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**STUDIES AND PILOT PROJECTS FOR CARRYING
OUT THE COMMON FISHERIES POLICY LOT 2:
Pilot projects to estimate potential and actual
escapement of silver eel**

Alan Walker, Eider Andonegi, P. Apolostaki, Miran Aprahamian, Daniele Bevacqua, Cédric Briand, Antonello Cannas, Elvira de Eyto, Willem Dekker, Giulio Alessandro de Leo, et al.

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**STUDIES AND PILOT PROJECTS FOR CARRYING OUT THE
COMMON FISHERIES POLICY**

LOT 2: Pilot projects to estimate potential and actual
escapement of silver eel

for

The European Commission

Directorate-General for Maritime Affairs and Fisheries

FINAL REPORT

NOTE THAT THE RESULTS OF APPLICATION OF MODELS TO DATASETS HERE ARE FOR ILLUSTRATIVE
PURPOSES ONLY AND MUST NOT BE CONSTRUED AS STOCK ASSESSMENTS

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Authorship

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Intellectual Property of data sets and models

The precarious state of the eel stock has given rise to several national/regional initiatives to document local eel stocks and to develop modelling tools. We gratefully acknowledge that data and models have been made available to this project, but recognise that their publication within this report must not breach intellectual property rights, nor interfere with original intentions and applications. Consequently, only limited technical detail is presented here.

Chapter 1. Executive Summary

The European eel is widely distributed throughout over 90,000 km² of inland, estuarine and coastal waters in Europe and parts of northern Africa (Moriarty & Dekker, 1997). Estimates at the glass eel stage indicate that recruitment across Europe fell in the 1980s to about 10% of former levels, and further to 1-5% since 2000 (ICES, 2008). ICES therefore advised that the stock is outside safe biological limits and that current fisheries are not sustainable (ICES, 1999). The status of the stock has not changed and remains critical (ICES, 2010).

The European Commission has initiated an Eel Recovery Plan (Council Regulation No 1100/2007, hereafter the Regulation) to protect and restore the European eel stock to sustainable levels of adult abundance and glass eel recruitment. The essentially local nature of eel stocks means that responsibility for the attainment of this objective largely resides with national governments, with individual river basins as the primary management units. Each Member State is required to establish national Eel Management Plans (EMPs). The objective of these plans is to permit with high probability the escapement to the sea of at least 40% of the biomass of silver eel relative to the best estimate of escapement that would have existed if no anthropogenic influences had impacted the stock.

The assessment of local stocks and impacts of anthropogenic factors is a complex issue for eel, given the considerable diversity in environment, biological, fishery-related factors, large spatial coverage, and differences among the monitoring schemes and available data found throughout Europe. The ultimate aim of this project, therefore, is to provide EU eel scientists and managers with a comprehensive knowledge of the techniques most suitable for the assessment of their local eel stocks, and thereby to support the conservation and management of eel through the Eel Management Plan process.

There are a variety of approaches available to assess silver eel production and escapement, which can be categorised into those technical measures that can be used to directly determine actual silver eel escapement by catching and/or counting silver eels, proxy indicators based on knowledge of yellow eel populations, and those that are based on model predictions and extrapolations.

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 can be adopted. Although yellow eel surveys are more widespread, surveys have a significant resource requirement and therefore numbers and distribution of surveys is often limited. When one considers the requirements for a suite of methods appropriate to the diverse range of habitats across Europe, therefore, we chose to focus on modelling approaches within this project. Four models were identified as being used in Eel Management Plans and/or immediately available and with ongoing support and development: Demographic model of the Camargue (DemCam); Eel Density Analysis 2.0 (EDA); German Eel Model (GEM); and, Scenario-based Model of Eel Production II (SMEP II). These have each been summarised and described in detail within this report.

