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Executive summary

This Report summarizes the presentations, discussions and recommendations of the 2011 session of the ICES Study Group on International Post evaluation on Eels which took place in London, United Kingdom, hosted by the Environment Agency, from 24 to 27 May 2011. This study group was chaired by Laurent Beaulaton (France) and involved 13 people from 8 countries.

This study group is intended to design, test, analyse and report on a method of scientific ex-post evaluation at the stock-wide level of applied management measure for eel restoration. After a first meeting mainly focused on designing the appropriate framework and the methods for eel ex-post evaluation and reviewing available data, this meeting test the reliability of this framework.

The scientific basis and the applicability of the modified ICES precautionary diagram have been improved. The possibilities of data deficiencies and inconsistencies have been explored and a first draft of a quality control sheet has been designed. Additionally a power analysis has been conducted to see the ability to detect any change in stock status indicator (recruitment and silver eel biomass). It shows that, given the high natural variability of biological processes, the probability to detect any change, even in case of strong management measures, is very low in 2012 but increase with time. As a consequence, in the short term, the most important parameter to post-evaluate the result of implemented eel management measures is anthropogenic mortality since most effects on biomass will only show up after several years.

1 Introduction

At the 98th Statutory Meeting of ICES (2010) it was decided that:

2009/2/SSGEF20: The **Study Group on International Post evaluation on Eels** (SGIPEE), chaired by Laurent Beaulaton, France, will meet in London, UK, 24–27 May 2011 to:

a) Review stock assessment and 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 post-evaluation of *Anguilla anguilla* and apply them to data collated by WGEEL at its annual meetings; (this may include aggregation of EMU 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 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.

Thirteen people from eight 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 was beyond the resources 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 did not include a stock-wide ex-post evaluation mechanism in the project. This SG is aimed at filling this gap.

A first meeting of the SG in 2010 (ICES, 2010a) has designed a pragmatic framework to ex-post evaluate at the stock-wide level eel management measures 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.

During 2010 WGEEL meeting (ICES, 2010b), this framework has been applied to real data coming from WGEEL country report. It shows both the potential usefulness of the modified precautionary diagram (MPD) but also underlines the possibilities of having missing data or inconsistency between data.

This meeting is dedicated to testing the feasibility, sensitivity and robustness of this framework and to make recommendations on the best ex-post evaluation method for 2012 and data collection and development needed after 2012.

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 "improvement of modified precautionary diagram", "data deficiencies and inconsistencies" and "power analysis" addressed the Terms of Reference as follows:

Chapter 2 reviews the modified precautionary diagram (MPD) developed in 2010 and presents the application of it in simple cases and its usefulness at the short, medium and long term (ToR b).

Chapter 3 reviews the vulnerability of recruitment series and the risk of having missing data preventing of making the MPD and the consequences on the post-evaluation process. A first step toward a quality control framework has been taken in order to evaluated data and method used to derive pristine and current biomass as well as anthropogenic mortality (ToR c).

Chapter 4 reviews methods to implement a power analysis adapted to eel case. Some of those methods are used to assess when an increase or a further decrease in recruitment or escapement can be detected (ToR c).

Chapter 5 presents the recommendation of the group in terms of gaps in data or knowledge and needs of further method development (ToR d).

2 The modified precautionary diagram

2.1 Introduction to post-evaluation

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 post evaluation process is given in Figure 2.1 (reproduced from ICES, 2010a). 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 silver eel 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, 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.

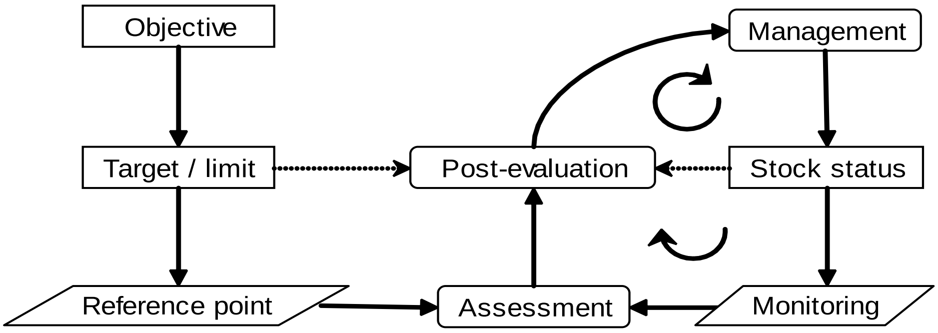

Figure 2.1. A conceptual view on the post evaluation process, and the role of stock assessment. To post evaluate whether the objective has been achieved by the implemented management, the stock status should be compared to the predefined targets/limits (dotted arrows). However, the actual status of the 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 post evaluation to its Member States (EU 2007; Dekker, 2009). Eel management plans (EMPs) have been submitted by Member States in 2008/2009 and a 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 post evaluated without considering the overall efficacy of all EMPs. This requires an international post-evaluation, as planned by WGEEL. ICES (2010a) considered two different approaches for this. 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. The 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". Most of the necessary monitoring structures and data should be available at the EMU level, and the interpretation of the results is easier. Additionally, the regional assessments will be required for post-evaluation of national Eel Management Plans anyhow. ICES (2010a) derived a framework for post-hoc summing up of stock indicators. 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, which also feeds into the international post-evaluation framework.

In the 2010 Report of SGIPEE, a pragmatic framework to post-evaluate the status of the eel stock and the effect of management measures has been designed and presented, including an overview of potential post-evaluation tests and an adaptation to the eel case of the classical ICES precautionary diagram. In the Precautionary Diagram, annual fishing mortality (averaged over the dominating age groups) is plotted versus the spawning stock biomass. In the modified Precautionary diagram proposed by Dekker (2010), lifetime anthropogenic mortality ΣA is plotted against silver eel escapement (in percentage of Bo). This modified diagram allows for comparisons between EMUs (%-wise SSB lifetime summation of anthropogenic mortality) and comparisons of the status to limit/target values, while at the same time allowing for the integration of local stock status estimates (by region, EMU or country) into status indicators for larger geographical areas (ultimately: population wide).

In this chapter, we discuss certain aspects and the interpretation of biological reference points used in the diagram, the time scale of post evaluation in eel and we describe the use and interpretation of the diagram with some examples. This chapter will also discuss different time scales for which this approach may be applied, and the values for the reference points.

2.2 Quantifying specific values for biological reference points

2.2.1 Biological reference points specified in the Eel Regulation

The Eel Regulation sets a limit for the escapement of (maturing) silver eels, at 40% of the natural pristine escapement B_0 (that is: in the absence of any anthropogenic impacts and at historic recruitment). Since current glass eel recruitment is far below pre-1980 levels (assumed to be so due to anthropogenic impacts), return to this target level is not expected before decades or centuries even if all anthropogenic impacts are removed (FAO EIFAC and ICES 2006, 2007; Åström & Dekker 2007). Member States are obliged to develop a time schedule for the recovery process.

The EU Regulation thus sets a clear limit for the spawning stock biomass B_{lim}, as a percentage of B_0. However, no explicit limit on anthropogenic impacts A_{lim} is specified, and current biomass is below B_0 and B_{lim}. We can however derive theoretical mortality reference point from this set limit B_{lim} (see next paragraph).

2.2.2 Theoretical Mortality Reference Point corresponding to the EU regulation

The Eel Regulation specifies a limit reference point (40% of pristine biomass B_0) for the size of the spawning stock in terms of biomass. For long-lived species (such as the eel) with a low fecundity (unlike the eel), biological reference points are often formulated in terms of numbers, rather than biomass. Though numbers-based and biomass-based reference points will differ slightly, a mortality-based reference point will be derived here, that results in 40% of the pristine stock *numbers*.

The number of silver eels escaping to the ocean equals[1]:

$$Esc_t^* = N_t^* \times \exp^{-A_t^*} = N_t \times \exp^{-A_t^* - S_t} = R_{t-a} \times \exp^{-S_t - \sum_{i=0}^{a} M_{t-a+i,i}} \times \exp^{-A_t^* - \sum_{i=0}^{a} A_{t-a+i,i}}$$

Without anthropogenic mortality, the last factor ($\exp^{-A_t^* - \sum_{i=0}^{a} A_{t-a+i,i}}$) vanishes. Hence, the number of silver eels escaping, as a percentage of the number that would have escaped without anthropogenic impacts is

$$\%SPR_t = \exp^{-A_t^* - \sum_{i=0}^{a} A_{t-a+i,i}} \quad (\times 100\%)$$

This is independent of the number of recruits and the natural mortality (unless density dependence is significant). If the limit reference point on the *number* of silver eels escaping is set at 40%, it follows that

$$A_t^* + \sum_{i=0}^{a} A_{t-a+i,i} = -\ln(\%SPR) \leq -\ln(40\%) = 0.92$$

i.e. the sum of all anthropogenic impacts, summed over the entire continental life span (∑A) should not exceed a fixed value of 0.92.

For stock levels above the limit of 40% silver eel escapement (EU target, B_{lim}), a lifetime anthropogenic mortality (∑A) of less than 0.92 is expected to ensure that the numbers of silver eels escaping remains above 40% of the numbers that would have escaped if no anthropogenic mortality would have been present.

For an SSB below 40% of pristine (Bo), a limit for anthropogenic mortality cannot be set as a robust stock-recruitment relationship for eel does not exist. The varying degrees of uncertainty in the estimates of pristine silver eel production make direct evaluation of progress toward the 40% biomass level (called for in the EU Regulation) difficult.

