod, salmon, sea bass and blue fin tuna by angling and non-angling recreational or leisure fishers in Europe. A Planning Group of Rec-

reational Fisheries Surveys met in Bergen, Norway (7-11 June 2010). In the near future this Planning Group should be able to compile European estimates of recreational catches that can be used by eel managers and stock assessment scientists.

- Integration between eel-specific data collection programmes and fish monitoring programmes conducted in accordance with the Water Framework Directive is recommended. Although the eel is not specifically targeted by the WFD, such monitoring programmes could still contain useful data on the distribution and abundance of eel. Further, it may be possible to make modest adjustments to existing sampling programmes to obtain more suitable data on eel abundance.
- Efforts to establish time series for glass eel in non-EU countries (e.g. Norway, Turkey, Egypt, Tunisia, and Morocco) should be continued.

5 Conclusion

5.1 Main achievements

This SG design a pragmatic framework to ex-post evaluate at the stock-wide level eel management measures. This includes:

- A definition of stock indicators and reference points;
- An overview of potential ex-post evaluation tests;
- A practical representation of results from a classical ICES precautionary diagram;
- A framework to compile lower-scale stock indicators into stock-wide stock indicators;
- An overview of available methods to assess required stock indicators;
- Some proposals to improve those methods;
- An overview of available data;
- Some proposals to improve data collection to cover data requirement for international ex-post evaluation.

5.2 Next steps

Future work will be dedicated to test the feasibility, the sensitivity and the robustness of this framework (ToR c) such as the SG will be able to make recommendations on ex-post evaluation methods for 2012 and data collection and development needed after 2012 (ToR d).

The following tasks are thus foreseen:

- To apply the ex-post evaluation framework to real data, particularly to data collected by WGEEL;
- To apply this framework to simulated data to check the reliability of this method for detecting any change in eel stock and conduct a power analysis;
- Considering those test and analyses, to recommend any improvements in this framework as well as further knowledge development and data collection.

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Annex 2: Agenda

Agenda for SGIPEE 2010, Vincennes, France

Monday, 10 May

09:30–10:00 welcome coffee

10:00–10:30 introduction and housekeeping

10:30–10:45 place of SGIPEE work in WGEEL work (RP)

10:45–11:00 POSE project (AW)

11:00–11:30 ex-post evaluation discussion

11:30–12:00 meeting organisation

13:00–18:00 subgroup work

18:00–19:00 plenary

Tuesday, 11 May

08:30–10:00 plenary

10:00–18:00 subgroup work

18:00–18:30 plenary

Wednesday, 12 May

08:30–10:00 subgroup work

10:00–14:00 report reviewing

14:00–15:00 conclusion writing

15:00–16:00 get organised for next steps

16:00 end of meeting

Annex 3: SGIPEE Terms of Reference for the next meeting

The **Study Group on International Ex-post evaluation on Eels** (SGIPEE), chaired by Laurent Beaulaton, France, will meet in VENUE, DATE May 2011 to:

a) Review stock assessment and ex-post evaluation methods available for species of eels, and those used by ICES Expert Groups on other species, that could be successfully applied to eels at the stock-wide level in 2012;

b) Adapt methods for stock-wide ex-post evaluation of *Anguilla anguilla* and apply them to data collated by WGEEL at its annual meetings; (this may include aggregation of EMU ex-post evaluation);

c) Analyze sensitivity of the selected methods to stock improvement or deterioration using simulated data;

d) Submit recommendations to WGEEL on: the best available ex-post evaluation method for 2012; gaps in data or knowledge that need to be filled before 2012; and methods that should be developed and data that should be collected after 2012 for the next stock-wide evaluation.

SGIPEE will report by 30 June 2011 (via SSGEF) for the attention of WGEEL, WGRECORDS and SCICOM.