DemCam is a stage-, age-, and length-structured model that provides a detailed description of the status of the eel stock in a homogeneous water body, considering the main aspects (both natural and anthropogenic) that affect eel population dynamics. The model requires annual indicators of recruitment (time series or index), fishing impact (mortality rates) and biological parameters (sex ratio of silver eels, natural mortality of juveniles (density dependent) and adults (density independent), growth rates and size and age at silvering. These can either be directly assessed for the studied population (when data are available) or taken from the literature. The results consist of annual estimates of biomass and number of eels in catches, and yellow and silver eel stock by age, length, sex and maturation structure under different management scenarios, such as stocking, fishing regulations, and/or different environmental conditions. DemCam is programmed in MatLab, and therefore can only be used by someone experienced in programming in this language. However, a user-friendly interface is being developed.

EDA is a framework of eel density analyses rather than a fixed, end-user model, which can be applied at River Basin District, Eel Management Unit or even national scales. It operates on a geolocalized river network database and relates yellow eel densities to environmental variables, including anthropogenic impacts, extrapolated from survey sites to the river basin. The predicted yellow eel stock is converted to a potential silver eel escapement using a user-defined conversion rate. The model requires data on the presence/absence and densities of yellow eel at sites throughout the river network, typically derived from scientific surveys (e.g. electro-fishing surveys), and environmental data describing the distance of each site from sea and source, the temperature in each segment of the river network, the mean rainfall, the elevation, slope and stream order (Strahler and Shreve). The anthropogenic impacts are described as the obstacle pressure (cumulative number of dams and their passability), the land use, and fisheries. The model results are the yellow eel density in each reach of river network, the overall yellow eel stock abundance and a potential silver eel escapement under pristine and actual conditions. EDA was developed with the R software and with the PostgreSQL/PostGIS. The software packages are open source so are freely available, but using EDA requires a working knowledge of these software packages.

GEM is an age-based model working on a single spatial unit. The model starts with an estimate of the numbers of eel per age group in the population, and then estimates the number of eels of each age group which leave the system for various reasons (natural mortality, fisheries, predation, turbines, etc) each year, along with updates for recruitment and stocking. The model requires data on the annual catches by fisheries and predators, as weight or numbers of eels, the numbers per age group of eel recruiting or stocked each year, and the annual mortality (%) of silver eels due to hydropower plants and water abstractions. Counts or length distributions are converted to age profiles based on survey data and knowledge of growth rates, and the mean weight of eel per age group is estimated from numbers using user-defined weight-length relationship. The results are presented as annual estimates of population size, fishery catches, catch by predators, mortality by other natural reasons, and silver eel escapement, all expressed as numbers per cohort. GEM runs in MS-Excel® so can be run by anyone with a standard Windows® pc and knowledge of spreadsheets.

SMEP II is an age-, sex- and length-structured model which is applied at the river basin scale. It simulates the biological characteristics of the eel population (growth, natural mortality, sexual differentiation, silvering and dispersal) and a number of potential anthropogenic influences on that population (fishing, turbines, barriers, stocking). It accounts for density dependent effects on

biological processes, as well as the effects of habitat structure and quality. It tracks changes in undifferentiated, yellow (male and female) and silver (male and female) eels every year and for each reach in the catchment. The model can be used to project the population forward from a predetermined starting condition or estimate the starting conditions that could lead to a given population size or structure. As a projection tool, the user may vary anthropogenic influences and levels of recruitment in order to create 'what-if' management scenarios, relative to given reference points. The model must at least have information describing the eel life history processes (either site-specific or from literature), the size and structure of the river basin, and the quantity of annual recruitment. Where data are available, either for historic or present conditions, these can be used to characterise the yellow eel population, impacts on production (e.g. fishing or turbines), inputs such as stocking events, and changes in the available area and quality of habitat. Model results are provided both as numbers and biomass of eel, per sex and life stage (elver, yellow, silver), river reach and year; and length frequency distributions. The model runs in MS-DOS® on any Windows® pc, using .csv files for input and results files, so can be run by anyone with knowledge of spreadsheets. One of the key aims and novel approaches of this project was to test and compare the accuracy and precision of the presently available assessment models in their predictions of silver eel escapement under various scenarios, as a means to aid scientists and managers in the selection and application of models most appropriate to particular management situations. Although several assessment models have been developed and applied to a variety of eel datasets elsewhere, such formal comparisons had not been achieved before this project.

