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Report of the 2008 session of the Joint EIFAC/ICES Working Group on Eels

Leuven, Belgium, 3–9 September 2008

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Food and Agriculture Organization of the United Nations
Rome

International Council for the Exploration of the Sea
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Preparation of this document

This publication is the report of the 2008 session of the Joint European Inland Fisheries Advisory Commission (EIFAC) and International Council for the Exploration of the Sea (ICES) Working Group on Eels which was held in Leuven, Belgium from 3 to 9 September 2008.

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Abstract

Available information on recruitment, stock and fisheries continues to support and reinforce the advice that the European eel stock has declined in most of the distribution area and is outside safe biological limits. Recruitment of glass eel to the continental stock continues to decline with no obvious sign of recovery. Current levels of anthropogenic mortality are not sustainable and there is an urgent need that these should be reduced to as close to zero as possible, as soon as possible. All glass eel recruitment series demonstrate a clear decline since about 1980 with no sign of recovery. The Baltic indices of young yellow eel recruitment demonstrate a clear decline since about 1950. The decline in recruitment appeared stronger in the more northern and southern parts of the distribution.

In the 1970s, recruitment of glass eel was still at historically high levels indicating that Spawning Stock Biomass was not limiting the production of recruits at that time. Quantifying the 1970s spawner escapement therefore is the simplest derivation of a restoration threshold. The reference threshold should be set at 100% of the 1970s silver eel escapement where data are available, or in the absence of data, at a percentage (40%) of the notional pristine state which would have existed if no anthropogenic mortalities had impacted on the stock.

It is of utmost importance that existing recruitment monitoring is continued and improved, easing the dependence on commercial fisheries, and extended where inadequate. A radical improvement in the assessment of the current state of the stock, including quantification of the impact of anthropogenic mortalities, is urgently needed. Although comprehensive datasets exist in some river basins, this assessment will not be achievable in most river basins from currently limited data. Data discontinuities are likely to occur simultaneously and unlike in the past, statistical modelling will not be able to correct for this.

The first post-evaluation of the EU Regulation is required by mid-2012. Timely development of stock-wide assessment procedures is required, geared to the data becoming available, while indicating the progress towards recovery of the stock. The absence of any internationally driven requirement to maintain a recruitment dataseries needs to be corrected, with reference to the recommendations of the EU contract 98/076: Establishment of a recruit monitoring system for glass eel. The current legislative instruments including the Eel Regulation, DCR, CITES and WFD do not, either individually on in combination, contain sufficient provisions to ensure adequate data supply for such assessments.

It is suggested that managers define interim targets for the management measures in order to integrate local action efficiently to the aim of long-term recovery of the European eel stock. For this purpose sub-targets defining the magnitude of management measures will be linked with eel sub-targets reflecting the expected short-term response of the local eel population. Eel sub-targets should therefore allow a fairly rapid evaluation of the management measures taken but sensitivity and time response of some of the proposed eel sub-targets would need further investigation before their application would be operational. Eel sub-targets should finally be integrated into the evaluation of the status of the whole eel stock. However it has to be recognized that adequate methods, or modelling approaches, for achieving this are still lacking.

There are few quantitative estimates of pristine (pre-1980) and current silver eel production (Regulation EU 1100/2007) to allow comparisons to be made between systems

and there is few data on the importance of estuarine and coastal populations to overall production. Modelling will be needed to transfer estimates from data rich to data poor systems. Some approaches have been outlined by this Working Group which compliment those presented in previous working groups and in EU SLIME (Dekker *et al.*, 2006).

Implementation of EMPs requires the development of methods to obtain silver eel escapement data. They can include either direct (e.g. mark-recapture) or indirect measures (yellow eel proxies to determine habitat-based silver eel production). Use of direct methods, though preferable in many respects, will be severely restricted by uneven distribution of silver eel fisheries within and between regions, limited fishery monitoring resources and extreme fluctuations in river flows during migratory runs affecting the efficiency of capture methods.

A variety of indirect methods, mostly dependant on yellow eel proxies and modelling, are available for areas where direct measurements of silver eel escapement are not possible and should be extensively used to estimate regional and national silver eel escapement. Validation of indirect methods should be undertaken on an ongoing basis for a network of river systems where reliable direct estimation of silver eel escapement biomass is possible. Direct assessment of silver eel may, however, not inform on the impacting factors that require management, where yellow eel monitoring and assessment would be more informative.

Estimation of effective spawner biomass requires quantification of the adverse effects of contaminants, parasites, diseases, low fat levels, non-lethal turbine damage, along the lines previously proposed for *Anquillicola crassus*, as well as other mortality rates throughout the river basin. Present knowledge does not fully permit quantitative assessment of the effects of these factors on the overall stock. The European Eel Quality Database (EEQD) has been updated with data on contaminants, parasites and fat levels in eel, allowing the compilation of an overview of the contaminant load in eel over its distribution area. The data are highly variable within river basin districts, according to local anthropogenic pollution, linked with land use. Persistently elevated contamination levels, above human consumption standards, are seen in many European countries. Fat content of the yellow eels (i.e. in Belgium and the Netherlands) has decreased over the last number of years, which raises concern regarding the migratory and reproductory success of silver eels. *A. crassus* is spreading further into new areas and new data indicate the presence of the nematode in Canada for the first time.

At present, it is estimated that around 7.5 to 15% of the glass eel catch is used for stocking, either directly or as on-grown eels. Estimates suggest an insufficient supply of glass eel from the total fishery for stocking to full capacity at the European level. Nevertheless, the Regulation 1100/2007 requires that 35%, rising to 60%, of glass eel catches are made available for stocking to enhance the stock. If these percentages were applied to recent annual catches of glass eel, the potential lifetime effect of this increased level of stocking, in the absence of anthropogenic mortalities, could be in the same order of magnitude as current fisheries or eel culture. However, there is a continuing and urgent requirement for robust evidence of the extent to which stocking and transfers on local, national and international scales can increase silver eel escapement and spawner biomass.

The risks remain of disease and parasite transfer via stocked material, both from stocking glass eel and on-grown eels. For example, eels in aquaculture infected with pathogens (viruses, etc.) should not be used for stocking purposes. At least half the countries surveyed (17) do not have formal stocking protocols. These should include procedures to prevent the introduction and spreading of parasites and diseases, and eel should be included in the European fish disease prevention policies to help minimize the risks.

Sufficiently long time-series of glass eel recruitment, covering several periods of the natural climatic oscillation over the North Atlantic, reflect the same periodicity. However, the causal link between climate and recruitment strength, is unknown, as well as where and when ocean environmental factors operate on the eel. As long as the causal factors of oceanic influence are unknown, it is not safe to assume that the decline is explained by climate alone, especially while anthropogenic influences are known to be large and better understood. The fact that oceanic climate may contribute to recruitment variation is not grounds for abstaining from all possible measures to increase silver eel escapement to boost spawning-stock biomass. The recent, prolonged strong decline in eel recruitment is out of phase with the dominating climate cycle, the North Atlantic Oscillation.

FAO European Inland Fisheries Advisory Commission; International Council for the Exploration of the Sea.

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Executive summary

This report summarizes the presentations, discussions and recommendations of the 2008 session of the Joint EIFAC/ICES Working Group on Eels which took place in Research Institute for Nature and Forest, Leuven, Leuven (Belgium) from 3 to 9 September 2008.

In this section, the main outcomes from the report are summarized, a forward focus is proposed in the light of the EU Regulation for the Recovery of the Eel Stock and the main recommendations are presented.

It is clear from this report that recruitment is still low, the stock is in decline and urgent protection measures are required. Significant pressures have been placed on the scientific and technical system to support the delivery of Eel Management Plans by December 2008 with parallel processes and undetermined actions resulting in some uncertainties to be coped with by the Working Group in 2008.

Summary of this report

Reviewing the available information on recruitment, stock and fisheries continues to support and reinforce the advice that the global European Eel stock has declined in most of the distribution area and is outside safe biological limits. Recruitment of glass eel to the continental stock continues to decline with no obvious sign of recovery. Current levels of anthropogenic mortality are not sustainable and there is an urgent need that these should be reduced to as close to zero as possible, as soon as possible. All glass eel recruitment series demonstrate a clear decline since about 1980 with no sign of recovery. The Baltic indices of young yellow eel recruitment demonstrate a clear decline since about 1950. The decline in recruitment appeared stronger in the more northern and southern parts of the distribution. It is recommended to use recruitment indices per area (Baltic, North Sea, British Isles, Atlantic Coast, eastern and western Mediterranean), and to collect and analyse additional data to confirm the spatial pattern, and to establish the reliability and bias in the different sampling methods.