2.2.3 Mortality Reference values derived from historical time trends

A limit for anthropogenic mortality was proposed by Åström & Dekker (2007) at ∑A =0.48 over the lifetime of the eel, which quantifies the objective to hold the decline. However, there are inconsistencies between the data used (Dekker 2000b) and the analyses made by Åström & Dekker (2007). Specifically, it was assumed that these

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[1] Notation in these equations:

X*	parameter X as applied in the silver eel stage. Hence: A* is the anthropogenic mortality (A) in the silver eel stage.
Esc	silver eel escapement. the number of silver eels leaving the area towards the ocean.
t	time, in years
a	age, in years since recruitment to the continent
%SPR	ratio of spawner per recruit (SPR), the current SPR as a percentage of SPR in the pristine state.
A	anthropogenic mortality (fishing F & other anthropogenic mortality H)
M	natural mortality.
N	number of eels in the stock; N* is the number of silver eels produced (before mortality)
R	recruitment
S	instantaneous rate of the silvering process, i.e. the silvering process expressed as a rate

data were derived from a steady state, in which contemporary glass eel catch data could be matched to contemporary yellow & silver eel catch data, as if these were coming from the same cohorts. The mortality estimates by Dekker (2000b) are crucially based on the assumption of a steady state, while Åström & Dekker (2007), however, analysed the trend in recruitment, and derived estimates of the lack of a steady state in the population, using the mortality estimates by Dekker (2000b) without correction. Dekker (2000b) indicates that the mortality estimates given will probably underestimate the true mortalities and therefore there is some concern about the validity of this estimate.

The Simple Eel Dynamics Model (SED) used in Lambert (2008) is an adaptation of Aström and Dekker (2007) model applied to French Atlantic coasts. It assumes an eel population with spawners only produced in the French Atlantic, uses a continental lifespan of 9 years (instead of 16 years) and an anthropogenic mortality level ΣA of 1.83 instead of 3.24, resulting in a threshold anthropogenic mortality of $\sum A$ =0.73.

FAO EIFAC and ICES (2007) was unable to determine whether the anthropogenic mortality rate ($\sum A$) should be kept below 0.03 or 2.9 (two extremes for north and south Europe) in order to safeguard long-term recruitment, and consequently advised that the only option was:

"...to apply the precautionary principle and recommend complete closure of all fisheries. Since this alone might not suffice, reductions of other anthropogenic factors will be required."

2.2.4 Reference points in ICES advice

Since 1998 (ICES 1999 through to ICES 2010), ICES has given advice[2] that the stock has shown a long-term decline and therefore management is not sustainable; that fishing and other anthropogenic impacts should be reduced; that a recovery plan should be compiled and implemented; that preliminary reductions in mortality to as close to zero as possible are required until such a plan is implemented, respectively until stock recovery has been achieved.

ICES (2002a) discussed a potential reference value for spawning stock biomass: "a precautionary reference point for eel must be stricter than universal provisional reference targets. Exploitation, which provides 30% of the virgin (F=0) spawning stock biomass is generally considered to be such a reasonable provisional reference target. However, for eel a preliminary value could be 50%.". That is: ICES advised to set B_{lim} above the universal value of 30%, at a value of 50% of B_0. ICES (2007) added: "an intermediate rebuilding target could be the pre-1970s average SSB level which has generated normal recruitments in the past."

The Eel Regulation (Council Regulation 1100/2007) sets a limit for the escapement of (maturing) silver eels, at 40% of the natural escapement (that is: in the absence of any anthropogenic impacts and at historic recruitment). That is: EU decided to set B_{lim} at 40% of B_0, in-between the universal level and the level advised. ICES (2008) noted that its 2002 advice was "higher than the escapement level of at least 40% set by the EU regulation."

ICES has not advised on specific values for mortality-based reference points, but the wordings "the lowest possible level" and "as close to zero as possible" imply that F_{lim} resp. A_{lim} should be set (close) to zero. Over the years, the implied time-frame for this advice has changed from "until a plan is agreed upon and implemented", to "until stock recovery is achieved" and "until there is clear evidence that the stock is increasing". The first and third phrases are more interim precautionary mortality advice

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[2] ICES (1999) advised "The eel stock is outside safe biological limits and the current fishery is not sustainable. (…) Actions that would lead to a recovery of the recruitment are needed. The possible actions are 1) restricting the fishery and/or 2) stocking of glass eel. "

ICES (2000) recommended "that a recovery plan should be implemented for the eel stock and that the fishing mortality be reduced to the lowest possible level until such a plan is agreed upon and implemented."

ICES (2001) recommended "that an international rebuilding plan is developed for the whole stock. Such a rebuilding plan should include measures to reduce exploitation of all life stages and restore habitats. Until such a plan is agreed upon and implemented, ICES recommends that exploitation be reduced to the lowest possible level."

ICES (2002) recommended "that an international recovery plan be developed for the whole stock on an urgent basis and that exploitation and other anthropogenic mortalities be reduced to as close to zero as possible, until such a plan is agreed upon and implemented."

ICES (2006) advice read: "An important element of such a recovery plan should be a ban on all exploitation (including eel harvesting for aquaculture) until clear signs of recovery can be established. Other anthropogenic impacts should be reduced to a level as close to zero as possible."

ICES (2008a) concluded "There is no change in the perception of the status of the stock. The advice remains that urgent actions are needed to avoid further depletion of the eel stock and to bring about a recovery."

ICES (2009) reiterated its previous advice that "all anthropogenic impacts on production and escapement of eels should be reduced to as close to zero as possible until stock recovery is achieved".

ICES (2010c) reiterated its previous advice that "all anthropogenic mortality (e.g. recreational and commercial fishing, barriers to passage, habitat alteration, pollution, etc.) affecting production and escapement of eels should be reduced to as close to zero as possible until there is clear evidence that the stock is increasing."

than clear reference point related to any biomass. If $B>B_{lim}$ is considered as the translation of "stock recovery", the second phrase is the only providing a quantifiable reference value which is $A_{lim}=0$ at $B<B_{lim}$.

2.2.5 Remark on unquantifiable effects

In the precautionary diagram, only quantitative effects are represented. E. g., pollution is only included if it has a quantifiable effect on survival during the continental stage or on growth rates. In turn this means that only management measures can be evaluated, which act on such quantitative parameters. Oceanic factors are also not directly included (only via potential effects on recruitment, which is not explicitly shown in the diagram). Therefore, with the precautionary diagram only effects of management measures during the continental phase can be assessed.

2.2.6 Conclusion on biological reference points to be used in the modified precautionary diagram

In the absence of accepted values for quantitative biomass and mortality based reference points and noting that unquantified processes are involved in ICES advice, the Study Group decided to abstain from actual comparisons between (observed or predicted) states of the stock and quantified reference values, while recommending that WGEEL further considers the situation.

2.3 Time scales

Due to the long life cycle of the eel, the time scale for post evaluation has to be considered. In addition, because of the time-varying character of the stock status, as well of the management measures being taken, the data collection and the analysis methodology should allow for time-varying results. Moreover, simulation of the expected stock status presented by FAO EIFAC and ICES (2007) indicates that in the short-run, even major reductions in fishing impact are expected to result in relatively minor changes in abundance and age composition. It is therefore important, to include time-varying parameters in the stock assessment procedures. High stochastic variation is a recurring theme in the analysis of trends in eel abundance, and explained variance is typically less than 25% of the total variation (Dekker 1998, 2000a, 2003a,b). Power-analysis (Dekker 2005; current report, section 4) indicates that increasing the number of samples is a costly solution and environmental nuisance factors (e.g. water temperature, river flow) will still hide the signal in the data. Therefore, accurate estimates can likely not be derived within a single year. Accumulating information and averaging over several years will be required to get a sensible signal, even if protective management measures would have been introduced immediately and to the full extent.

The EU-Regulation 1100/2007 defined the biomass of escaping silver eels as a limit parameter, since silver eel represent the final stage in the continental phase. Yet, the effect of many possible management measures will only be reflected in silver eel biomass after some delay following implementation. It is therefore important to consider the time scale of post evaluation in relation to different indicators.

The main indicators are:

- anthropogenic mortality;
- silver eel escapement;
- glass eel recruitment.

With regard to the time scale, short-, medium and long-term aspects can be differentiated. Whereas changes in anthropogenic mortality become immediately visible in the precautionary diagram (Y-axis, short-term) changes in the spawner biomass (escapement of silver eels) will usually need some years to develop (medium-term). Changes in natural glass eel recruitment, and subsequent follow through to silver eel, will become visible only with greater delay (long-term) and are not reflected directly in the precautionary diagram.

These aspects of time scale apply similarly for the potential post-evaluation test provided in Table 2.2 in ICES (2010a). For the tests of biomass-parameters, the delay in the response of silver eel biomass must be considered, whereas the mortality-based tests can be applied immediately.

Table 2.1. Schematic overview of potential post evaluation tests, based on biomass or anthropogenic mortalities, detecting trends or testing against specific set-points (reproduced from ICES 2010a) .

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, $B_{best} < B_{lim}$).

	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?	$\mathbf{B}_{post} << \mathbf{B}_{best}$ 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.

For the post-evaluation, three different time scales are relevant:

- Short term. This includes the period for implementing stock-protection measures and evaluating their immediate effect. In almost all cases, this boils down to a single year, but data collection and analysis might delay the actual post-evaluation. Within a single year, a change in mortality level can be expected, but most effects on the biomass of the stock and the biomass of silver eel escapement will be delayed until all eels have grown to the silvering eel stage. The exception to this are management measures impacting on the silver eel stage, where the effect is immediate. In practice, this short term might well coincide with the three-year evaluation cycle of the EU Regulation, but this is not necessarily the case.
- Medium term. This covers the period for stock protection measures to get full effect on all year-classes that have already been recruited to the stock the moment the measures are taken. For instance, measures related to the glass-eel stage will only affect the silver eel escapement after the glass eel have grown to the silver eel stage, nearly a full life span later. In medium term projections, no newly recruiting year classes are considered. As a consequence, this time scale covers the maximum period for which local

scale predictions can be generated. Later year classes immigrating will depend on oceanic stock dynamics, which (also) depend on management regimes and conservation measures taken in other areas and requires adequate knowledge of the Stock-Recruitment relation. Excluding later year classes from the medium-term, local stock dynamics are locally predictable, in principle. Note that for management actions affecting the silver eel stage, the short-term and medium-term effectively overlap.

- Long term effects (called secondary effects in Åström and Dekker 2007) include the dynamics in the oceanic phase of the life cycle, generating new year classes. Since it is assumed that reproduction may involve silver eels escaped from (any/all) other management areas, the long-term dynamics cannot be predicted at a local or regional scale. Consequently, the long-term necessarily is dealt with at the international scale.