We have examined a number of candidate data sets from river basin districts (eel management units) across the continental productive range of the European eel, including several each from the North Sea-Baltic, Atlantic and Mediterranean regions. We selected 8 candidate data sets encompassing these three regions, which we considered presented elements that were 'rich' and 'poor' in terms of the eel data they provided, and which broadly represented the variety of eel-producing habitats and anthropogenic impacts found across Europe.

The River Elbe Basin District (Germany: North Sea/Baltic region) provides data for a large, single catchment area with time series data from 1985 onwards documenting eel recruitment and stocking inputs, growth rates and age-length-weight relationships, and losses associated with commercial and recreational fisheries, cormorant predation and passage at hydropower plants. The availability of these time series of data meant that the Elbe was considered as data-rich for this project.

The Anglian River Basin District (UK: North Sea/Baltic region) provided a long time series of eel density and biomass measures from electro-fishing surveys for some river, but individual length and weight data were only available for the most recent 5 years. In the absence of information on recruitment, yellow eel production and silver eel escapement from the same river, the basins of this district were considered relatively data-poor for this project.

The West Coast River Basin District (Sweden: North Sea/Baltic region) is the only basin district considered for this project that includes a significant proportion of open coastal waters. Eel data were available from marine fishery catches, and estimates were also available for mortality associated with eel passing hydropower dams in freshwater. However, as the eel data were limited to catch sizes and associated biological information about the eels in the catches from the saline parts of the district, it was considered data-poor for this project. Indeed, none of the four models

could be applied to this RBD because of its open-water nature, and therefore it does not feature in this report.

The Western River Basin District (Ireland: Atlantic region) provides data for a whole EMU and also for some data rich catchments within the EMU such as the Corrib system and the small, commercially unexploited Burrishoole river basin where a 40+ year time series of complete silver eel counts and measures, along with scientific surveys of the rivers and lakes upstream meant that we considered this data set to be data-rich for this project. The WRBD also introduces the complexity of eel data collection and assessments in catchments where eel habitat is dominated by lakes.

The Brittany Eel Management Unit (France: Atlantic region) provided data from a comprehensive series of electro-fishing surveys for eel, time series data on substantial glass and yellow eel fisheries, and a full GIS database mapping the locations and impacts of obstacles to eel dispersal. Therefore, this data set was considered relatively 'data-rich' for this project.

The Basque River Basin District (Spain: Atlantic region) provided a time series of glass eel catches since 2003, abundance and biometric data for yellow and silver eel caught during electro-fishing surveys since 1988, and an inventory of dams and hydropower facilities. The River Oria was the site of pilot studies for the Indicang project and therefore fishery-independent data on glass eel and yellow eel recruitment were available from 2005, along with yellow eel density data throughout the river basin from eel-specific electro-fishing surveys since 2004, and estimates of silver eel production from 2007. Therefore, the Oria was considered as 'data-rich' for this project.

The Rhone Eel Management Unit (France: Mediterranean region) includes three compartments, the main river basin, the many river basins flowing directly to the sea, and a series of Mediterranean lagoons. Glass eel fishing is forbidden throughout the area, but large yellow and silver eel fisheries occur in the lagoons and River Rhone. There are large numbers of hydropower dams on the rivers, which have a significant impact on silver eel escapement. As with the Brittany EMU, eel presence/absence and density data were available from electro-fishing surveys throughout the Rhone EMU. However, the lack of accompanying quantitative biological information about eel production, or about the human impacts on this production, meant that this data set was considered relatively 'data-poor' for this project.

The Sardinian Eel Management Unit (Italy: Mediterranean region) is characterised by a series of lagoons that produce eel. Some eel data were available on age and size of recruits (but not counts), yellow and silver eels, the length distribution and sex ratio of silver eel samples, and rates of natural and fisheries-related mortality. Information describing the spatial dimensions of the eel habitats was also available. However, all these data were relatively sparse and therefore this data set was considered 'data-poor' for the project.