In the 1970s, recruitment of glass eel was still at historically high levels. This indicates that SSB was not limiting the production of recruits at that time. Quantification of the 1970s spawner escapement therefore is the simplest derivation of a restoration threshold. Note that in this case, the full escapement of the silver eels in the 1970s (given the anthropogenic mortality of that time) corresponds to the escapement level advised by ICES (2002). That is: one should either set the reference threshold at 100% of the 1970s silver eel escapement where data are available, or in the absence of data, at a percentage (40%) of the notional pristine state which would have existed if no anthropogenic mortalities had impacted on the stock.

It is of utmost importance that existing recruitment monitoring is continued and improved, easing the dependence on commercial fisheries, and extended where inadequate. A radical improvement in the assessment of the current state of the stock, including quantification of the impact of anthropogenic mortalities, is urgently needed. Although comprehensive datasets exist in some river basins, this assessment will not be achievable in most river basins from currently limited data. Data discontinuities are likely to occur simultaneously and unlike in the past, statistical modelling will not be able to correct for this. Therefore, discontinuities will have to be taken for granted.

The first post-evaluation of the EU Regulation is required by mid-2012. Timely development of stock-wide assessment procedures is required, geared to the data becoming available, while indicating the progress toward recovery of the stock. The absence of any internationally driven requirement to maintain a recruitment dataseries needs to be corrected, with reference to the recommendations of the EU contract 98/076: Establishment of a recruit monitoring system for glass eel. The current legislative instruments including the Eel Regulation, DCR, CITES and WFD do not, either individually on in combination, contain sufficient provisions to ensure adequate data supply for such assessments.

It is suggested that managers define interim targets for the management measures in order to integrate local action efficiently to the aim of long-term recovery of the European eel stock. For this purpose sub-targets defining the magnitude of management measures will be linked with eel sub-targets reflecting the expected short-term response of the local eel population. Eel sub-targets should therefore allow a fairly rapid evaluation of the management measures taken but sensitivity and time response of some of the proposed eel sub-targets would need further investigation be-

fore their application would be operational. Eel sub-targets should finally be integrated into the evaluation of the status of the whole eel stock. However it has to be recognized that adequate methods, or modelling approaches, for doing this exercise are still lacking.

There are few quantitative estimates of pristine (pre-1980) and current silver eel production (Regulation EU 1100/2007) to allow comparisons to be made between systems and there is few data on the importance of estuarine and coastal populations to overall production. Modelling will be needed to transfer estimates from data rich to data poor systems. Some approaches have been outlined by this Working Group which compliment those presented in previous working groups and in EU SLIME (Dekker *et al.*, 2006).

Implementation of EMPs requires the development of methods to obtain silver eel escapement data. They can include either direct (e.g. mark-recapture) or indirect measures (yellow eel proxies to determine habitat-based silver eel production). Use of direct methods, though preferable in many respects, will be severely restricted by uneven distribution of silver eel fisheries within and between regions, limited fishery monitoring resources and extreme fluctuations in river flows during migratory runs affecting the efficiency of capture methods.

A variety of indirect methods, mostly dependant on yellow eel proxies and modelling, are available for areas where direct measurements of silver eel escapement are not possible and should be extensively used to estimate regional and national silver eel escapement. Selection of models should take account of SLIME conclusions (Dekker *et al.*, 2006) and advice given elsewhere in this report. Validation of indirect methods should be undertaken on an ongoing basis for a network of river systems where reliable direct estimation of silver eel escapement biomass is possible. Direct assessment of silver eel may, however, not inform on the impacting factors that require management, where yellow eel monitoring and assessment would be more informative.

Estimation of effective spawner biomass requires quantification of the adverse effects of contaminants, parasites, diseases, low fat levels, non-lethal turbine damage, along the lines previously proposed for *Anquillicola crassus*, as well as other mortality rates throughout the river basin. Present knowledge does not fully permit quantitative assessment of the effects of these factors on the overall stock.

The European Eel Quality Database (EEQD) has been updated with data on contaminants, parasites and fat levels in eel, allowing the compilation of a comprehensive overview of the contaminant load in eel over its distribution area. Results demonstrate highly variable data within river basin districts, according to local anthropogenic pollution, linked with land use. Persistently elevated contamination levels, above human consumption standards, are seen in many European countries. The most important reported impact is seen on the fat content of the yellow eels (i.e. in Belgium and the Netherlands) which has decreased over the last number years and which raises concern regarding the migratory and reproductory success of silver eels. There is growing evidence that *A. crassus* is spreading further into new areas and new data indicate the presence of the nematode in Canada (not included in the EEQD yet) for the first time.

At present, it is estimated that around 7.5 to 15% of the glass eel catch is used for stocking, either directly or as on-grown eels. Estimates suggest an insufficient supply of glass eel from the total fishery for stocking to full capacity at the European level. Nevertheless, the Regulation 1100/2007 requires that 35%, rising to 60%, of glass eel catches are made available for stocking to enhance the stock. If these percentages were applied to recent annual catches of glass eel, the potential lifetime effect of this increased level of stocking, in the absence of anthropogenic mortalities, could be in the same order of magnitude as current fisheries or eel culture. However, there is a continuing and urgent requirement for robust evidence of the extent to which stocking and transfers on local, national and international scales can increase silver eel escapement and spawner biomass.

The risks remain of disease and parasite transfer via stocked material, both from stocking glass eel and on-grown eels. For example, eels in aquaculture infected with pathogens (viruses, etc.) should not be used for stocking purposes. At least half the countries surveyed (17) do not have formal stocking protocols. These should include procedures to prevent the introduction and spreading of parasites and diseases, and the eel should be included in the European fish disease prevention policies to help minimize the risks.

Sufficiently long time-series of glass eel recruitment, covering several periods of the natural climatic oscillation over the North Atlantic, reflect the same periodicity. However, the causal link between climate and recruitment strength, is unknown, as well as where and when ocean environmental factors operate on the eel. As long as the causal factors of oceanic influence are unknown, it is not safe to assume that the decline is explained by climate alone, especially while we know that the anthropogenic influences during the continental life stage of the eel are large and better understood. The fact that oceanic climate may contribute to recruitment variation is not grounds for abstaining from all possible measures to increase silver eel escapement to boost spawning-stock biomass. More research is needed to compare the relative impact of climatic effects and continental factors on reproductive success. The recent, prolonged strong decline in eel recruitment is out of phase with the dominating climate cycle, the North Atlantic Oscillation.

Forward focus

This report constitutes a further step in an ongoing process of documenting eel stock status and fisheries and developing a methodology for giving scientific advice on management to affect a recovery of the European eel. A European plan for recovery of the stock was adopted in 2007 by the EU Council of Ministers. This plan obliges the Member States to develop Eel Management Plans by the 31st December 2008. This will require further scientific advice, on the national and international level. The implementation of these plans, foreseen in 2009, will improve and extend the information on stock and fisheries. Improved reliability and better spatial coverage, however, will also generate a breakpoint in several currently available time-series; correction procedures need to be considered. In 2012, Member States will report on protective measures implemented in their territories, and their effects on the stock, for which methodology is currently limited. International post-evaluation requires that data, gathered within this framework of national/regional management plans, become available to the Working Group, although gaps have been identified where these data may fall short of that required. Establishment of an international database and the development of international post-evaluation procedures for measuring the impact on the stock will be required.

The Eel Regulation and eel management plans, CITES and the DCR for Eel will likely radically change management of eel and the Working Group is therefore entering into a dynamic period in which it is difficult to be categorical on it's future focus. The future focus of the Working Group might concentrate on:

- the assessment of the trends in recruitment and stock, for international stock assessment, in light of the implementation of the Eel Management Plans;
- the development of methods to post-evaluate effects of management plans at the stock-wide level;
- the development of methods for the assessment of the status of local eel populations, the impact of fisheries and other anthropogenic impacts, and of implemented management measures;
- the establishment of international databases on eel stock, fisheries and other anthropogenic impacts, as well as habitat and eel quality related data, and the review and development of recommendations on inclusion of data quality issues, including the impact of the implementation of the eel recovery plan on time-series data, on stock assessment methods;
- reviewing and developing approaches to quantifying the effects of eel quality on stock dynamics and integrating these in stock assessment methods;
- responding to specific requests in support of the eel stock recovery Regulation, as necessary; and
- reporting on improvements to the scientific basis for advice on the management of European and American eel.

Main recommendations

1) Since recruitment remains at an all time low since records began, the stock continues to decline and stock recovery will be a long-term process for biological reasons, all exploitation and other negative anthropogenic factors impacting on the stock and affecting the production/escapement of silver eels should be reduced to as low as possible, until long-term stock recovery is achieved.

2) Assessment of the current and future status of the European spawning stock, in light of implementation of EMPs, including an assessment of the impact of anthropogenic mortalities and management actions, is urgently needed. This process should include:

  2.1) The aggregation of river basin specific data and assessments, into stock-wide assessments;

  2.2) The further development of models to assess compliance with the recovery target and evaluate management actions;

  2.3) The development of coherent local stock assessment procedures;

  2.4) The development of proxies for mortality rates;

  2.5) The international assessment of recruitment and stock trends to assess the response of the stock to management actions.