2.3.1 Short term and medium-term evaluation and prediction

The short term covers one or a few years, in which management measures have been (newly) implemented. The post-evaluation in 2012 (using data up to 2011) focuses on the effects of measures taken in 2010, that is: just one year before. Consequently, by 2012, only short-term effects can be considered, showing up in the vertical axis (mortality) of the precautionary diagram, but not having a (full) effect on silver eel escapement (horizontal axis), except for measures affecting the silver eel stage.

In principle, there can be two ways to calculate the effect of recently introduced management measures. SGIPEE (ICES, 2010a) advised to calculate %SPR=Bcurrent/Bbest, which ultimately is equal to exp(-ΣA). In the short run, however, these two calculations are not identical. Cohorts present in the stock have experienced previous year’s mortality levels in the past and will experience future mortality levels in the coming years. Ultimately, coming silver eel escapement will be determined by the sum of mortalities in previous and future management regimes. As a consequence, actual escapement will only slowly converge to a level corresponding to the newly implemented mortality regime, while lifetime mortality based on today’s mortality level will show an immediate response.

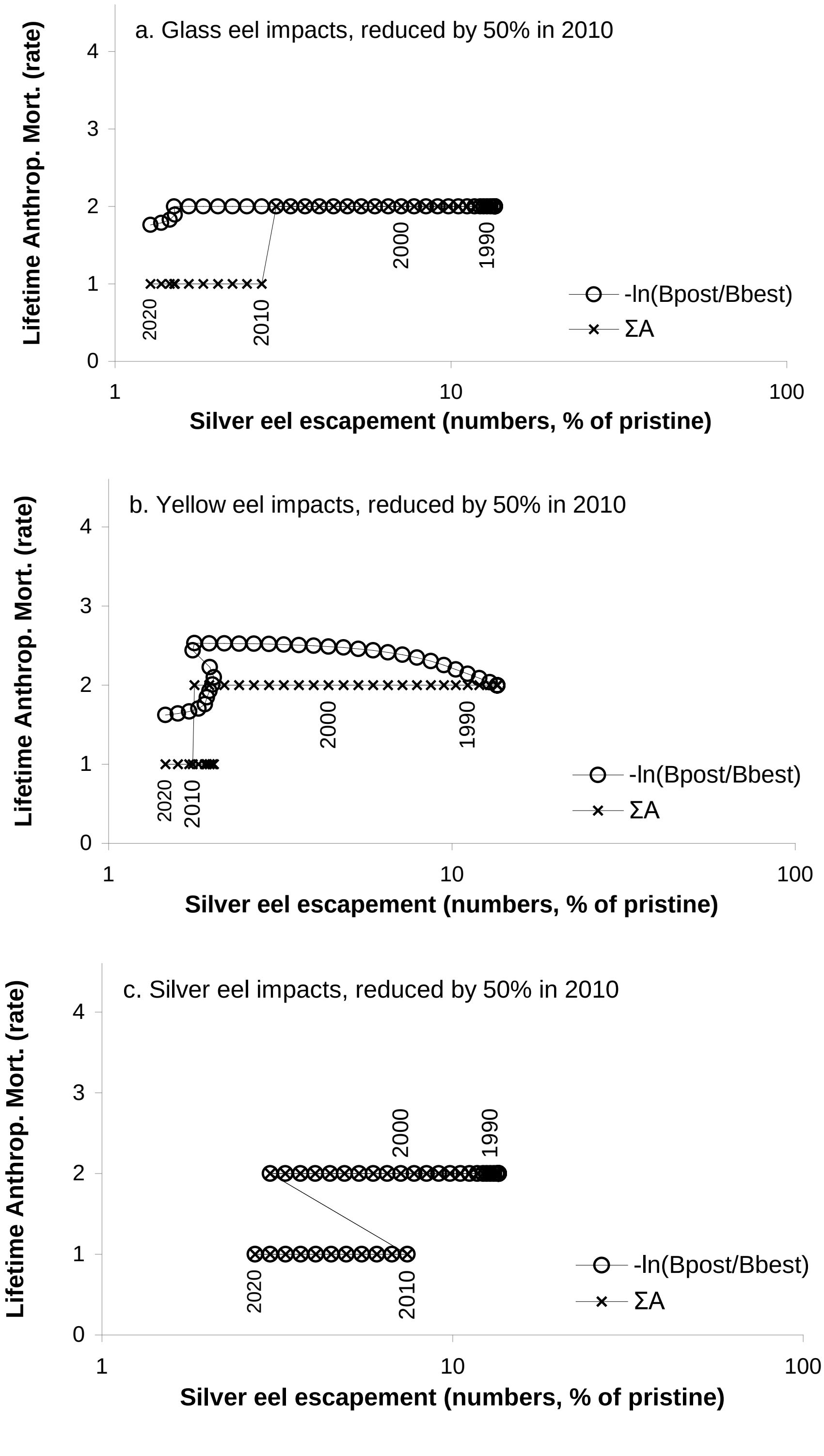


Figure 2.2. Modified Precautionary Diagrams for three simulated case studies, showing the difference between lifetime anthropogenic mortality quantified by the ratio of "observed" to "best" silver eel escapement, respectively by the sum of "observed" mortality rates. For all three cases, a stable recruitment starts to decline by 10% per year in 1980; a stable mortality level of ∑A=2.0 in (a) the glass eel stage, (b) the yellow eel stage, respectively (c) the silver eel stage, is maintained stable until 2009 and then set to ∑A=1.0 for all years following. The model used is the WHEM-model, described in FAO EIFAC and ICES (2009). Note that a declining trend in recruitment leads to an increasing estimate for $-\ln(B_{current}/B_{best})$ in the yellow eel stage, because the stock becomes increasingly dominated by older yearclasses, that have a longer lifetime. If recruitment would increase in future, the reverse (lower apparent mortality) would occur.

Figure 2.2 shows medium term predictions for a simulated case, in which there is either a large impact on the glass eel, on the yellow eel, or on the silver eel, each of which is reduced by 50% in 2010 (Note: each case has an impact on just a single life stage). The figure has both $-\ln(B_{post}/B_{best})$ showing delayed effects and ΣA showing immediate effects on the vertical axis. For the glass eel case, it takes nearly a life time before any effect of management measures on silver eel escapement is predicted, while for the silver eel case, all effects show up immediately. The yellow eel case shows intermediate effects.

It will be in line with the conventional ICES procedures and the standard Precautionary Diagram to focus on ΣA, that is: to show the full effect of management measures taken (vertical) even though the effect on biomass (horizontal) has not yet fully occurred.

ICES (2010a, b) listed the minimum data requirements as B_0, B_{best}, and B_{post} where one of the B's could be replaced by ΣA. The above discussion of the short-term now indicates that ΣA must also be included in all cases.

2.3.2 Long term evaluation and prediction

On the long-term, coming recruitment will be influenced by the current and future escapement levels. At this scale, local/regional recruitment may depend on stock-wide protection measures, which is not predictable at the local/regional scale. At the international level addressed by ICES, evaluation of the combined effects in all management areas and future recruitment might indicate whether management is effective, whether recruitment indeed recovers. If no recovery in recruitment is observed, either the implemented protection measures might have not been effective enough, or other processes (changing ocean climate, effects of pollution, impacting the stock dynamics in the oceanic phase) might have been interfering. Gaps in the data (from missing EMU, country or regions) might also make it difficult to detect a change (see 3.2). Because of the long delay in effect of some management measures especially those affecting the glass eel stage, this can only be analysed after many years, say after 2020.

3 Data deficiencies and inconsistencies

3.1 Recruitment time-series

The assessment of the status of eel stock has been previously based almost exclusively on the analysis of recruitment time-series. ICES (2010a) made a preliminary review that indicated a total of 47 time-series of varying time available for the analysis. Additional data series were discovered during the preparation of EMPs. The participants of this SG (France, Germany, Ireland, Italy, the Netherlands, Spain, Sweden and UK, Annex 1) have updated this list so that there are now 56 time-series, with extra series added by France (two yellow eel series), Germany (two glass eel and two yellow eel series), the Netherlands (one yellow eel series) and Spain (one yellow eel and one silver eel series) (Table 3.1).

In ICES (2010a), the recruitment series were grouped as glass eel, immigrating yellow eel. Noting that the EIFAC/ICES Working Group on Eel (FAO EIFAC and ICES, 2008) cautioned that data discontinuities could occur because of the implementation of EMPs and CITES restrictions on trade, the ICES (2010a) table assigned each data series as either Vulnerable to Change, OK for Historical Analysis and/or OK for Future Analysis. Give that these risks may be particularly great for data from commercial fisheries (e.g. management measures might affect fishing effort, season quota, size limits), here the series are presented separately in the table as fisheries-dependent and fisheries-independent.

Amongst the glass eel recruitment series, at least 19 of the 37 total series are available for time analysis, as 14 are vulnerable to major changes and 4 have now ceased. As indicated by the EIFAC/ICES Working Group on Eel (ICES, 2010b), 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.

Most of the yellow eel time-series are largely unaffected by management measures, as all series are fisheries-independent. Only two appear vulnerable, but it should be noted that five series (one from Spain and four from Germany) are very recent (2000, 2002*2, 2003 and 2004 to present). However, as noted by the EIFAC/ICES Working Group on Eel (ICES, 2010b), the yellow eel time-series are strongly focussed in the Scandinavian area with seven Swedish, four German, one Norwegian and one Danish series. The quality of the "new" time-series will have to be addressed by WGEEL 2011. In Table 3.1 yellow eel recruitment series are separated from yellow eel time-series that target older yellow eels. During WGEEL 2011 silver eel series will be added to the table of eel time-series.

Table 3.1. Numbers of recruitment time-series available for historic and future time-series analysis, along with those lost, or vulnerable to discontinuity changes. The "?" indicate to occurrence of 'new' time-series that have not been quality assured for inclusion in the global analysis. It is anticipated that this QA will be addressed by WGEEL 2011, who will also split the table further to distinguish between young yellow eel (recruits) and older yellow eel (catch) series and add silver eel series.