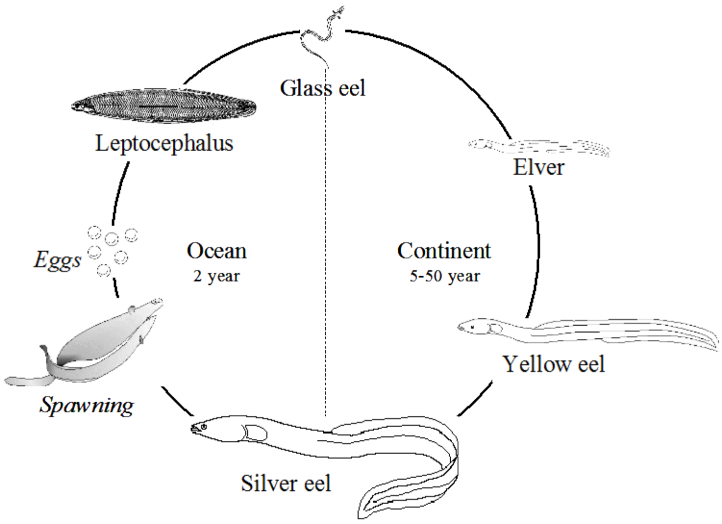
Supporting Information

Priority:	Evaluating the status of the stock and post-evaluating the effect of management plans at the European level should be of the uttermost priority. An urgent requirement to prepare for EU 2012 reporting.
Scientific justification and relation to action plan:	European and American eel stocks are currently in a severely depleted state. ICES has proposed that biological reference points for eels could be derived from spawner-per-recruit (SPR) analysis and the EU Regulation for the Recovery of the Eel Stock requires biomass estimates of current silver eel escapement. So far the difficulty of having many different independent parts of the stock isolated in different river basins and areas with varying anthropogenic impacts, and levels of information has hampered the achievement of a stock-wide analysis of the stock and precluded fully informed analyses of the stock-recruitment and recruitment-stock relations. Nevertheless, the attempts made so far to estimate the restoration time and to calibrate required management actions are alarming and highlight the necessity of better knowing the stock status, and threats posed by density-dependent (depensatory, compensatory) mechanisms. Management plans when put into action should bring a wealth of new data, which will fail to produce a clear picture of the stock if they lack the structure and coordination required for a stock wide assessment. However, if collected correctly and used judiciously they could be used to enhance the current knowledge of stock status, and provide a European overview of current mortalities and biomass levels. Analyses, development and testing of the methods, and their dependence on data, will help to build a consistent pan-European post evaluation tool, leading in turn to calibrate future measures. It is highly likely that ICES will be requested to undertake the evaluation of the outcome of the Regulation following Member State reporting in 2012 and 2015. It is beyond the capacity of the WGEEL in its annual meetings to develop this capacity and WGEEL strongly recommend the formation of the SG. DGMARE have funded a pilot study to estimate silver eel biomass at the local level but neglected to include a stock-wide ex-post evaluation mechanism in the project. This SG is aimed at filling this gap.

Resource requirements:	
Participants:	Members of WGEEL and invited experts from areas of the North Atlantic and elsewhere with eel populations.
Secretariat facilities:	A centralized database should help the achievement of international ex-post evaluation
Financial:	
Linkages to advisory committees:	The proposal is of direct relevance to ACOM in relation to the development of appropriate assessment methods for eel.
Linkages to other committees or groups:	WGEEL, WGRECORDS, SCICOM , other Working Groups on inshore fisheries.
Linkages to other organizations:	EU FP7 EELIAD, European Union Recovery Plans; DGMARE pilot project on estimating silver eel escapement; Canadian Eel Science Working Group, U.S. Atlantic States Marine Fisheries Commission Eel Technical Committee

Annex 4: Glossary

Eels are quite unlike other fish. Consequently, eel fisheries and eel biology come with a specialised jargon. This section provides a quick introduction for outside readers. It is by no means intended to be exhaustive. This glossary repeats and completes WGEEL 2009 glossary.



The life cycle of the European eel. The names of the major life stages are indicated. Spawning and eggs have never been observed in the wild.

EEL LIFE STAGE	
Glass eel	Young, unpigmented eel, recruiting from the sea into continental waters
Elver	Young eel, in its 1st year following recruitment from the ocean. The elver stage is sometimes considered to exclude the glass eel stage, but not by everyone. Thus, it is a confusing term.
Bootlace, fingerling	Intermediate sized eels, approx. 10–25 cm in length. These terms are most often used in relation to stocking. The exact size of the eels may vary considerably. Thus, it is a confusing term.
Yellow eel (Brown eel)	Life stage resident in continental waters. Often defined as a sedentary phase, but migration within and between rivers, and to and from coastal waters occurs. This phase encompasses the elver and bootlace stages.
Silver eel	Migratory phase following the yellow eel phase. Eel characterized by darkened back, silvery belly with a clearly contrasting black lateral line, enlarged eyes. Downstream migration towards the sea, and subsequently westwards. This phase mainly occurs in the second half of calendar years, though some are observed throughout winter and following spring.
EEL MANAGEMENT	
Eel River Basin or Eel Management Unit (EMU)	"Member States shall identify and define the individual river basins lying within their national territory that constitute natural habitats for the European eel (eel river basins) which may include maritime waters. If appropriate justification is provided, a Member State may designate the whole of its national territory or an existing regional administrative unit as one eel river basin. In defining eel river basins, Member States shall have the maximum possible regard for the administrative arrangements referred to in Article 3 of Directive