3) Eel Management Plans and their accompanying data should be made available to the joint EIFAC/ICES Working Group on Eel at the earliest opportunity to facilitate the assessments of the stock.

A toast to Leuven, by WGEEL

There are many ways to measure eel
Length, weight, number found in creel
But if the numbers were your only policy
Don't forget to test the *quality*.

We tried to do this, here in Belgium
Without drinking to delirium
Writing decision trees on table mats
While beer flowed fast from the taps.

Our SPR curves were made from chips
And designed us surveys for big ships
To re-search the uncertain ocean
For leptocephali in motion.

Now -Instead of moving down the text
We back-track from what should come next
So go back to line nineteen-twenty
For targets set when eels were plenty.

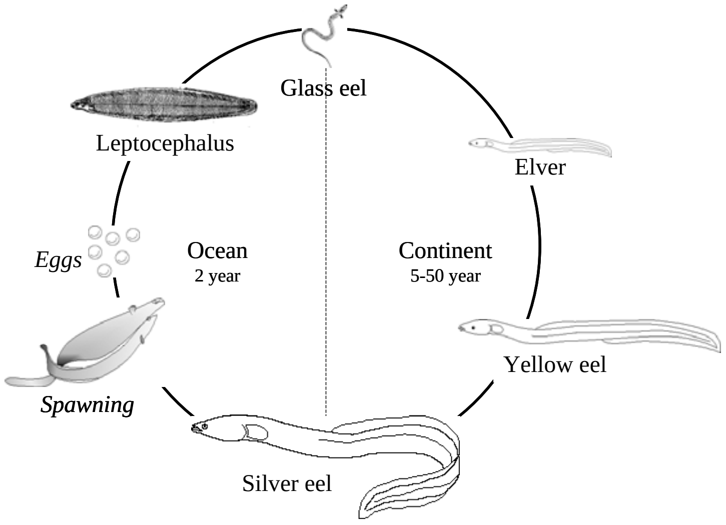
But all this thought is much too hard
For the inebriated bard
So let us re-check the strength of drink
Before our research vessels sink.

Yes, the best beer's rather strong
Best drunk from glasses short, not long
Test them all-find what you like
But don't ride home on a condemned bike.

Or you'll fall on Leuven's cobbled lanes
Tear your *stockings*, or rip your *genes*
So after an evening of perfect libation
Take a taxi home-in *assisted migration*.

Glossary

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



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

Glass eel	Young, unpigmented eel, recruiting from the sea into continental waters
Elver	Young eel, in its 1st year following recruitment from the ocean. The elver stage is sometimes considered to exclude the glass eel stage, but not by everyone. Thus, it is a confusing term.
Bootlace, fingerling	Intermediate sized eels, approx. 10–25 cm in length. These terms are most often used in relation to stocking. The exact size of the eels may vary considerably. Thus, it is a confusing term.
Yellow eel (Brown eel)	Life stage resident in continental waters. Often defined as a sedentary phase, but migration within and between rivers, and to and from coastal waters occurs. This phase encompasses the elver and bootlace stages.
Silver eel	Migratory phase following the yellow eel phase. Eel characterized by darkened back, silvery belly with a clearly contrasting black lateral line, enlarged eyes. Downstream migration towards the sea, and subsequently westwards. This phase mainly occurs in the second half of calendar years, though some are observed throughout winter and following spring.

Eel River Basin	“Member States shall identify and define the individual river basins lying within their national territory that constitute natural habitats for the European eel (eel river basins) which may include maritime waters. If appropriate justification is provided, a Member State may designate the whole of its national territory or an existing regional administrative unit as one eel river basin. In defining eel river basins, Member States shall have the maximum possible regard for the administrative arrangements referred to in Article 3 of Directive 2000/60/EC [i.e. River Basin Districts of the Water Framework Directive].”
River Basin District	The area of land and sea, made up of one or more neighbouring river basins together with their associated surface and groundwaters, transitional and coastal waters, which is identified under Article 3(1) of the Water Framework Directive as the main unit for management of river basins. Term used in relation to the EU Water Framework Directive.
Stocking	Stocking is the practice of adding fish [eels] to a waterbody from another source, to supplement existing populations or to create a population where none exists.

Contents

1 Introduction

1.1 The 2008 WGEEL

At the 95th Statutory Meeting of ICES (2007) and the 25th meeting of EIFAC (2008) it was decided that:

2007/2/ACOM15 The **Joint EIFAC/ICES Working Group on Eels** [WGEEL] (Chair: Russell Poole, Ireland), will meet in Leuven (INBO/KUL), Belgium, 3–9 September 2008, to:

(i) assess the trends in recruitment, stock and fisheries indicative of the status of the European stock, and of the impact of exploitation and other anthropogenic factors; analyse the impact of the implementation of the eel recovery plan on time-series data (i.e. data discontinuities). This might also include the establishment of an international database for data on eel stock and fisheries, as well as habitat and eel quality (update EEQD) related data; review and make recommendations on data quality issues;

(ii) develop methodologies for the assessment of the status of the eel stock, the impact of fisheries and other anthropogenic impacts and of implemented management measures; this might include, for example, support for EMPs on the determination of "pristine" spawner production levels and relative contribution of stocking;

(iii) review hypotheses and information on the possible relationships between the European (and American?) eel stock(s), recruitment patterns and climatic and oceanic factors;

(iv) respond to specific requests in support of the development and implementation of the stock recovery Regulation as necessary;

(v) report on progress in work on improvements in the scientific basis for advice on management of European eel fisheries.

WGEEL will report by 16 September 2008 for the attention of ACOM and DFC.

41 people attended the meeting, from seventeen countries (see Annex 1).

The current Terms of Reference and Report constitute a further step in an ongoing process of documenting the status of the European eel stock and fisheries and compiling management advice. As such, the current Report does not present a comprehensive overview, but should be read in conjunction with previous reports (ICES, 2000; 2002; 2003; 2004, 2005a, 2006, 2007).

In addition to documenting the status of the stock and fisheries and compiling management advice, in previous years the Working Group also provided scientific advice in support of the establishment of a recovery plan for the stock of European Eel by the EU. In 2007, the EU published the Regulation establishing measures for the recovery of the eel stock (EC 1100/2007). This introduced new challenges for the Working Group, requiring development of new methodologies for local and regional stock assessments and evaluation of the status of the stock at the international level. Implementation of the Eel Management Plans will likely introduce discontinuities to data trends and may require a shift from fisheries-based to scientific survey-based assessments.

The structure of this report does not strictly follow the order of the Terms of Reference for the meeting, since different aspects of subjects were covered under different headings, and a rearrangement of the Sections by subject was considered preferable. The meeting was organized using the Agenda in Annex 2. Five subgroups, under the headings of "Data and International Stock Assessment", "Methods and Methodologies", "Stocking", "Eel Quality" and "Oceans and Climate" addressed the Terms of Reference.

Chapter 2 presents trends in recruitment, stock, fisheries and aquaculture (ToR a).

Chapter 3 introduces the concept of post-evaluation and stock assessment at the international level, discusses data sources and gaps and presents a decision structure for stock assessment. (ToR a, b and e).

Chapter 4 discusses methods for the estimation of pristine and current escapement, (ToR a and e).

Chapter 5 reviews the data for stocking and aquaculture and updates previous advice on best practice for stocking (ToR a and b).

Chapter 6 updates the European Eel Quality Database (EEQD) and discusses the importance of the inclusion of spawner quality parameters in stock management advice (ToR a).

Chapter 7 reviews the hypotheses and information on possible relationships between recruitment, and climatic and ocean factors (ToR c.).

Terms of Reference a. (revision of catch statistics) is the follow-up of the analysis made in the report of the 2004 meeting of the Working Group (ICES 2005, specifically Annex 2). Following that meeting, a Workshop was held under the umbrella of the European Data Collection Regulation (DCR), in September 2005, Sånga Säby (Stockholm, Sweden). The Workshop report presented catch statistics in greater detail than had been handled by this Working Group before. Additionally, a further improvement of the catch statistics is foreseen, when the DCR is actually implemented for the eel fisheries across Europe.

It is envisaged that additional data and improved data will become available under the Eel and Data Collection Regulations.

2 Trends in recruitment, stocking, yield and aquaculture

2.1 Data

This Section collects the time-series datasets for the analysis of the status of the European eel population through the trends in recruitment, commercial landings, non-commercial and recreational catches stocking and aquaculture production of eel.