	Total Number	Number ceased	Number vulnerable to changes	Number OK for historical analysis	Number OK for future analysis
Glass eel	37	4	14	34	19
Fishery dependent	15	4	8	14	3
Fishery independent	22	0	6	20	16
Yellow eel (recruitment)	12	0	2	12	10
Fishery dependent	0	0	0	0	0
Fishery independent	12	0	2	12	10
Yellow eel	7	0	0	1	7
Fishery dependent	0	0	0	0	0
Fishery independent	7	0	0	1	7?
Total	56	4	16	47	36

3.2 Missing Data for the Modified Precautionary Diagram approach

From above discussion (2.3.1), the minimum data requirements for the post-evaluation is B_0, B_{best}, B_{post} and ΣA ("3Bs&A").

We considered here the possibility that some of these data would not become available as part of the 2012 review process, what would be the consequences of an in-complete data set for the post-evaluation, and what alternative actions might be taken to work with the missing data.

All those countries that implemented Eel Management Plans in the 2009–2011 will have to review these in 2012 and report these reviews to the European Commission. Ideally for the post-evaluation of the Regulation, therefore, these B and A estimates should be provided in these reviews, and reported either at the country level and/or disaggregated at the EMU or catchment level.

However, a likely scenario is that these estimates are not made available from all countries in their review of EMPs. Furthermore, there are some countries in the EU who have not implemented EMPs, and there are a number of countries outside the EU that have an eel production but are not subject to the Eel Regulation. The potential implications of this scenario is considered here.

On the whole, 38 countries are comprised within the eel distribution area including Europe, Africa and Asia and have presently (or have had in the past) eel capture fisheries production according to FAO (2011). Of these, 19 countries are in the EU and have produced EMPs (Table 3.2).

The relative role these countries play in eel exploitation can be roughly derived by examining eel capture fisheries statistics. Table 3.2 gives the annual catches of eel reported to FAO statistics for 2007–2009. Note that ICES (2005) has previously identified some inconsistencies in the FAO eel statistics, so those reported in Table 3.2 should be viewed with caution, but we use them here for illustrative purposes. In each year, countries that have implemented EMPs account for most of the eel exploitation, but countries not involved account anyway for considerable productions in the region of 27 to 39% of the total catch (Figure 3.1). In the latter group, Egypt accounts for most of the eel yields, but Albania, Tunisia and Turkey also contribute. However, in the absence of information on relative catches of yellow and silver eel in these statistics, and in silver eel characteristics of these countries, it is difficult to provide any greater understanding of the relative contribution (potential) of these other countries to the spawning stock and therefore future recruitments.

Table 3.2. Overview of the EU (green) and other countries (gray) that produce(d) eel according to FAO statistics

	Eel Management Plan	EU Member	*Production (t)*			
			Before 2007	2007	2008	2009
Albania	N		Y	116	93	66
Algeria	N		Y	-	-	-
Belarus	N		Y	-	-	-
Belgium	Y	Y	Y	3	3	3
Bulgaria	N	Y	Y	30	30	30
Croatia	N		Y	-	-	0
Cyprus	N	Y	Y	-	-	-
Czech Republic	Y	Y	Y	21	21	21
Denmark	Y	Y	Y	531	457	467
Egypt	N		Y	2055	944	940
Estonia	Y	Y	Y	31	30	22
Finland	Y	Y	Y	0	0	4
France	Y	Y	Y	1229	1221	1116
Germany	Y	Y	Y	294	328	305
Greece	Y	Y	Y	21	19	16
Hungary	Y	Y	Y	34	52	92
Ireland	Y	Y	Y	94	94	94
Italy	Y	Y	Y	109	75	87
Latvia	Y	Y	Y	10	13	5
Lithuania	Y	Y	Y	15	13	9
Montenegro	N		Y	2	2	2
Morocco	N		Y	41	40	41
Netherlands	Y	Y	Y	258	256	203
Norway	Y		Y	194	211	69
Poland	Y	Y	Y	181	160	161
Portugal	Y	Y	Y	12	10	11
Romania	N	Y	Y	-	-	-
Russian Federation	N		Y	36	17	9
Serbia and Montenegro	N		Y	-	-	-
Slovakia	N	Y	Y	3	3	3
Slovenia	N	Y	Y	-	-	-
Spain	Y	Y	Y	50	60	81
Sweden	Y	Y	Y	698	666	518
Switzerland	N		Y	2	2	1
Tunisia	N		Y	250	302	108
Turkey	N		Y	179	171	158
Ukraine	N		Y	-	-	-
United Kingdom	Y	Y	Y	486	416	463

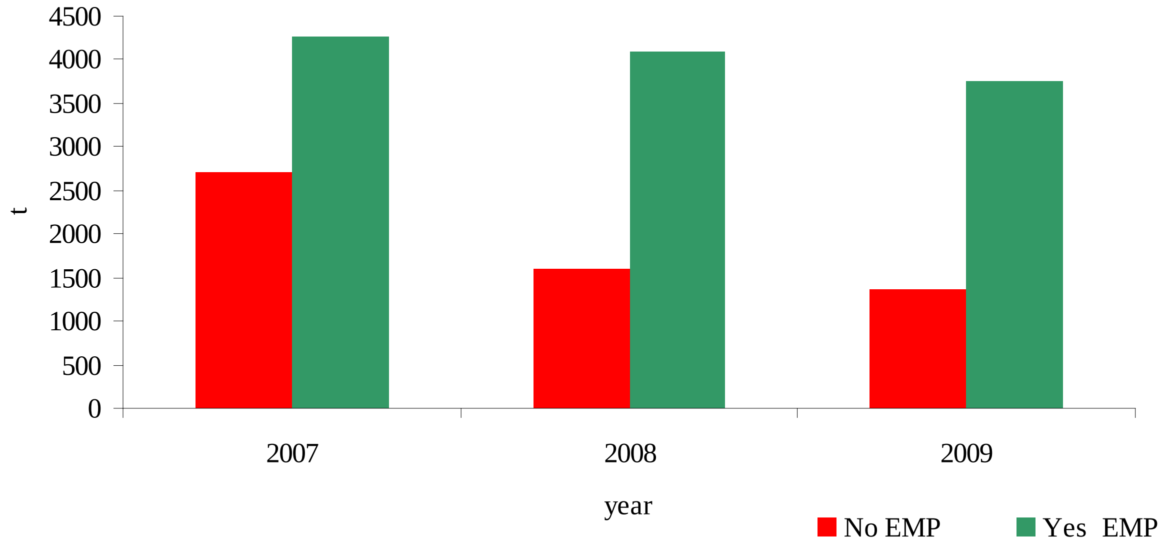


Figure 3.1. Combined catch of eel in 2007, 2008 and 2009 from countries that have implemented EMPs (including Norway outside EU) vs. those who have not implemented EMPs, based on data reported in the FAO eel catch statistics (FAO 2011).

Therefore, on the basis that the missing data may comprise a significant proportion of the stock production, the question arises about how to deal with the stock-wide evaluation if estimates are missing from these countries. The ideal response is to collect these data through another route.

The European Eel Regulation recognises that cooperation between countries within and outside EU is desired, especially where management measures taken in one country might interact with measures taken in other countries. This has brought attention to the fact that the "missing" countries that are most relevant to the production assessment are the Mediterranean countries. The Mediterranean area has been neglected up to now regarding its role in the stock-wide assessment. A distinctive contribution regarding potential and actual escapement for Mediterranean areas might be envisaged, on the basis of specific growth patterns, silvering rates and sex-ratios (Bevacqua *et al.*, 2006).

The fact that some distinctive features of eel exploitation and management, as well as biological life processes, are common to eel from countries in the Mediterranean area and in particular with reference to coastal lagoons environments, provides a key to the setting up of a relevant geographical management unit (Ciccotti, 2005).

The first approach is therefore to enhance knowledge and participation of Mediterranean countries, also increasing coordination and communication. A *Transversal expert meeting on European Eel* was held in Sfax, Tunisia, September 23-24, 2010, within the General Fisheries Commission (GFCM) Meetings (SAC-SCESS-SCMEE-SCSA). This meeting dealt with the involvement of some northern African countries in eel, particularly Tunisia. The interest and urgency to be strongly involved in the restoration of resources of this species and the need to establish a regional coordination have been underlined. (docs available at http://151.1.154.86/GfcmWebSite/SAC/2010/European_Eel/docs.html and http://151.1.154.86/GfcmWebSite/SAC/13/GFCM_SAC13_2011_Inf.14-f.pdf)

No representatives of the ICES/EIFAC Eel WG were at this meeting, while EU participated being a GFCM member, Italy and France were also present. It is recommended that such regional initiatives are coordinated and integrated with the wider picture, in order to achieve a better harmonization of efforts towards a common objective.

The opportunity to proceed to stock-wide assessment including (rough) assessment and estimates of missing countries can be dealt with by means of an extension of the "data-poor" approach developed within the POSE Project for data-poor situations.

The second approach to address the post-evaluation in the face of missing data from various countries is to limit the assessment to those Member States that do provide "3Bs&A" data (either as a group or individually). However this may prevent to have a robust long term evaluation (2.3.2)

The third approach could be to complete the missing values based on some alternative estimates. The DG MARE "Pilot studies to estimate escapement of silver eel (POSE)" is developing an approach to estimate potential silver eel production rates for those river basins where there is little or no information about the local eel stock (the data-poor river basins). Note that this approach is not intended to supplant the application of other models where eel data are available, the assumption being that these local data will provide a more appropriate and complete local assessment. This should be noted also that this model is still under development and the following is provisional.

The analytical approach has been to develop a framework for extrapolation from areas of known potential eel production measured against commonly available environmental/habitat characteristics to areas where production of eels in not known.

It was the intention from the beginning that the framework application would require data that are generally available to eel scientists throughout Europe, and this 'rule' determined which data could be applied in the framework development. Thus, these data can be found mostly in the European GIS available through the CCM (http://ccm.jrc.ec.europa.eu/php/index.php?action=view&id=23). However, there are some data that are not available from the CCM dataset but these are expected to be available to national scientists, or can be estimated using informed opinion.