Although some of these data sets summarised above were considered to provide elements that were rich in eel data, the comprehensive test of the accuracy and precision of assessment models requires data that provides a complete knowledge of those factors controlling the life history and production of the eel. Furthermore, it requires this knowledge over a time series of sufficient length and with sufficient changes in impacts to represent all likely assessment and management scenarios found in reality. None of the candidate data sets from around Europe includes sufficient data on all these aspects to allow comprehensive testing of approaches to accurately predict or identify all of

the assessment (potential target) and management (compliance assessment) scenarios. Therefore, we developed a new, virtual data set (CREPE) encompassing the present understanding of biological processes, management contexts, and the typical availability and quality of survey data in river networks. This data set provided a unique opportunity to test the performance of the models against a truly data-rich scenario.

We applied the models to this artificial, data-rich resource and examined their performance in terms of the accuracy and precision of their predictions of silver eel production/escapement under conditions of high and stable recruitment (synonymous with the 'pristine') and in response to decadal reductions in recruitment (the 'present'), both in terms of the predicted absolute values and in their ability to match the trends in production/escapement over the time series of changing recruitment.

The model testing procedures were conducted in two phases. In the first phase, input data were derived from the document describing CREPE and from the data files provided for each model. The silver eel escapement biomass predictions by the four models were compared to those from CREPE, which had been withheld from users to create a "blind" test. This phase simulated a "data not quite rich" scenario, but probably the best that could be expected in the 'real' world.

In the second phase, the input data were adjusted or 'tuned' to improve the fit between the predictions of silver eel biomass and the actual results from CREPE. 'Tuning' is the systematic revision of model parameter values to produce a model output as close to desired as possible. This illustrates the ideal data-rich situation from which to examine the potential accuracy and precision of the assessment model. However, as such a truly data-rich situation does not exist in the real world, the results represent the best possible but not necessarily what managers should expect in other situations.

The models did not perform well under the Phase 1 test conditions, failing to correctly estimate pristine or current escapement. Three of the models generally overestimated silver eel escapement: SMEP II by a factor of 5 to during the period of high recruitment and 14 to 18 during low recruitment; GEM by a factor of nearly 40 during the high recruitment period and about 10 times during the low recruitment period; and, DemCam by a factor of about 3. In contrast, EDA underestimated silver eel production by a factor of about 6.

However, all four models did succeed in predicting the general trends in escapement.

When comparing the results of the four models from the first phase of test applications, we identified three features of the CREPE dataset which could explain the some of the difficulties encountered by the assessment models during Phase 1 of testing. First, the eel distribution in CREPE environment was concentrated in the downstream part of the catchments, which complicated the application of the single-compartment assessment models GEM and DemCam. In contrast, the multiple compartment approaches of SMEP II and EDA were able to 'handle' this spatial complexity. Second, the growth rates of CREPE eels were relatively high, corresponding to a situation in north of the Gulf of Biscay, and the lognormal variability used in the growth rate calculation led to exceptionally high growth rates for some fish. Third, the mortality rate used in the CREPE dataset was particularly high, and especially so for glass eel, probably too high to be captured and represented by classical approaches in assessment models. Note however that those applying

DemCam, GEM and SMEP II all identified that this early mortality rate was much higher than could be expected from the CREPE information. This feature did not affect the EDA application because it used data for the older yellow eels.

Knowledge of these features of CREPE significantly improved the performed of the assessment models in the second phase of testing, showing a clear convergence towards the CREPE output.

Although DemCam overestimated pristine escapement by a factor 2, it predicted escapement accounting for human impacts to within, on average, 9% at high and 13% at low recruitments. SMEP II also predicted silver eel escapements that were, on average, within 9% of pristine and 16% of 'current' escapement from CREPE under high recruitment conditions. However, SMEP II underestimated silver eel escapement under low recruitment, being on average only 32% of the CREPE result, probably because the whole time series was modelled using the mortality rate curve associated with high densities. EDA overestimated pristine escapement by a factor of 3, but was much better at estimating escapement under 'current' conditions when taking human impacts into account, producing results within, on average, 24% of CREPE for the high recruitment period, and within 57% under the low recruitment conditions. The GEM results were also considerably improved over those from Phase 1, but still overestimated escapement by a factor of about 10 at high recruitment, and about 3 at low recruitment.