2.1.1 Recruitment

Information on recruitment is provided by a number of datasets, relative to various stages (glass eel and elver, yellow eel) recruiting to continental habitats (Dekker, 2002). Data of recruiting glass eels and elvers (young of the year) and yellow eels from 28 rivers in 11 countries are updated to the last season available (2007 and in some cases 2008) and provide the information necessary to examine the trends in recruitment. These data were derived from fishery-dependent sources (i.e. catch records) and fishery-independent surveys across much of the geographic range of European eel, and cover varying time intervals. Some of them date back as far as 1920 (glass eel, Loire France) and even the beginning of 20th century (yellow eel, Göta Älv Sweden). All of them, however, date back as far as 1970. The recruitment time-series data in European rivers are presented in Annex 3 (Tables 1 and 2).

Declining trends were evident over the last two decades for all time-series. After the high levels of the late 1970s, there was a rapid decrease that still continues to the present time. The trend is similar in recruitment dataseries for glass eels in estuarine areas (Figure 2.1) and in time-series for yellow eel colonization, monitored in northern countries where transition to yellow eel stage occurs before entering fresh waters (Figure 2.2).

Latest data for 2007 and 2008 demonstrates that recruitment continues to be at a very low level in most catchments. Although some series demonstrated a slight increase, most series remained at similar or lower levels to the previous season for both eel developmental stages.

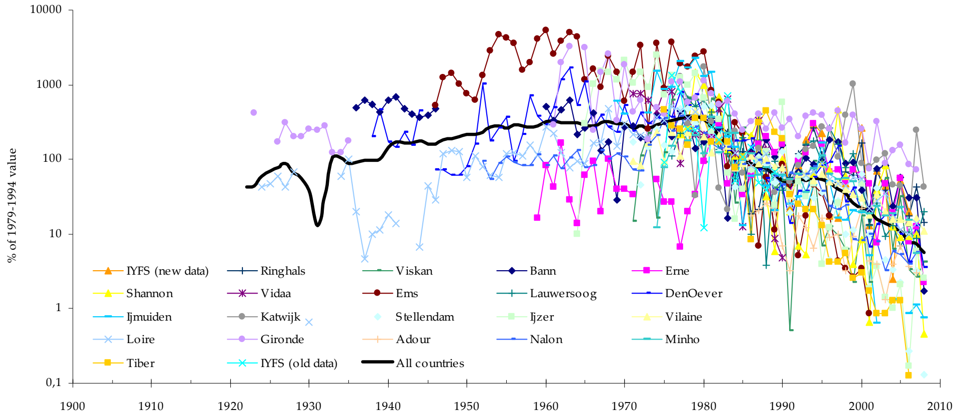


Figure 2.1: Time-series of monitoring glass eel recruitment in European rivers. Each series has been scaled to its 1979–1994 average. Note the logarithmic scale on the y-axis.

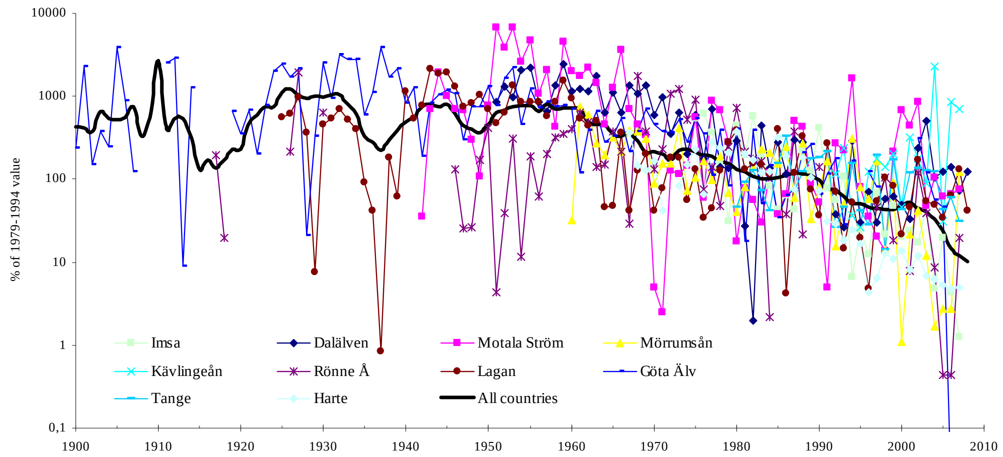


Figure 2.2: Time-series of monitoring yellow eel recruitment in European rivers. Each series has been scaled to the 1979–1994 average. Note the logarithmic scale on the y-axis.

2.1.2 Data on landings

Data on yellow/silver eel landings obtained from country reports 2008 are presented in Annex 3 (Table 3) and in Figure 2.3. Data on official eel landings from FAO sources are presented in Annex 3 (Table 4) and in Figure 2.4. Those two datasets do not include aquaculture production. To compare the two datasets the mean values for corresponding periods were compared (Figure 2.5).

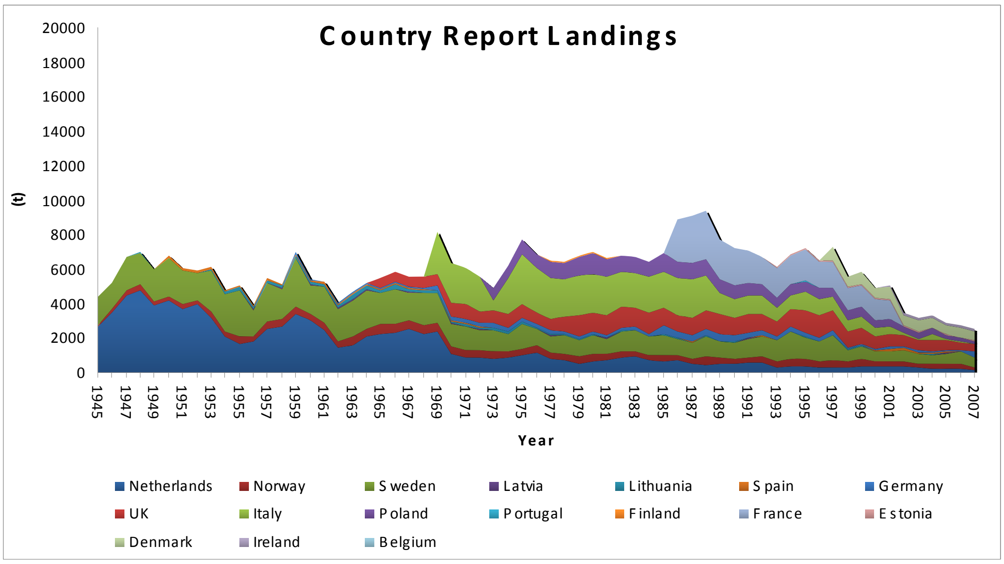


Figure 2.3: Landings of European eel in Europe (tonnes). Source: Country Reports 2008.

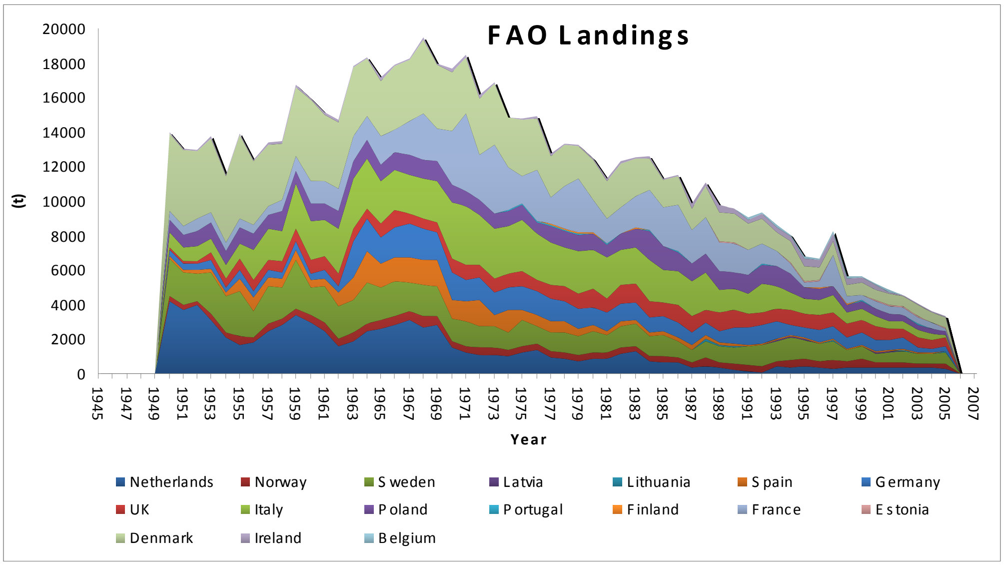


Figure 2.4: European eel landings in Europe (tons). Source: FAO.