	2000/60/EC [i.e. River Basin Districts of the Water Framework Directive]." EC No. 1100/2007
River Basin District (RBD)	Area of land and sea, made up of one or more neighbouring river basins together with their associated surface and groundwaters, transitional and coastal waters, which is identified under Article 3(1) of the Water Framework Directive as the main unit for management of river basins. Term used in relation to the EU Water Framework Directive.
Stocking	Stocking is the practice of adding fish [eels] to a waterbody from another source, to supplement existing populations or to create a population where none exists.
Geographical unit	Some analysis (e.g. modified precautionary diagram) can be done for different geographical scale (watershed, EMU, RBD, country, …). Geographical unit are the unit of the defined geographical scale.
EEL REFERENCE POINTS / POPULATION DYNAMIC	
Anthropogenic mortality after management (A_{post})	Estimate of anthropogenic mortality after management actions are implemented
Anthropogenic mortality before management (A_{pre})	Estimate of anthropogenic mortality before management actions are implemented
Best achievable biomass (B_{best})	Spawning biomass corresponding to recent natural recruitment that would have survived if there was only natural mortality and no restocking; that is
Interim Target for biomass ($B_{interim}$)	Pragmatic intermediate goals for spawner escapement biomass; set by managers.
Interim Target for mortality ($A_{interim}$)	Pragmatic intermediate anthropogenic mortality goal; set by managers.
Limit anthropogenic mortality (A_{lim})	Anthropogenic mortality, above which the capacity of self-renewal of the stock is considered to be endangered and conservation measures are requested. (Cadima, 2003)
Limit spawner escapement biomass (B_{lim})	Spawner escapement biomass, below which the capacity of self-renewal of the stock is considered to be endangered and conservation measures are requested. (Cadima, 2003)
Precautionary anthropogenic mortality (A_{pa})	Anthropogenic mortality, above which the capacity of self-renewal of the stock is considered to be endangered, taking into consideration the uncertainty in the estimate of the current stock status.
Precautionary spawner escapement biomass (B_{pa})	The spawner escapement biomass, below which the capacity of self-renewal of the stock is considered to be endangered, taking into consideration the uncertainty in the estimate of the current stock status.
Pristine biomass (B_0)	Spawner escapement biomass in absence of any anthropogenic impacts..
Spawner escapement biomass after management (B_{post})	Estimate of spawner escapement biomass after management actions are implemented
Spawner escapement biomass before management	Estimate of spawner escapement biomass before management actions are implemented

(B_{pre})	
Spawner per recruitment (SPR)	Estimate of spawner production per recruiting individual.
%SPR	Ratio of SPR as currently observed to SPR of the pristine stock, expressed in percentage. %SPR is also known as Spawner Potential Ratio.
Anthropogenic mortality after management after (A_{post})	Estimate of anthropogenic mortality after management actions are implemented
Anthropogenic mortality before management (A_{pre})	Estimate of anthropogenic mortality before management actions are implemented
Best achievable biomass (B_{best})	Spawning biomass corresponding to recent natural recruitment that would have survived if there was only natural mortality and no restocking; that is
Interim Target for biomass ($B_{interim}$)	Pragmatic intermediate goals for spawner escapement biomass; set by managers.
Interim Target for mortality ($A_{interim}$)	Pragmatic intermediate anthropogenic mortality goal; set by managers.

Annex 5: Mathematical notation

%SPR	ratio of spawner per recruit (SPR)
A	anthropogenic mortality (F+H)
B	spawning stock biomass
F	fishing mortality
H	anthropogenic mortality other than fishing mortality
L	length
N	number of silver eel escaping
R	recruitment
S	fraction of eel that silver

<u>Subscript:</u>

∞	asymptotic
0	pristine
a	silvering
interim	interim target
lim	limit
pa	precaution
post	after management
pre	before management
t	year of silvering