The ratio of current/pristine is the primary reference target of the Eel Regulation (EC 1100/2007) – the 40% or 0.4. This ratio predicted by SMEP II during the period of high recruitment was very close to that of CREPE. In contrast, EDA and DemCam both underestimated this ratio considerably during this period, but this is probably because both these models derived pristine biomass as the maximum potential biomass from an excess of recruitment, rather than escapement under a high but not necessarily maximum recruitment described for CREPE. The second application of GEM did not include an estimate of pristine escapement so this ratio could not be calculated for this model.

Given this overestimate of pristine biomass, it is hardly surprising that DemCam and EDA underestimate the ratio of pristine/current silver eel escapement during the period of low recruitment. SMEP II also underestimates this ratio, but this is probably because a high rate of natural mortality was applied in SMEP II and this meant it underestimated the current escapement during this period. This underestimation during the period of low recruitment is to err on the side of caution for the assessment and management of the eel stock as it would probably lead to extra management measures to protect and recover the stock. However, there are potentially social and economic consequences of this cautious approach by inducing management actions which are possibly more than severe than required to achieve the target.

That proves that the four models can each predict an escapement close to the CREPE value, providing there is access to sufficient input and tuning information such as in the virtual fully-data-rich situation of CREPE. However, the application of these (and other models) in the real world should not be so optimistic when most of the time only default values describing eel life processes (as Bevacqua *et al.* 2011 mortality rates) are available. Natural mortality data are rare, especially river-specific, and therefore most model applications will use the average values developed by Bevacqua *et al.* (2011). In the absence of better, more site-specific data, those values derived on the basis of Bevacqua *et al.* may be an improvement from using a single default value but the outputs should still be treated with caution. Applicants and assessors must recognise this limitation of the

data and the models. To some extent, in the absence of site-specific data, it makes sense to standardise life history parameters across models and across regions so that we are at least all working to the same set of rules.

Accuracy is a measure of how close the predicted result was to the actual result. The Phase 2 results showed that three of the four models can be quite accurate when given sufficient input and tuning data, reaching average levels within 9% (DemCam, SMEP II), 24% (EDA). GEM was less accurate, a best overestimating silver eel biomass by, on average, a factor of about 3. This possibly suggests that GEM was less flexible than the other models to eel production values that were far outside those of its development data set from the River Elbe. A new CREPE data set based on eel production characteristics from northern Europe would probably have produced more accurate results from GEM. It will be useful in the future to use CREPE to simulate several new datasets corresponding to different biological hypotheses of eel population functioning and different management scenarios in order to test the robustness of the assessment model and their interest in a management process, but this was not practicable within the POSE project.

All four models presented results for silver eel escapement biomass to the nearest kg or even g, so in strictest terms, the models could all be considered to report results with high precision (the detail of the answer). However, although reporting to the nearest kg may seem an attractive quality of any model, it is actually a potentially misleading result, giving the perhaps false impression that the result has a high degree of confidence. A much more meaningful test of precision, which gives a proper measure of the confidence associated with the result, is the measure of the uncertainty associated with this result, e.g. we are 95% sure that the actual result lies between X and Y kg. None of the model results reported results with any degree of uncertainty, and therefore their precision could not be determined.

In addition to these tests of the virtual data-rich scenario, we applied the models to the real data set that came closest to being data-rich (the Western River Basin District, Ireland) to examine their performance under 'real' conditions. Comparisons between the model predictions and the 'known' outputs of Burrishoole silver eel production revealed that the different modelling approaches did not converge to a single conclusion in terms of their accuracy in predicting silver eel production. The predicted results from the models were far from the actual reality under some conditions, but more accurate under other conditions.