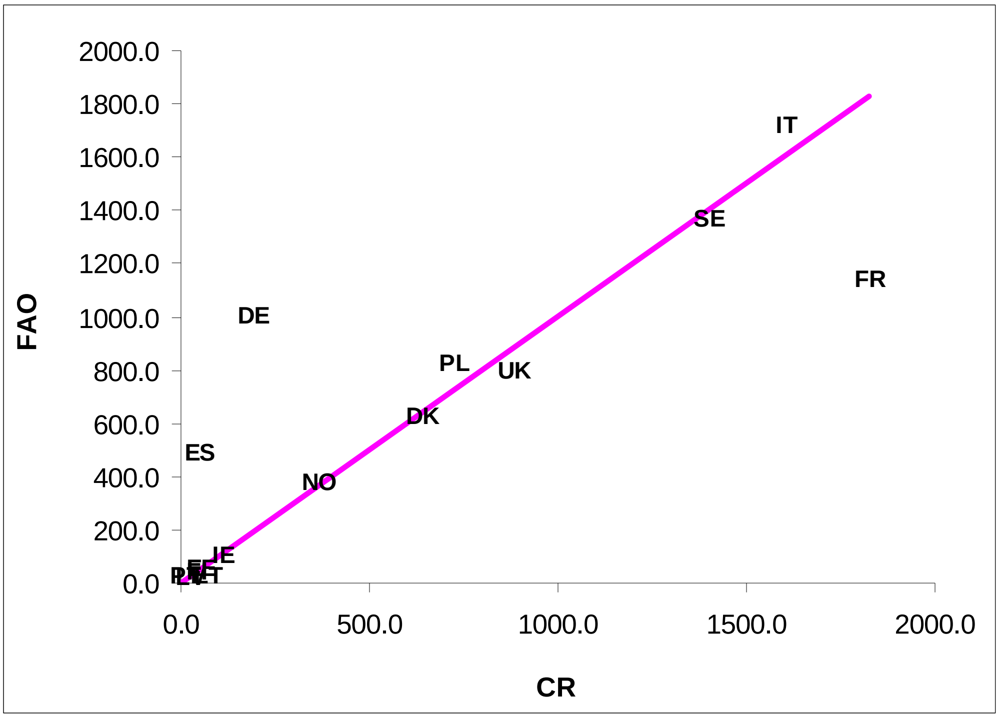


Figure 2.5: Differences in data on European eel landings in Europe obtained from FAO and similar data presented in country reports.

2.1.2.1 Data discontinuities

Both the data officially reported to FAO and the best estimates presented in the Country Reports suffered from reporting discontinuities in the past. Implementation of the EU Eel Regulation will require Member States to implement a full catch registration system. This will lead to considerable improvement of the coverage of the fishery, i.e. underreporting will probably reduce markedly. Dekker, 2003 analysed the trend in historical catch records, correcting for historical discontinuities on the basis of a series of increasingly complex statistical models. Since the discontinuity caused by the implementation of the EU Eel Regulation will affect all dataseries in the same year, statistical analyses will not be able to cope with this. Consequently, the discontinuity will have to be taken for granted.

However, future assessment of the status and trends in the stock, the anthropogenic impacts and the effect of recovery and restoration measures will heavily depend upon new data, which will be collected from the implementation of the Regulation onwards (see also Chapter 3). It seems not that likely, that before/after-comparisons will be achievable. Consequently, the discontinuity in landings data might be of relative minor importance. Direct stock estimates, such as scientific stock surveys, will not suffer from discontinuities, and these might therefore be used to mend the gap. It is therefore of utmost importance, that existing monitoring series will be continued, and additional series be implemented long before the first post-evaluation in 2012.

2.1.3 Recreational and non-commercial fisheries

Non-commercial (i.e. non-commercial usage of fishing gear except angling, which is classed as recreational fishing) catch data of glass eel were made available by France and Spain (Basque Country). For the Gironde Basin in France, non-commercial catches 1978–1982 exceeded commercial landings of glass eel (given in Table 2.1), but thereafter the dominance changed to commercial landings. Non-commercial fishery catches of glass eel have decreased over the time-series available.

Table 2.1: Non-commercial glass eel catches (t) for 1978–2007. FR Total applies to total catch of non-commercial fisheries in France.

GLASS EEL					
Year	FR Adour	FR Gironde	FR Loire	FR Total	ES Basque country
1978		107.8		647	
1979		116.2		697	
1980		217.1		1303	
1981		150.6		904	
1982		36.5		219	
1983		26.9		161	
1984		26.0		156	
1985		11.8		71	
1986		14.4		87	
1987		28.6		172	
1988		6.7		40	
1989		17.3		110	
1990		9.0		54	
1991		14.5		87	
1992		12.8		77	
1993		21.7		130	
1994	18	12.4		74	
1995	10	18.9		113	
1996	12	4.2		25	
1997	6	6.4		39	
1998	7	1.0		6	
1999	2	2.7	1	6	
2000		0.3	1	2	

GLASS EEL			
2001	0.1	1	
2002	6.2	37	
2003	0.1		0.9
2004	0.1		1.2
2005	0.5	2	1.3
2006			0.7
2007	0.1		

There is a lack of data on eel catches by non-commercial fisheries. Where estimates are available for some countries or regions it appears that commercial catches are generally dominating non-commercial catches but latter may comprise up to one third of total yields (Figure 2.6). Therefore, recreational yields and other non-commercial catches are a very important source of mortality in fresh-water eel stocks and reliable estimates are urgently needed.

Estimates of yellow eel catches of anglers were available only for four countries/rivers (Table 2.2). National angling catches of yellow eels of between 86 and 3300t have been reported and can comprise a relatively important part of the total yield.

Table 2.2: Yellow eel landings (t) of anglers from River Elbe, Germany (DE), Netherlands (NL), France (FR) and Poland (PL).

YELLOW EEL (ANGLING)				
Year	DE Elbe	NL	FR	PL
1970				3300
1971				
1972				
1973				
1974				
1975				
1976				
1977				
1978				
1979				
1980				
1981				
1982				
1983				
1984				
1985	114.5			
1986	116.9			
1987	117.5			
1988	118.4			
1989	112.2			
1990	104.6			
1991	92.1			
1992	83.7			
1993	88.0			

YELLOW EEL (ANGLING)				
1994	86.5			
1995	87.8			
1996	89.9			
1997	91.1			
1998	106.0			
1999	108.3			
2000	103.8			
2001	111.2			
2002	112.2			
2003	113.6			
2004	107.5			
2005	105.1		508.655	
2006	104.1			
2007	111.2	200		100

Data for non-commercial catches on yellow eel are given in Table 2.3. In contrast to Norway, where catches have been remaining in the same order of magnitude since 1989, they collapsed in the Gironde Basin.

Table 2.3: Yellow eel landings (t) of non-commercial fisheries other than angling from Norway (NO) Denmark (DK), Netherlands (NL) and France, Gironde Basin (FR).

YELLOW EEL (NON-COMMERCIAL)				
Year	NO	DK	NL	FR Gironde
1978				204.1
1979				229.5
1980				155.7
1981				148.8
1982				133.1
1983				76.2
1984				164.1
1985				170.3
1986				160.5
1987				134.3
1988				97.7
1989	124.9			40.2
1990	133.9			28.3
1991	130.6			15.8
1992	143.0			27.7
1993	116.3			21.4
1994	180.5			21.1
1995	297.6			18.4
1996	178.2			7.7
1997	242.3			9.7
1998	171.9			7.3
1999	187.4			1.5
2000	108.6			1.4

YELLOW EEL (NON-COMMERCIAL)				
2001	127.9			0.6
2002	138.5			1.1
2003	107.2			0.5
2004	97.3	138.1		1.3
2005	106.0			0.6
2006				1.3
2007			25.0	1.3

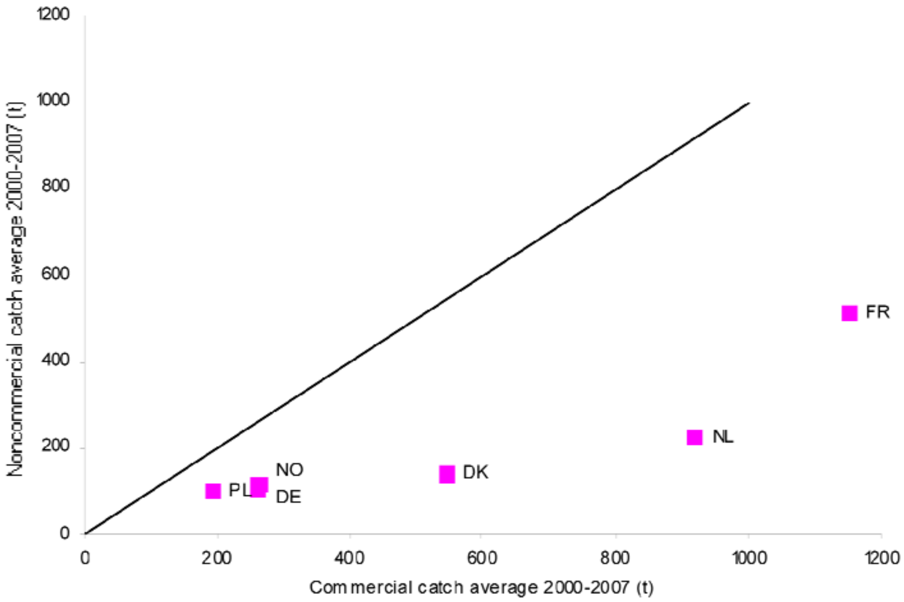


Figure 2.6: Non-commercial catches (Sum of angling and other fishing gear) against commercial catches as an average in 2000–2007. Note that there are inconsistencies in the data quality for commercial vs. non-commercial catches.