However, there are several challenges with this approach:

First, the POSE framework will provide an estimate of potential silver eel production value in kg per unit area (hectares, ha). The wetted area of the river basin in question is therefore required in order to convert this production rate to an estimate of potantial biomass production (a B). Data on wetted area of river basins are not provided in the CCM European datasets used by POSE, and may not be readily immediately available to eel scientists at national level or to the assessors. So, in the circumstance where MS do not provide 3Bs, it may not be possible to easily estimate biomass production using the POSE approach. The solutions are 1) a concerted action to compile wetted area data for all river basins across Europe (possibly achieved in combination with the CCM dataset) (see ICES, 2010b), or 2) to develop an approach to estimate production for an area of river using river length, which is provided in the CCM dataset –wetted area of lakes (lacustrine) is provided in the CCM dataset.

Second, the training data used to develop the framework in POSE are heavily influenced by data from Europe while data from the Mediterranean in general, and North Africa and the eastern Mediterranean in particular were limited. As a consequence, any extrapolation outside the range of the training dataset, e.g. to North Africa should be treated with caution.

Third, the POSE approach aims to provide a means to estimate the recent potential silver eel production in the absence of anthropogenic impacts (B_{best}), and possibly the historic potential silver eel production (B_0) (depending on the outcome of the framework development for pre-1980s training data), but not the actual escapement of silver eel occurring at the present time (B_{cur}). B_{cur} can be derived from B_{best} if anthropogenic mortality rates are known. So, MS would need to supply these mortality rates. As the review of EMPs in 2012 should include estimates of the level of fishing effort that catches eel and the level of mortality factors outside the fishery, the MS of EU will have to go some way towards estimating these mortality rates.

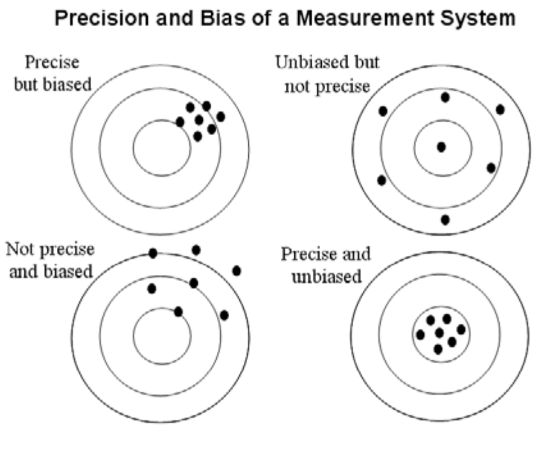
3.3 Quality criteria for "3Bs&A" estimates; developing a scorecard

This subchapter outlines the beginnings of a process of developing quality criteria for the data and models underpinning the estimates of the "3Bs&A". These quality criteria could be used initially by the member states as a check list (see Annex 5 ICES, 2010b) when preparing the 2012 reports for the EU. At a later stage the quality criteria may be used as a tool (to assess quality of the estimates and identify over- and underestimates) during the post-evaluation of European eel stocks. The following recommendations on international stock assessment were formulated during ICES (2010b):

- the reporting on stock status by countries is standardized;
- the minimal information on stock status required is Bpost, Bbest and Bo (or equivalent trios, e.g.. Bpost, ΣA and Bo);
- *quality criteria for national stock assessments are considered, and implemented*;
- intercalibration between assessment methods be executed to standardize results. This might link in with EU Project POSE and/or the ICES Study Group SGIPEE.

During the international evaluation of the status of European Eel stock it is of crucial importance that an objective quality control of accuracy of the estimates of the "3Bs&A" supplied by individual countries is implemented.

Accuracy of the "3Bs&A" will determined by the amount of bias (systematic errors) and the precision (random errors) of estimates of key parameters.



The figure above illustrates bias and precision for a parameter of interest, where the target, true value is the smallest circle in the middle, the bull's-eye.

Precise and unbiased estimates of the target values are accurate (bottom right corner). It should be noted (and emphasized) that accurate estimates cannot be obtained from significantly biased sampling schemes. Whereas precision can be improved by increasing the sample sizes in data collection programs, this is generally not the case with bias. Bias is a systematic departure from the true values caused by non-representative data collections and other persistent factors, and can generally not be quantified because the true values seldom are known. The focus should be to minimize or eliminate sources of bias by developing and following sound field data collection procedures and analytical methods.

Indicators of bias could be developed for estimates of the "3Bs&A" to identify the existence of bias in data collection schemes underlying the estimates. Indicators of bias could for example be developed following the experiences of the ICES 2008 workshop on "Methods to evaluate and estimate accuracy of fisheries data used for assessment" (ICES, 2008b) and the ICES 2009 workshop on "Methods to evaluate and estimate the precision of fisheries data used for assessment (ICES, 2010c)". It was recognized by ICES (2010c) that measures of precision estimates based on fisheries data used for assessments only are meaningful for catch sampling programs that obtain representative ("unbiased") data. In other words, and this will probably also be true for the estimates of the "3Bs&A", a minimum requirement should be that these estimates first pass basic checks for bias using a scorecard developed in this report and during WGEEL 2011 before precision measures are addressed.

Table 3.3 is an attempt to summarise some of the important criteria that needs further development (e.g. during WGEEL 2011): the list of criteria should be reviewed and realistic standards for these criteria should be formulated. Another important step during the evaluation of the "3Bs&A" is to predict if certain biases will produce an over estimate or underestimate. Finally a decision needs to made on which "rule of aggregation" to apply when moving from the individual criteria, to the three estimates and to the overall quantification of the status of a EMUs "3Bs&A" estimate (Figure 3.2).

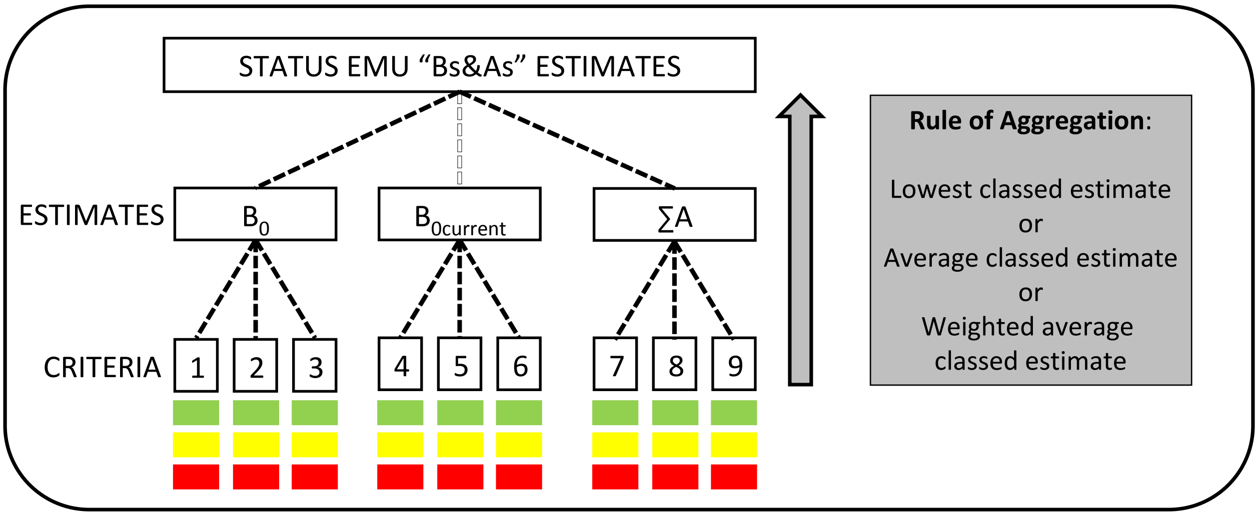


Figure 3.2. Schematic representation of how scores of individual criteria may lead through different rules of aggregations to a score for the overall status or quality of the "3Bs&A" estimates of a EMU.

Table 3.3. Example of criteria that could be a) checked and addressed by member states when reporting to the EU in 2012; and b) scored to identify and quantify potential bias in the estimates of "3Bs&A" during the international post-evaluation.

	CRITERIA	STANDARD	NO BIAS	RISK OF BIAS	CONFIRMED BIAS	DIRECTION BIAS
1	Adhere to defined minimum data requirements of the model					
2	Based on field data					
3	Assumptions transparent and robust					
4	Sensitivity of parameters					
5	Validation/calibration with field data					
6	Are all habitats (rivers, lakes, estuaries, coastal waters) covered in EMU?					
7	Scale of map used to determine wetted area					
8	Coverage eel/general fish surveys (km river sampled in relation to total river length and number of catchments sampled in relation to total number of catchments)					
9	Survey data eel specific or general fish surveys (ratio eel specific vs. general fish surveys)					
10	Are survey data from the littoral zone extrapolate to the whole surface area in wide rivers and lakes?					
11	Glass eel recruitment series (literature or locally measured)					
12	Commercial Fisheries landings (fresh water and marine) included (CV supplied by DCF regulation)					
13	Recreational Fisheries landings (freshwater and marine) included					

14	Estimates IUU Fisheries (freshwater and marine) included					
15	Temporal and spatial coverage length frequency data surveys and landings					
16	Growth rate from literature or locally measured					
17	Silvering rate from literature or locally measured					
18	Predation rate from literature or locally measured					
19	Turbine mortality from literature or locally measured					
20	Location of the turbine and wetted area/eel production above the turbine					
21	Pump station mortality from literature or locally measured					
22	Location of the pumping station and wetted area/eel production above the turbine					
23	Location of migration obstacles and wetted area/eel production above them					
24	amount of catchment/wetted area made re-accessible					
25	Amount glass eel/young yellow eels stocked					
26	Stocking density					
27	Size at stocking					
28	Biomass from stocking estimated to survive to silver eel escapement from the EMU					

4 Power analysis

4.1 Introduction

Estimates of stock size have an inherent variability (stochasticity) over time due to natural processes (variability in recruitment for example). This variability can impair any detection of trend in stock size over time, and any change in that trend. The instrument to assess the probability to detect a trend or change in trend if it is indeed present, is the power analysis. A power analysis is intimately related to the set of models that are tested against each other. We have explored various groups of trend models that we believe are suitable for evaluating the European eel management plan, in terms of changes in trends in recruitment or escapement time-series.