In order to provide an illustrative guide to local stock assessment procedures suited to the various habitats from which silver eel can escape, we described the manner in which these assessment models could be applied to a number of additional 'real' scenarios from across the regions of Europe to further illustrate how the models could be modified to suit local conditions.

This work identified that each of the models is suitable for application to a different character set of eel data and scenarios. Given the broad range of assessment data, impacts and management scenarios that may occur in eel management units across Europe, there are a vast number of possible combinations, making it impracticable to list these and assess each of the four models for their suitability. As an alternative, therefore, we have considered the broad types of scenarios to which the assessment models are probably best suited. This guide will assist managers in identifying the model or models that should be most appropriate for their specific circumstances.

DemCam and GEM are similar in that they are typically applied to a single spatial unit. As a consequence, they are best applied to those areas where the eel production processes are not expected to vary much throughout the management unit. DemCam was developed to model eel production in lagoons, so clearly it is best suited to being applied to such environments. GEM was developed for the River Elbe, but on the basis of a series of production process values being representative across the entire river network.

SMEP II is an eel life history model in the same manner as DemCam and GEM, albeit that they each only model the life history from recruitment to spawner escapement. However, SMEP II specifically incorporates the spatial complexities of a river basin, including any network of rivers, lakes, estuaries and lagoons. Although the descriptions of growth, natural mortality, sex differentiation and silvering are common throughout the river basin, the ability to model the dispersal of eel, the effects of density dependence, and to localize impacts allows a more complex and spatially explicit assessment.

DemCam, GEM and SMEP II all require information describing these biological processes. Although each model can use information taken from the literature, the results from our phase 1 tests of the CREPE data set highlight the risks this poses of introducing additional uncertainty in the model results and the potential pitfalls in assuming that information taken from other rivers, districts or regions is representative of the eel population in question. Local knowledge of growth and natural mortality rates, and of recruitment levels, appears particularly important and emphasizes the importance of collecting local field data.

The EDA model adopts a very different approach to the other three models, at its core relying on identifying relationships between yellow eel densities and habitat characteristics, extrapolating these across the area in question, accounting for any losses due to impacts, and applying conversion rates to produce results for silver eels. Two key consequences of this approach are that EDA is far less reliant on local knowledge of eel production processes, and that it is best applied at much larger spatial scales than the other models – typically at RBD / EMU scale.

This ability of EDA to produce results at the default spatial scale of the Eel Management Plans is no doubt appealing. The other three models have been applied at much smaller management units – even though the GEM was developed for the Elbe river basin district, this was in effect a single, albeit very large, river basin. As such, DemCam, GEM and SMEP II are best applied to “index” rivers and the results then extrapolated to other rivers, etc within the River Basin District. On the other hand, EDA requires a substantial distribution of eel density and habitat data from across the management unit, so is best applied to those areas with comprehensive national eel survey programmes.

Natural mortality data are rare, especially river-specific, and therefore most model applications will use the average values developed by Bevacqua *et al.* (2011). In the absence of better, more site-specific data, those values derived on the basis of Bevacqua *et al.* may be an improvement from using a single default value but the outputs should still be treated with caution. Applicants and assessors must recognise this limitation of the data and the models. To some extent, in the absence of site-specific data, it makes sense to standardise life history parameters across models and across regions so that we are at least all working to the same set of rules. A gap identified which will require attention in the future is the lack of assessment methodology(s) for quantifying eel

production in large water bodies (e.g. lakes, large rivers, large estuaries, coastal waters). The ICES SGAESAW began the process of developing assessment methods for marine eels in 2007, with a synthesis of knowledge, but the next steps to actually develop methods and indicators have not been taken yet. The resource limits of POSE prevented this project from exploring this topic further.

Our work reveals that typical eel assessment models require a substantial knowledge of the local eel population if they are to provide good results. However, there are without doubt very large numbers and areas of habitats across Europe that are producing eels, or at least have the potential to do so, but for which there is an absolute lack of any knowledge of the eel stock. Extrapolation of knowledge gained from the data rich monitored catchments to catchments where little or no eel data exists is therefore required. A Bayesian framework was developed for estimating silver eel production for sites across Europe where absolutely no prior knowledge of eel was available, by linking models of growth rate, survivorship and recruitment. The growth rate modelling appeared robust but there were weaknesses in the survivorship and production modelling. The production model estimates did not appear to respond adequately to the higher growth rates. Lack of data (recruitment, production) and maybe lack of appropriate explanatory variables were identified as factors warranting further consideration and development before the Bayesian framework would be suitable for general applications.