2.1.4 Trends in stocking

Data on stocking were obtained from a number of countries, separated for glass eels and for young yellow eels. The size of 'young yellow eel' varies between countries. Most data available were on a weight base. Weights were converted to numbers, using estimates of average individual weights of the eels at the size stocked. These were 3.5 g for Denmark, 10 g for Poland, 33 g for the Netherlands, 20 g for (eastern) Germany, 30–60 g for Elbe RBD (up to 2005, after which actual counts are available), and 90 g for Sweden. An overall number of 3000 glass eels per kg was applied to data from Belgium and Northern Ireland. An overview of data available up to 2008 is compiled in Annex 3 (Tables 5 and 6). Stocking in other EU countries, for which there are no time-series data, and hence are not included in Tables 5 and 6, are also summarized in Annex 3.

In the 2007 report of the WGEEL a sharp drop in glass eel stocking series around 1969 was mainly explained with the fact that Polish stocking figures ceased to be recorded. However, now the old Polish data have been included, but the graph still demonstrates a remarkable drop in glass eel stocking at that time. Obviously, there must have been other causes for the observed decrease.

Stocking with glass eel has decreased strongly since the early 1990s and appears now to be on a very low level with a still decreasing trend (Figure 2.7). However, this has partly been compensated for by an increasing number of young yellow eels stocked since the late 1980s. During the 1990s stocking of young eel demonstrated an increase but dropped again in the late 1990s (Figure 2.8). During the last years, a slight increase could be observed again. If several countries use stocking as a management option in their EMP's, an increasing tendency in stocking numbers may be expected, if sufficient glass eels are available on the market.

Figures 2.9 and 2.10 give a country by country breakdown of glass eel and young yellow eel numbers stocked respectively. Poland, Germany and the Netherlands stocked the largest numbers of glass eel and Germany, Denmark and the Netherlands stocked the largest numbers of young yellow eel.

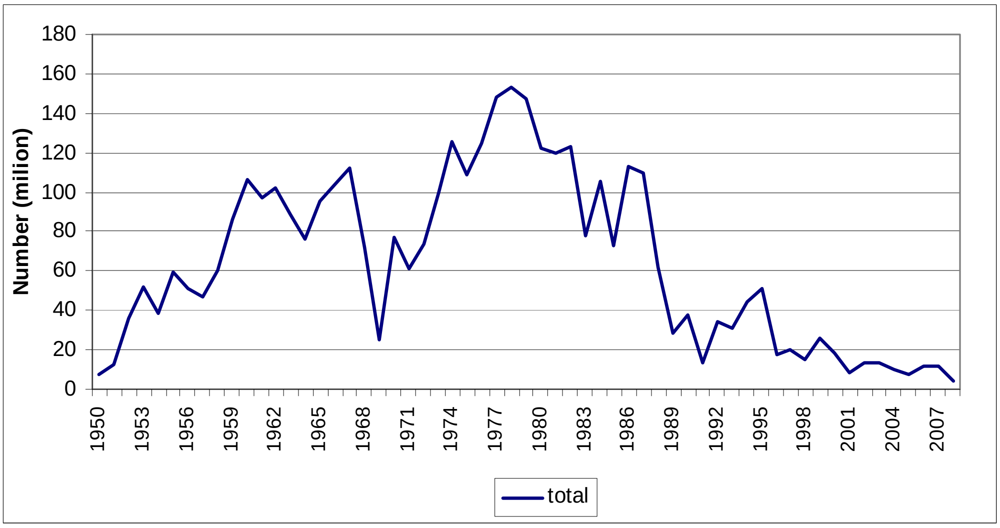


Figure 2.7: Stocking of glass eel and young yellow eel in Europe (East Germany and Elbe RBD, Lithuania, Netherlands, Denmark, Poland, Sweden, Northern Ireland, Belgium, Finland, Estonia and Latvia), in millions re-stocked.

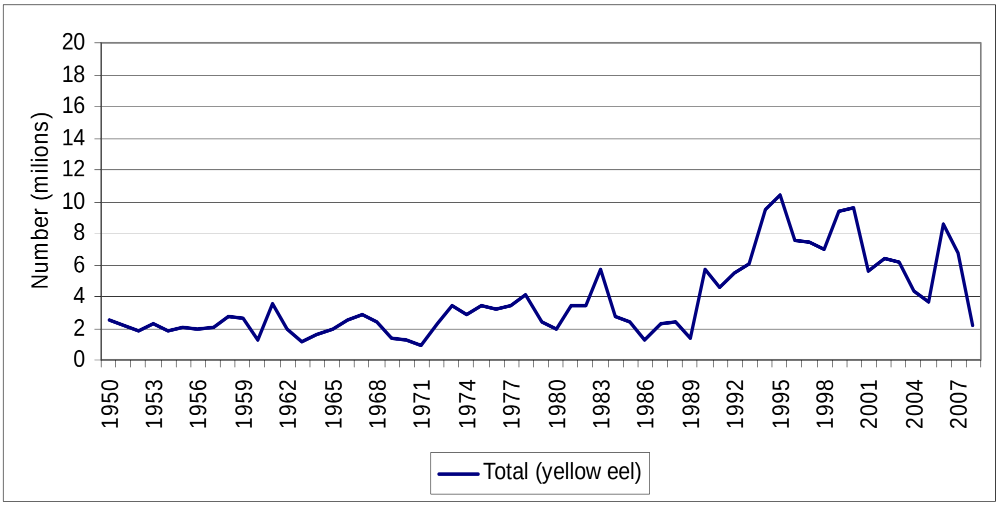


Figure 2.8: Stocking of young yellow eel in Europe (East Germany and Elbe RBD, Lithuania, Netherlands, Denmark, Poland, Sweden, Belgium, Finland, Estonia and Latvia), in millions stocked.

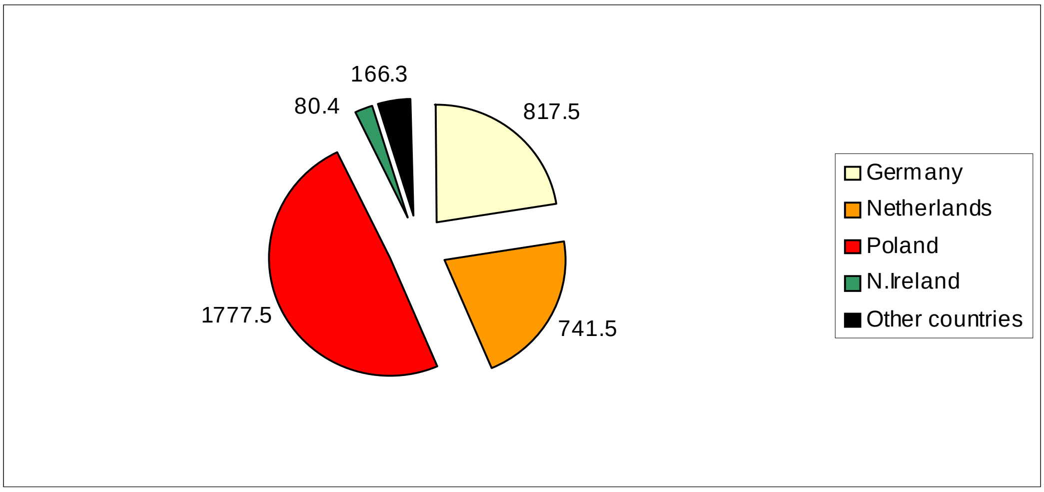


Figure 2.9: Total numbers of stocked glass eels in Europe (former East Germany and Elbe RBD, Netherlands, N. Ireland, Poland and other countries) cumulated for all reported years, in millions stocked.