The first model type is a simple analysis of change over time in recruitment series, which can be expressed as, "what would have been the power to detect the change that occurred in 2009 (first year of EMP implementation)?" As there are only 1 or 2 points in the time-series since this date, it is not possible to use these data to analyze the power of any test to detect changes brought about by the EMPs. It is thus tested on past time change in recruitment. Therefore, our second and third analyses use a more complex model that simulates the response of the eel population to management actions. The second is to test whether we can detect a change relative to a default or "business as usual" scenario, while the third tests the power to detect the change in slope of the simulated recruitment series.

4.2 Estimation of the variability around model in data.

The first step in the power analysis is to analyze the inherent stochasticity of the process studied.

The Working Group on Eel (ICES, 2010b) has analyzed the trend in recruitment for two separate areas: the basins flowing into the North Sea where the decrease seems more severe, and elsewhere in Europe. The fitted generalized linear model (glm) trend on series from Europe except the North Sea area was used to build the estimate. The series was restricted to data after 1960 to ensure that the glm was fitted on more than 5 data series. Before that date, the variability in the fitted trend increases as the result of fewer series available to fit the glm.

It was assumed that the trend was exponential, with a 'regime' shift that occurred around the early 1980s when recruitment started to fall. Indeed, the breakpoint calculated by the segmented regression on the log-transformed recruitment is 1981 (Figure 4.1), and this allowed us to calculate the standard deviation around the curve as 0.3.

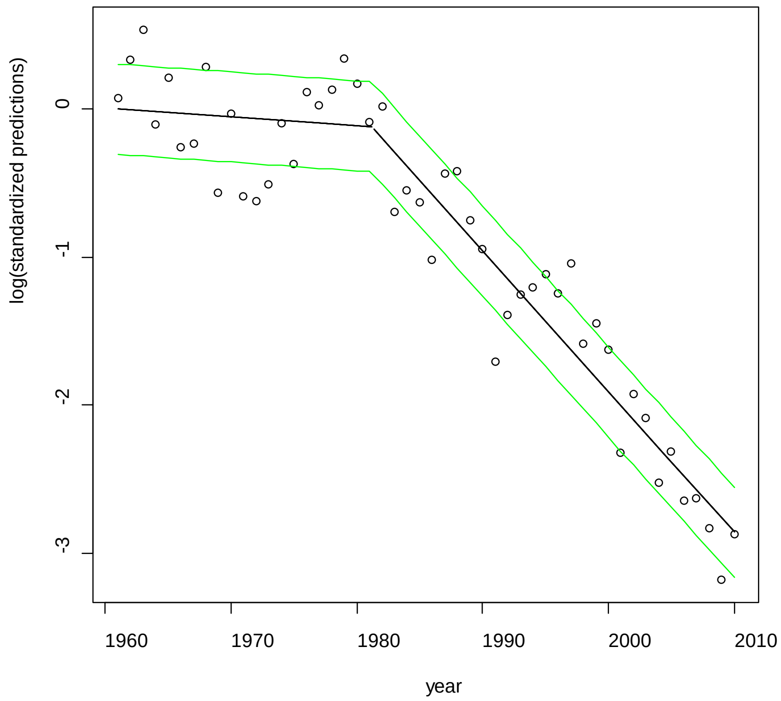


Figure 4.1. Segmented regression calculated on the glm fits of the recruitment series of glass eel (green lines indicate the standard deviation around the trend).

4.3 Statistical approach: an analysis of change in recruitment in the past

Concerning recruitment changes over time at known time t_0, a simple model has the form

(equation 1) y = a + b t + c (t-t_0) (t>t_0) + e,

where y is the random variable recruitment, t is time, t>t_0 is a Boolean that either takes the value 0 for year before t_0 and 1 after, e is an IIND error with mean 0 and standard deviation sigma, and a, b and c, are estimable parameters. The model is tested against the simple linear regression model

(equation 2) y = a + b t + e

which means that the null hypothesis H0: c=0 is tested

Practically, power analysis can be performed using the approach as described by Cohen (1988, 1992) and implemented in the R program in the function pwr.f2.test. The R function (Annex 3) may act as an example. Here the power to detect the change in recruitment since 1980 was calculated using the historical data only. The results are not very interesting in themselves, but only meant for illustrative purposes and as a starting point for further analyses. For the change analyzed in 1980, Cohen's f^2 is 1, which is very high and the power associated with the test is 0.99, which means that there is a high the probability that the segmented regression is chosen to describe the change that occurred in 1981. Instead of using Cohen's approach, power can also be calculated using simulation. The noise added to the log transformed data is the standard deviation of the residuals calculated in the previous paragraph. Using this approach the null hypothesis that c=0 is rejected 1000 times out of 1000 so this 'stochastic approach' does not bring in much more information.

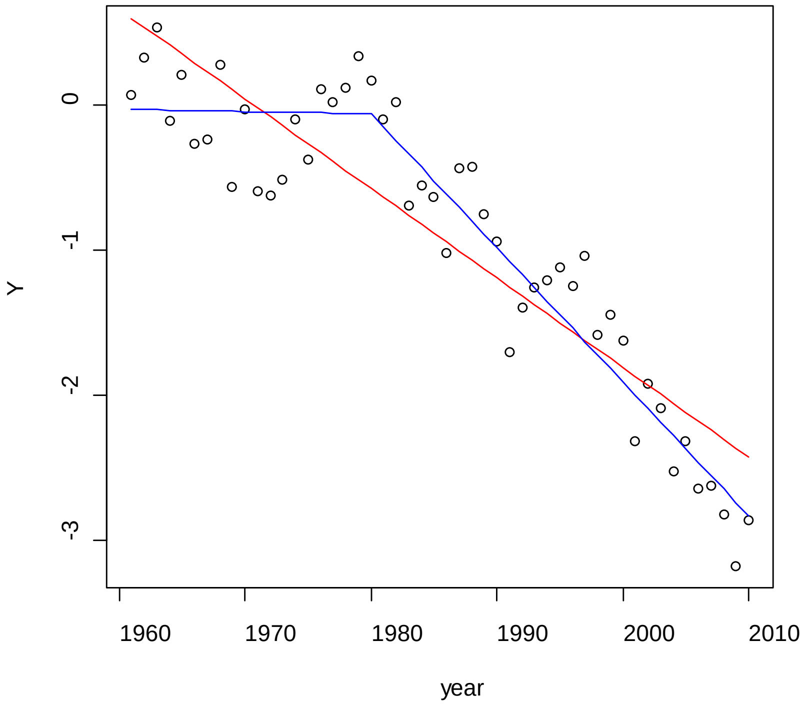


Figure 4.2. Trend in recruitment Y=log(annual recruitment) fitted with a simple linear equation (equation 1) and with a segmented regression line (equation 2).

One problem with this entirely statistical approach is that the models are extremely simple and do not contain any biologically information. As a consequence, they refer poorly to the actual biological processes being described. Alternatively, in the next paragraph, we will apply a much more relevant but complex stochastic population dynamic model, and use that model to test the hypothesis of no change in recruitment as a result of the change in management strategy. The accompanying power analysis would be performed by simulating the population trajectories and constructing the probability function of some appropriate test statistic under the various hypothetical scenarios.

4.4 SED model used to simulate time-series

In an approach similar to Åström and Dekker (2007), the Simple Eel Dynamics (SED) combines a stock recruitment relation with a mortality curve to simulate the dynamics of an eel population (Lambert 2008). The mortality curve is 'procusteanly' calibrated to fishery captures and to values from expertise for anthropogenic mortalities other than fishery. For the purpose of illustrating this approach, we used parameters describing the situation on river basins flowing into the Atlantic, Channel and North Sea French coasts (Lambert 2008, FAO EIFAC and ICES 2009). SED assumes a hockey stick stock recruitment (Barrowman and Myers, 2000) in which the slope is adapted to fit the observed trend in recruitment. The observed recruitment is actually based on the three glass eel time-series in the Vilaine, in the Adour and in the Garonne. The trend is close to the one found for Europe excluding the North Sea (ICES, 2010b).

To perform the power analysis we added a log-normal stochasticity on the stock-recruitment relationship. The standard deviation is fixed to 0.3 according to the variability observed in the glass eel times series since 1960 (see above).

First to test the ability to detect a change in the management regime, the null hypothesis H0 is fixed to the situation with no change in mortality. Alternative hypothesis are either a situation corresponding to the stabilization of the stock after 2009 or a 100% reduction of mortality that would lead to the fastest recovery of the stock. For the null hypothesis SED model was used with current mortality to estimate the state of the stock in the future. The average of the escapement biomasses from 2010 to 2012 was then calculated. The model was run 1000 times to obtain a frequency distribution of the output. The distribution allowed calculating the 95% percentile (Figure 4.3). Above the 95% percentile, H0 (no change in management regime) is rejected with a probability of 5%. For the two alternative hypotheses SED was also run 1000 times with the corresponding reduction in mortality. The frequency above the threshold corresponding to 95% percentile in the H0 output gives the power for the alternatives hypotheses. The power of 10.3% found for "Stable escapement" hypothesis means that the probability to detect a reduction mortality corresponding to a stabilization of the escapement during the 2010–2012 period if this management action is effectively implemented is 10.3%. The power is 15.2% for the second alternative hypothesis. These powers are far below the value of 80%, which is the accepted threshold standard.