The main body of the report concludes with a consideration of the suitability of the assessment models, illustrated by an analysis of their Strengths, Weaknesses, Opportunities and Threats (SWOT analysis), and makes recommendations for further developments in these models and assessment approaches in light of the results of this project.

A series of annexes are also available which provide additional information including more detailed descriptions of the existing assessment models examined in the project, the new virtual, data-rich data set and associated model development, the structure of a database developed to facilitate complex data exchange between data providers and modellers, the development of the Bayesian framework to predict eel growth and production in the absence of any eel data, the Minutes from the various Project Meetings, and a List of names and address details for those who are first points of contact for the models and data sets used in this project.

In conclusion, POSE has provided a standardised, benchmarked suite of assessment methodologies that can feed into the reporting requirements for the EU Regulation and facilitate assessments of the international stock. Our work identified gaps and sensitivities in the models and their approach to stock assessments. Understanding these sensitivities means we are better informed about the modelling processes, and managers who employ the models as part of the EMP reporting process avoid unnecessary pitfalls.

A critical lesson learned during the project has been that it takes a lot of time to evolve the application of a model to a dataset to produce a confident result, and that is providing that the appropriate tuning data are available. Without these tuning data, the model application can be achieved quicker, but the results must be treated with considerable caution! Modelling fisheries data can be time consuming and this extensive time needs to be built into the whole process of stock assessment, particularly with respect to management and reporting of eel under the Regulation. Likewise, we caution against the blind use of model outputs without ground truthing.

We identified several crucial data requirements in each of the models, and these data are rare in the real world. The anticipated developments in the Data Collection Framework (DCF) sampling requirements for eel should fulfil many of the data requirements for local modelling that were identified during this project. The data collection must be coordinated and conducted at appropriate spatial and temporal scales, and embrace both fisheries and non-fisheries sources of data. The inclusion of non-fisheries related data collection under an agreed programme of surveys will close data gaps and improve our ability to undertake good quality assessments.

POSE developed CREPE which can be used as a framework to provide a series of baseline data sets benchmark test these and other models developed in the future. Countries adapting existing models or developing new models should benchmark test the model against CREPE. This will maximise the opportunity for successful reporting to the EU in future years and reduce the threat of uncoordinated assessment outputs. The original version of CREPE produced for POSE created a data set of virtual eel with characteristics closest to the southern parts of the eel's range, and this caused some difficulties for those models that had been developed for more northerly eel populations. Different scenarios (biological, management) will have to be included in different versions of CREPE in the future.

POSE also developed a database structure for eel (DBEEL) in order to facilitate the collation and dissemination of standard data. This structure could be adopted at the national or international level to support the coordinated assessment and management of *Anguilla anguilla*, and the intercalibrations requiring exchanges of eel data. The requirement for such a database has already been raised by the EIFAAC/ICES WGEEL. However, management of the database is a substantial task also requiring quality control measures.

The international coordination of data exchange and reporting, already in place for other species, will support both local and international assessments and reporting. The DBEEL developed in the POSE project provides a cost-effective and practical solution to eel data management and exchange, but this database needs a home, management and a formal data exchange and quality assurance procedure.

However, international coordination of data collection is lacking and in its absence, benchmarking and quality assurance (planning stage) and control (ongoing) of the local stock assessments is difficult to say the least. It should also be acknowledged that some data sets are coming to an end because of reductions or closure of fisheries or other economic factors. Our model testing in POSE highlights the great importance of historic data and time series which are fundamental to deriving the historic eel production values required by the Eel Regulation. Clearly, time series data collections should be protected, and new time series commenced, especially of recruitment and silver eel escapement.