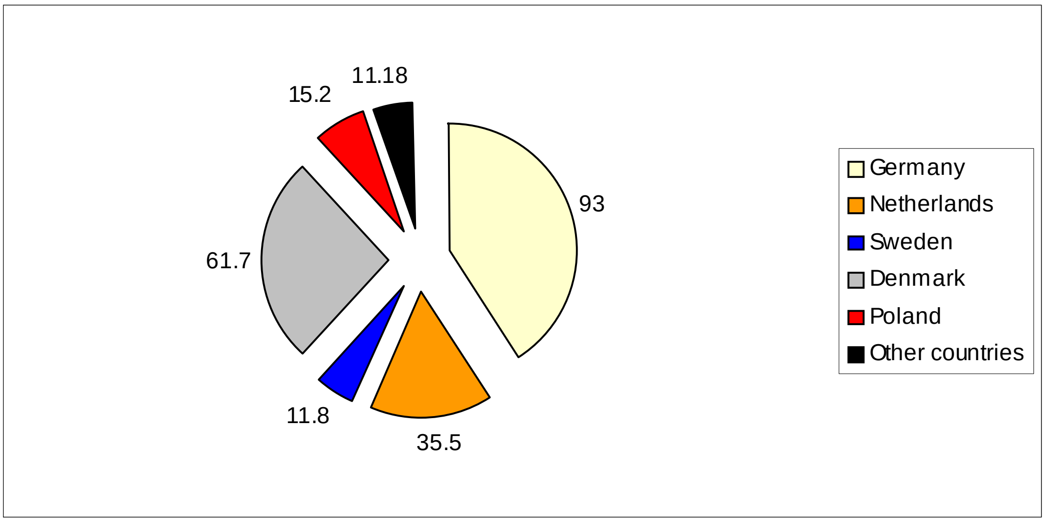


Figure 2.10: Total numbers of stocked young yellow eels in Europe (former East Germany and Elbe RBD, Netherlands, Sweden, Denmark, Poland and other countries) cumulated for all years reported, in millions stocked.

2.1.5 Aquaculture

Aquaculture production data for European eel limited to European countries from 1996 to 2007 are compiled by integrating different sources, FAO (Table 2.4), FEAP (Table 2.5), and Country Reports to WGEEL 2008 (Table 2.6). Some discrepancies still exist between databases and the national reports annexed to this report. These differences are, in some cases, caused by different purposes of using aquaculture production. For example, the total aquaculture production of eel in Germany in 2007 was 740 tons, where 300 tons was used for stocking and 440 tons for human consumption. The peak of production in Europe was reached in 2000 (11 000 tons), although most recently it seems to be fluctuating around 8000–9000 t. Fifty-nine eel farms were estimated to exist in 2006, twenty-nine of which were in the Netherlands, nine in Denmark and the rest scattered in other countries.

Table 2.4. Aquaculture production of European eel in Europe. from 1996 to 2006, in tonnes. ***Source: FAO.***

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Belgium	125	125	125	100	100	100					
Czech	4	3	3	1	1	1	1	1	<0.5	1	1
Denmark	1400	1689	2468	2717	2674	2100	1166	2012	1883	1673	1739
Estonia							5	15	7	40	40
France	160	160	42	42	42	42					
Germany					150	150	150	150	322	329	567
Greece	584	545	681	518	602	639	433	544	557	372	385
Hungary						73	36	11	11	6	
Ireland			20	25	1						
Italy	3000	3100	3150	3200	2700	2500	1699	1550	1220	1132	807
Malta	<0.5										
Netherlands	2800	2443	2634	3228	3700	4000	3868	4200	4500	4000	4200
Portugal	5	4	6	2	4	7	4	5	2	1	1
Romania			1								
Serbia	2	2	3	7	5	7	4	6	9	9	
Spain	249	335	347	383	411	339	424	339	424	427	403
Sweden	161	189	204	222	273	200	167	170	158	222	191
Total	8491	8595	9684	10445	10663	10158	7957	9003	9094	8212	8334

Table 2.5. Aquaculture production of European eel in Europe from 1996 to 2007, in tonnes. Source: Aquamedia (FEAP).

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Belgium	150	150	150	40								
Denmark	1200	1700	2468	2700	2675	2100	2300	2050	1500	1700	1900	2100
Estonia					5	5	13		24	17	23	30
France	160											
Germany	140	150	150		150	150		350	350	350	350	400
Greece	350	312	500	500	300	550	500	500	500	500	450	450
Hungary				19	13	104	48					
Italy	3000	3100	3100	3100	2900	2400	1400	1400	1200	1200	1000	1000
Lithuania			2	2	1	5	17	20	9	8	14	40
Netherlands	1800	1800	3250	3800	4000	4000	4000	4200	4500	4400	3800	4200
Norway	200	200	200									
Portugal	200	200	200	200	200	200						50
Spain	210	266	270	300	425	330	355	325	350	400	400	450
Sweden	184	215	250	250	250	230	230	230	230	230	230	230
Turkey		200	200	200	200							
Croatia											25	50
Total	7594	8293	10740	11109	11111	10074	8863	9075	8663	8805	8192	9000

Table 2.6. Aquaculture production of European eel in Europe from 1996 to 2007, in tonnes: Country reports (CR 2007 and 2008).

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Denmark	1568	1913	2483	2718	2674	2000	1880	2050	1500	1700	1900	2100
Estonia					5	7	15	18	26	19	27	52
Germany	204	221	260	400	422	347	381	372	328	329	567	740
Netherlands	2800	2450	3250	3500	3800	4000	4000	4200	4500	4500	4200	4000
Portugal	21		13	3	4	7	4		2	1		1
Sweden	161	189	204	222	273	200	167	170	158	222	191	175
Total	4754	4773	6210	6843	7178	6561	6447	6810	6514	6771	6885	7068

2.2 Analysis of trends in recruitment

The trends in recruitment data available were analysed in relation to life stage, type of monitoring and geographical area. The objective of this analysis is to derive a reliable index of recruitment, both for the assessment of the stock-to-recruit phase, as for the management and assessment of the recruit-to-stock phase. The available dataseries were qualified regarding:

- life stage (unpigmented glass eel; pigmented young-of-the-year; immigrating yellow eel older than 1 year);
- sampling type (trapping all incoming recruits in a river, trapping the recruits only partially, commercial total landing figures, commercial cpue, scientific survey estimates);
- geographical area (Baltic Sea including Kattegat and Skagerrak, North Sea, Channel, British Isle, Atlantic Ocean, Mediterranean Sea). No datasets are available at the moment for the Channel area.

Considering the small number of datasets, the dataseries for glass eel and for young-of-the-year were merged, and analysed together. Given the spatial distribution of different sampling techniques in Europe (commercial fisheries in the South, trapping mostly in the north), the effect of sampling type and of area can not be analysed concurrently; for young yellow eel older than 1 year only trapping dataseries exist. Consequently three analyses were feasible:

- area effect on glass eel and young-of-the-year (combined);
- sampling type effect on glass eel and young-of-the-year (combined);
- area effect on young yellow eel older than 1 year.

The analyses used generalized linear models (GLMs) with a site effect as a scaling parameter, a log link (site effect and other effects are assumed to be multiplicative) and a gamma error (variance is varying with the square of the mean, i.e. a constant coefficient of variation). The resulting time-trends are scaled to the 1970–1979 geometric mean. Figure 11 and Table 2.7 gives the main characteristics of the 40 datasets used.

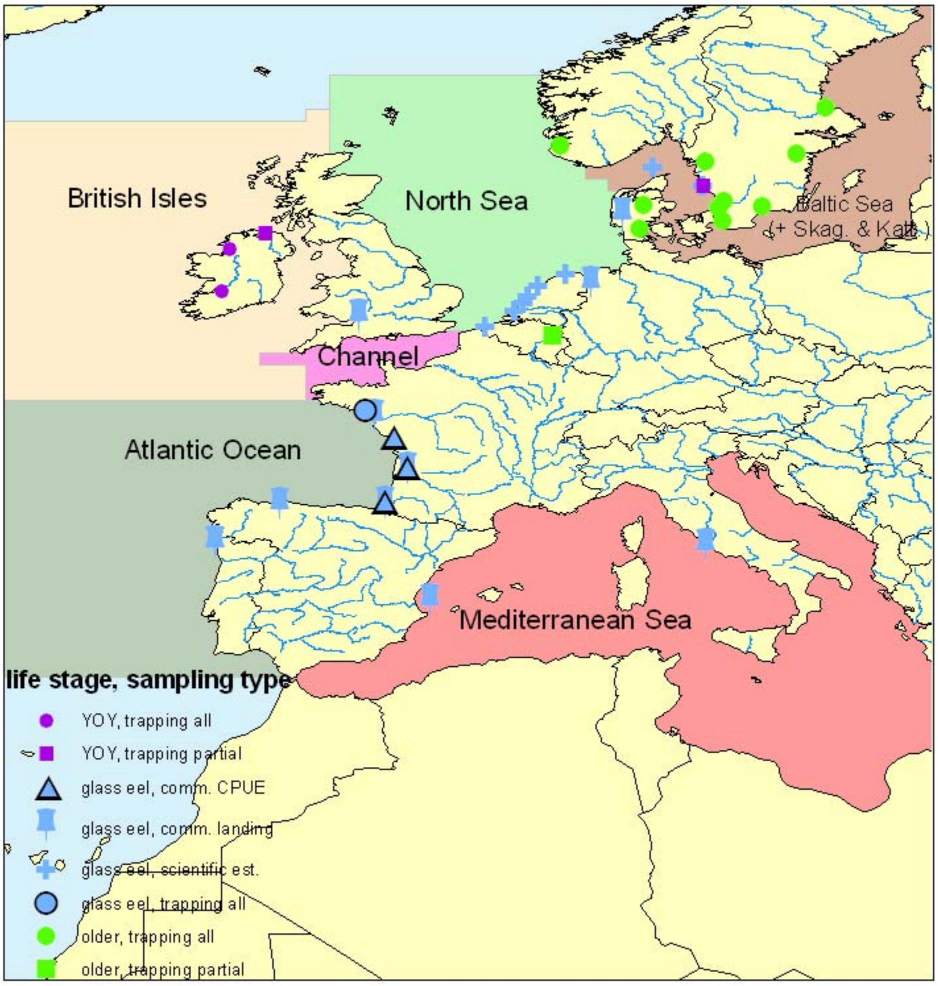


Figure 2.11: Map of the recruitment monitoring sites across Europe. Life stage and sampling method are indicated by the symbols.