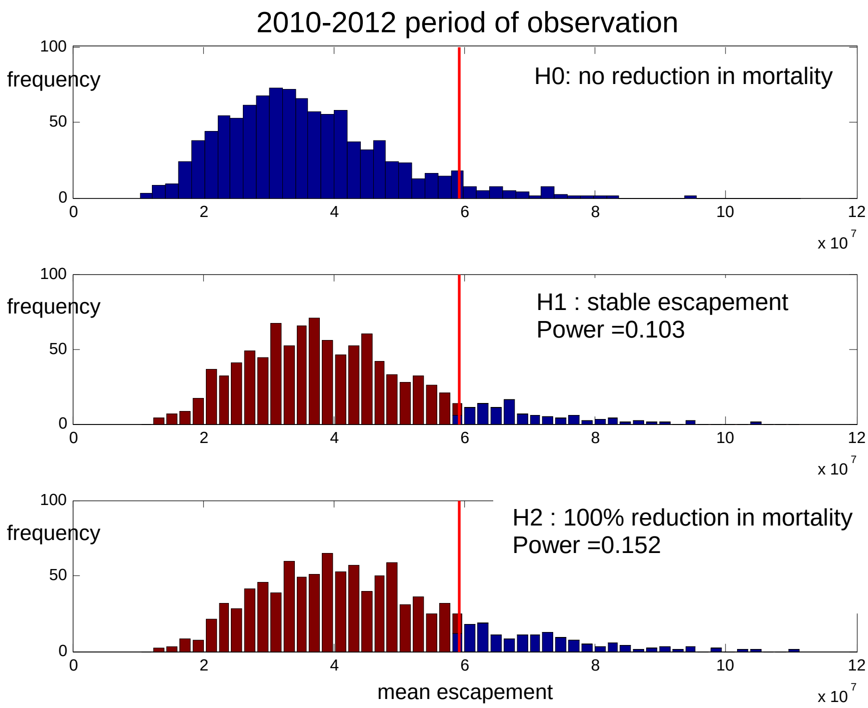


Figure 4.3. Frequency distribution of mean escapement biomass during 2010-2012 period for the null hypothesis H0 and two alternative hypotheses H1 (the red line indicates the 95% percentile for the H0 output)

This procedure was repeated for successive 3 year period of observation (2013–2015, 2016–2018, ...). The evolution of the power according to the period of observation are summarized in Figure 4.4. It shows that the alternative hypothesis is accepted with a power higher than 80% after the 2016–2018 for the "100% reduction" scenario and after the 2022–2024 for the "Stable escapement" scenario.

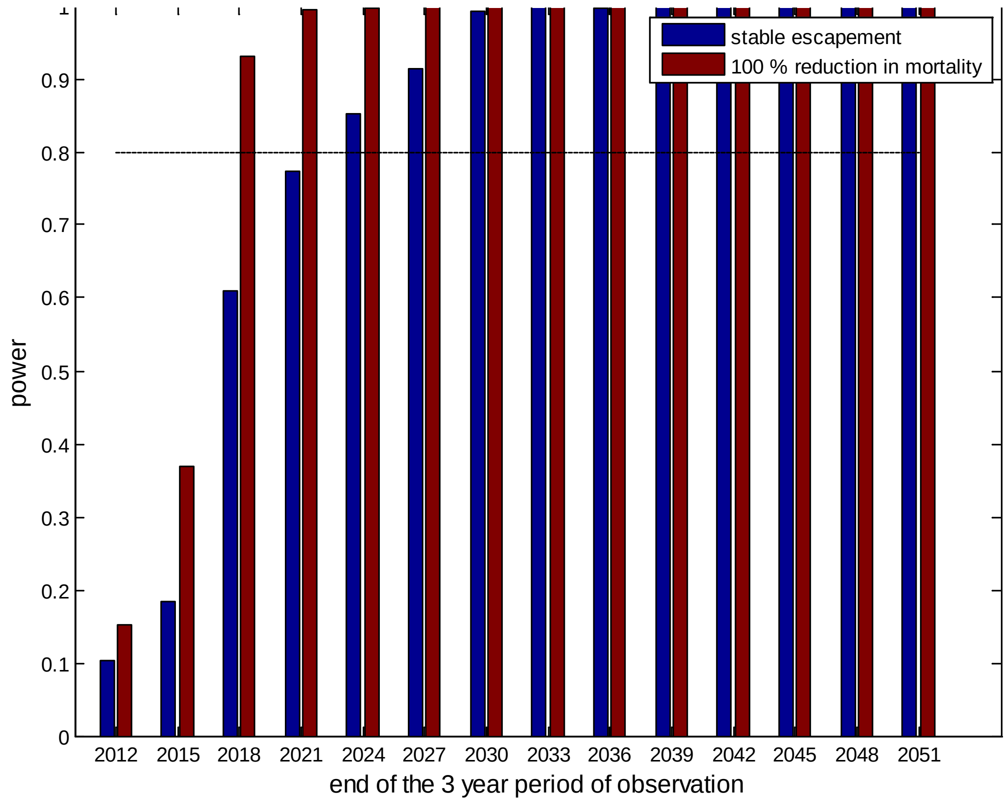


Figure 4.4. Evolution of the power according to the period of observation for the two alternative hypotheses (H0 = no reduction in mortality).

Now we wanted to test if we will be able to detect a management regime that would lead to the crash of the stock. The null hypotheses to test other scenarios against was the "Stable escapement" scenario and alternative hypotheses to "no reduction mortality". We repeated the previous procedure but this time considering the 0.05% percentile for the H0 distribution and the frequency under this threshold for H1 (Figure 4.5).

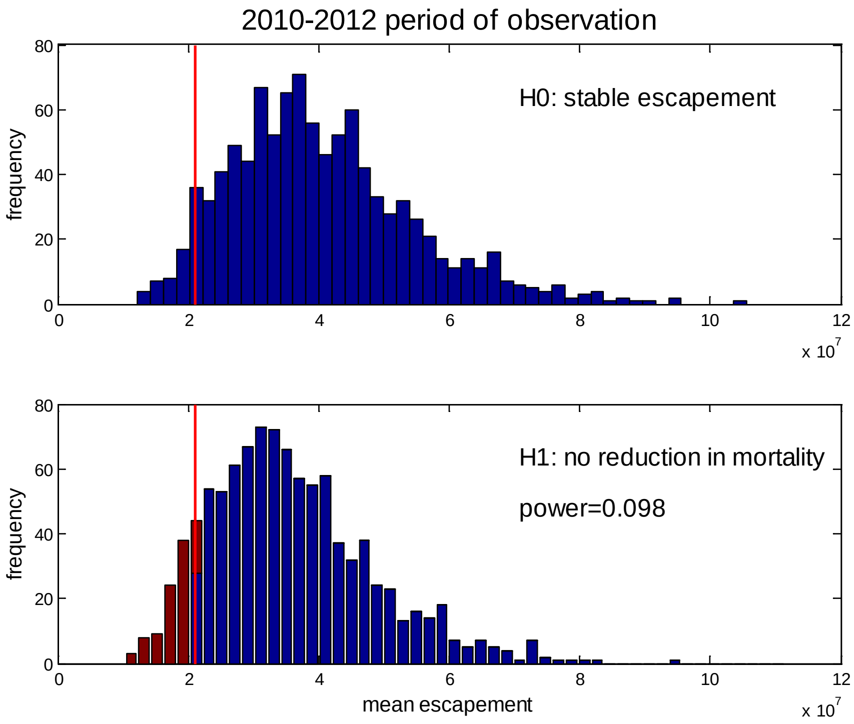


Figure 4.5. Frequency distribution of mean escapement biomass during 2010–2012 period for the null hypothesis H0 and the alternative hypotheses H1 (the red line indicates the 5% percentile for the H0 output).

In that case the evolution of the power according to the period of observation (Figure 4.6) shows that we have to wait for the 2022–2024 to be able to confirm a 'no reduction in mortality' with a high probability which could be too late to adapt the management actions, or in other words that at that time the stock could be crashing without having the power to detect it statistically.

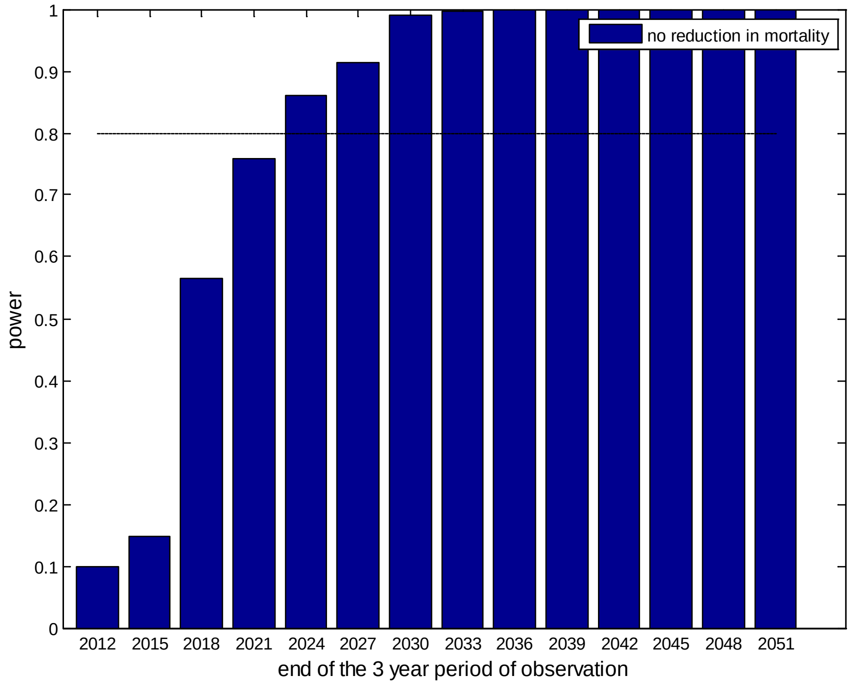


Figure 4.6. Evolution of the power according to the period of observation for the alternative hypothese (H0 = stable escapement).

4.5 Power to detect a change in the trend in escapement

In this analysis, we simply apply the comparison of a segmented regression with linear trend as described in the second paragraph. The SED model is used to build the estimated escapements for the three management scenarios described in paragraph 3. The null hypothesis again is that there is no change in the trend (no reduction in mortality = business as usual) and the two alternative hypotheses are stable escapement and 100% reduction in anthropogenic mortalities. The power of the test is calculated at regular interval after the implementation of management measures. The breakpoint brought by management measures is supposed to have occurred in 2009. The 80% probability is reached in 2017 for a 100 % reduction in mortality and 2025 for stable escapement (Figure 4.7).

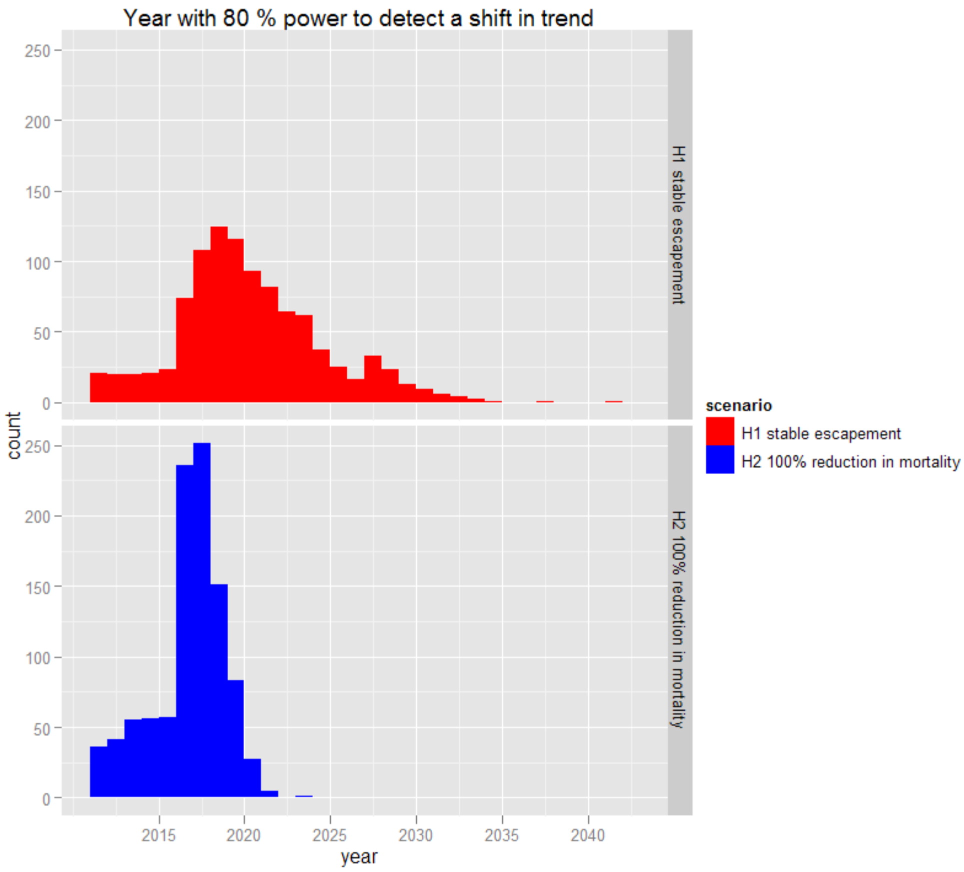


Figure 4.7. Year corresponding to a 80% power to detect a shift in the escapement trend. Results obtained on 1000 iterations of the scenario H1 stable escapement, H2 100% reduction in mortality tested against an H0 scenario.

4.6 Other power analysis that could be used on scaled change

For lifetime mortality ∑A, where sudden changes are likely to happen as the result of a sudden change in management strategy, an appropriate set of models might be:

y = a + b t + (c + d (t-t_0)) (t>t_0) + e

with the associated null hypothesis H0: c=0&d=0, or the simpler version:

y = a + b (t>t_0) + e

with the associated null hypothesis H0: b=0. A power analysis of the latter hypothesis can be performed with pwr.t2n.test.

This kind of model could not be tested during the working group SGIPEE as the mortality calculated by the SED model is fully deterministic.

4.7 Conclusion on power analysis

This first power analysis indicates that it will be difficult to detect any change in escapement and recruitment due to a change in management regime before the 2020s. This delay is clearly incompatible with a necessary adaptive management strategy for a threatened species like eel. Some methodological improvements have been developed here, but we recognize that the priority should be to define methodologies to directly estimate mortality and make the power analysis of this factor.

5 Recommendations

The Study Group on International Post Evaluation on Eels (24–27 May 2011 in London) recommends that:

1) Since short-term post-evaluation of eel management is primarily focused on (achieved and intended) mortality levels (rather than biomass-levels), SGIPEE recommends that WGEEL considers the relation between biomass reference point and mortality reference point, taking into account the objective of the EU Eel Regulation and previous ICES advice.

2) Since short-term post-evaluation is primarily focused on mortality levels and long-term post-evaluation on future recruitment trends, SGIPEE recommends that the power-analyses (on simulated silver eel escapements in this report) are extended to cover mortality estimates and recruitment trends.

3) the spatial coverage of the international stock assessment done by the Joint EIFAC/ICES Working Group on Eels is improved through the participation of countries throughout the distribution area, particularly through integration of ICES, EIFAAC and GFCM eel assessment and advice.

4) assessments of anthropogenic impacts and the dynamics of the stock (current, past and future) are improved

The following two recommendations are copied from WGEEL 2010 (ICES, 2010b) and endorsed by the study group:

5) The 2001 meeting of WGEEL (ICES 2002b) recommended the formation of an international commission that could act as a clearing house for handling and coordinating data collection and storage, stock assessment, management and research. Noting the urgent need to plan and coordinate the data collection and tool development for the 2012 post-evaluation; this recommendation is re-iterated.

6) In particular, it is recommended to organise a (series of) workshops in relation to local eel stock monitoring, with a focus on standardisation and coordination, preparing for the 2012 post-evaluation, setting the scene for the 2013 international stock assessment. The study group also underline that wetted area data is of utmost importance and should be collected and made publically available in priority.

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Annex 2: Agenda

May 24th

10:30 – 13:00

Introduction by EA and housekeeping

Summary of SGIPEE 2010 and WGEEL 2010

Introduction to power analysis

Progress in POSE WP5

Presentation of SGIPEE 2011 work and discussions

13:00 – 14:00

Lunch break

14:00 – 17:00

Subgroup work

17:00 – 18:00

Plenary discussion

May 25th

9:00 – 12:00

Subgroup work

12:00 – 12:30

Plenary discussion

13:30 – 18:00

Subgroup work

May 26th

9:00 – 11:00

Plenary – presentation of main findings by each group and discussions

11:00 – 12:00

Recommendations discussions (ToR d) and conclusion discussions

13:00 – 18:00

Report writing

May 27th

9:00 – 16:00

Report reviewing

Annex 3: Function to calculate the power and results for the detection of a breakpoint in the historical series in 1980

```
################################################################################
#
function ()
{
# This function calculates the power for a piecewise regression model
# It is preliminary, and has to be checked
# Author: Jaap van der Meer
# Last update: May 26, 2011, London
#
require(pwr)
#
# Data on log eel recruitment in France
year <- subdat[,"y"]
Y <- subdat[,"lee"]
k <- length(Y)
#
# Two models; simple and piecewise regression with known breakpoint time
m0=lm(Y ~ 1)
m1=lm(Y ~ year)
m2=lm(Y ~ year + pmax(year,1980))
out1 <- anova(m0,m1)
out2 <- anova(m1,m2)
#
# Plotting the data and models
plot(year,Y)
lines(year,predict(m1),col="red")
lines(year,predict(m2),col="blue")
#
# Power analysis using Cohen

# Effect f2 = (R^2_AB - R^2_A) / (1-R^2_AB) = (RSS_A - RSS_AB) / RSS_AB
# See Cohen(1988, 1992) and http://en.wikipedia.org/wiki/Effect_size
# To do: link Effect size directly to difference in slopes; dependence upon k
#
Effect <- (deviance(m1)-deviance(m2))/deviance(m2)
Power <- pwr.f2.test(u=1,v=k-3,f2=Effect,sig=0.05)
#
# Power calculation by simulation
Prediction <- predict(m2)
SE <- summary(m2)$sigma
outplus<-0
for (i in 1:1000){
	Yplus <- Prediction + rnorm(k,0,SE)
	m3=lm(Yplus ~ year)
	m4=lm(Yplus ~ year + pmax(year,1996))
	outplus <- outplus+(anova(m3,m4)$Pr[2]<0.05)
}
#
```

```
list(year=year,Y=Y,m0=m0,m1=m1,m2=m2,out1=out1,out2=out2,Effect=Effect,Power=
Power,outplus=outplus)
}
################################################################################
###
```

The output looks like:

```
$year
 [1] 1961 1962 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975
[16] 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990
[31] 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
[46] 2006 2007 2008 2009 2010

$Y
 [1]  0.07423709  0.33633482  0.53920472 -0.10609383  0.21536438 -0.25879383
 [7] -0.23482924  0.28120805 -0.56138595 -0.02714963 -0.59215091 -0.62204560
[13] -0.51182981 -0.09374819 -0.37114156  0.11437066  0.02737533  0.12793773
[19]  0.33786462  0.16971814 -0.09034909  0.02053851 -0.69077651 -0.54805583
[25] -0.63005088 -1.01757348 -0.43175917 -0.42071844 -0.74900561 -0.94192287
[31] -1.70650962 -1.39145422 -1.25197966 -1.20379032 -1.11871457 -1.24793196
[37] -1.03856494 -1.58189152 -1.44728581 -1.62266646 -2.32143459 -1.92089215
[43] -2.08930163 -2.52327547 -2.31500581 -2.64633035 -2.62890971 -2.83021167
[49] -3.17974727 -2.86914449

$m0
Call:
lm(formula = Y ~ 1)

Coefficients:
(Intercept)
    -0.9118


$m1
Call:
lm(formula = Y ~ year)

Coefficients:
(Intercept)         year
  122.05214     -0.06193


$m2

Call:
lm(formula = Y ~ year + pmax(year, 1980))

Coefficients:
     (Intercept)             year  pmax(year, 1980)
      183.526039        -0.001518         -0.091200
```

```
$out1
Analysis of Variance Table

Model 1: Y ~ 1
Model 2: Y ~ year
  Res.Df    RSS Df Sum of Sq     F    Pr(>F)
1     49 49.184
2     48  9.247  1    39.937 207.3 < 2.2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

$out2
Analysis of Variance Table

Model 1: Y ~ year
Model 2: Y ~ year + pmax(year, 1980)
  Res.Df    RSS Df Sum of Sq      F    Pr(>F)
1     48 9.2473
2     47 4.5777  1    4.6696 47.944 1.065e-08 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

$Effect
[1] 1.020089

$Power
     Multiple regression power calculation

              u = 1
              v = 47
             f2 = 1.020089
      sig.level = 0.05
          power = 0.9999996

$outplus
[1] 983
```