Table 2.7: Data sets used for recruitment analysis. YOY = Young-of-the-year.

LIFE STAGE	AREA	MONITORING TYPE	COUNTRY	RIVER	LOCATION	LATITUDE	LONGITUDE
glass eel	North sea	scientific est.	Belgium	Ijzer	Nieuwpoort	51.08	2.45
glass eel	North sea	comm. landing	Denmark	Vidaa	Højer sluice	55.58	8.4
glass eel	North sea	comm. landing	Germany	Ems	Herbrum	53.02	7.2
glass eel	North sea	scientific est.	Netherlands		Lauwersoog	53.25	6.12
glass eel	North sea	scientific est.	Netherlands	Rhine	IJmuiden	52.27	4.36
glass eel	North sea	scientific est.	Netherlands	Oude RIjn	Katwijk	52.12	4.24
glass eel	North sea	scientific est.	Netherlands	Haringvliet	Stellendam	51.50	4.02
glass eel	North sea	scientific est.	Netherlands	Rhine	DenOever	52.56	5.03
glass eel	North sea	scientific est.	Sweden		IYFS	58	10
glass eel	North sea	scientific est.	Sweden		IYFS2	58	10
glass eel	North sea	scientific est.	Sweden	Kattegat-	Ringhals	57.15	12.07
glass eel	British Isle	comm. landing	UK	Severn	EA	51.36	-2.42
glass eel	British Isle	comm. landing	UK	Severn	HMRC	51.36	-2.42
glass eel	Atlantic Ocean	comm. cpue	France	Sèvres	Estuary	46.18	-1.08

LIFE STAGE	AREA	MONITORING TYPE	COUNTRY	RIVER	LOCATION	LATITUDE	LONGITUDE
glass eel	Atlantic Ocean	comm. landing	France	Adour	Estuary	43.32	-1.32
glass eel	Atlantic Ocean	comm. cpue	France	Adour	Estuary	43.32	-1.32
glass eel	Atlantic Ocean	comm. cpue	France	Gironde	Estuary	45.02	-0.36
glass eel	Atlantic Ocean	comm. landing	France	Gironde	Estuary	45.02	-0.36
glass eel	Atlantic Ocean	comm. landing	France	Loire	Estuary	47.18	-2.00
glass eel	Atlantic Ocean	trapping all	France	Vilaine	Arzal	47.3	-2.24
glass eel	Atlantic Ocean	comm. landing	Portugal	Minho	portugese	41.52	-8.51
glass eel	Atlantic Ocean	comm. landing	Spain	Minho	spanish part	41.52	-8.51
glass eel	Atlantic Ocean	comm. landing	Spain	Nalon	Estuary	43.31	-6.04
glass eel	Mediterannean	comm. landing	Italy	Tiber	Fiumara	41.44	12.14
glass eel	Mediterannean	comm. landing	Spain		Albufera de	39.20	0.23
YOY	Baltic Sea	trapping	Sweden	Viskan	Sluices	57.12	12.07
YOY	British Isle	trapping all	Ireland	Shannon	Ardnacrusha	52.42	-8.36
YOY	British Isle	trapping all	Ireland	Erne	Ballyshannon	54.3	-8.15
YOY	British Isle	trapping	Northern	Bann	Coleraine	55.12	-6.42
older	Baltic Sea	trapping all	Sweden	Dalälven		60.34	17.26
older	Baltic Sea	trapping all	Sweden	Mörrumsån		56.20	14.40
older	Baltic Sea	trapping all	Sweden	Lagan		56.31	13.03
older	Baltic Sea	trapping all	Sweden	Motala		58.35	16.11
older	Baltic Sea	trapping all	Sweden	Göta Älv		58.16	12.16
older	Baltic Sea	trapping all	Sweden	Kävlingeån		55.43	12.59
older	Baltic Sea	trapping all	Sweden	Rönne Å		56.16	12.50
older	North sea	trapping	Belgium	Meuse	Lixhe dam	50.45	5.40
older	North sea	trapping all	Denmark	Guden Å	Tange	56.21	9.36
older	North sea	trapping all	Denmark	Harte		55.21	9.25
older	North sea	trapping all	Norway	Imsa	Sandnes	58.54	5.59

2.2.1 Area effect on glass eel and young of the year recruitment

The model explains 72% of deviance (Table 2.8) and all effects were highly significant (p<0.001). Table 2.9 and Figure 2.12 give results from this model, i.e. a recruitment index per year by area. Every area demonstrates a declining trend since the end of 1970s or the beginning of 1980s. Before, no particular trend is detected. In recent years, recruitment is continuously declining in all areas. The mean recruitment for the past 5 years (2004–2008) is 10%, 9%, 3%, 3% and 1% of the 1970s reference level, for the British Isles, Atlantic Ocean, Baltic Sea, Mediterranean Sea and North Sea respectively. Apparently, the decline is stronger in northernmost and southernmost area of the species distribution than in the central part. A unique and uniform recruitment index all over the distribution area would require weighing the specific contributions by area, which is not achievable at the moment. More importantly, however, such an index would incorrectly represent the actual trend in each area.

Table 2.8: Analysis of deviance of the area effect on glass eel and young of the year GLM.

MODEL	RESIDUAL DF	RESIDUAL DEVIANCE
NULL	1051	1763.27
Site effect	1023	1545.73
Year x area effect	776	501.83

Table 2.9: Recruitment index per area. Each series have been scaled to 1970–1979 average = 100%.

YEAR	BALTIC SEA	NORTH SEA	BRITISH ISLES	ATLANTIC OCEAN	MEDITERRANEAN SEA
1950		32.7		25.2	
1951		34.6		48.6	
1952		129.9		48.2	
1953		112.2		30.8	
1954		181.8		41.1	
1955		172.8		61.4	
1956		133.0		57.5	
1957		71.9		51.7	
1958		124.5		61.1	
1959		170.2		63.2	
1960		209.2	121.4	87.5	394.2
1961		130.2	76.5	60.7	255.1
1962		228.0	142.4	127.4	371.0
1963		308.2	123.3	214.2	255.1
1964		129.4	44.1	63.5	92.8
1965		98.7	68.7	158.0	139.1
1966		94.2	110.2	59.7	115.9
1967		107.8	30.8	93.6	92.8
1968		132.2	66.9	156.3	92.8
1969		92.2	19.4	70.6	115.9
1970		112.4	63.9	117.2	23.2
1971	3.9	79.8	63.6	60.4	23.2
1972	28.5	118.7	70.9	62.8	23.2
1973	57.3	57.5	90.0	77.2	46.4
1974	4.2	154.1	140.9	82.2	23.2
1975	32.1	69.9	59.4	81.3	220.4
1976	162.3	114.8	48.7	131.4	149.8
1977	275.4	105.1	106.4	138.8	161.7
1978	172.6	85.8	131.0	112.2	98.7
1979	163.7	101.8	225.2	136.5	230.3
1980	23.5	80.4	165.6	104.7	224.8
1981	104.1	58.7	144.0	116.1	70.0
1982	94.0	30.0	179.1	73.1	62.3
1983	63.6	31.1	37.0	80.4	82.5
1984	7.7	12.5	63.5	68.5	59.2
1985	41.8	11.5	55.3	42.3	38.9
1986	25.6	12.6	60.4	50.4	35.7
1987	24.1	15.9	90.0	43.5	150.8
1988	19.1	9.2	74.0	46.1	173.1
1989	9.8	4.4	49.4	39.6	90.7
1990	11.4	17.1	69.0	27.2	72.8
1991	3.5	2.9	14.8	23.2	20.6
1992	18.4	5.8	31.8	31.5	11.7

YEAR	BALTIC SEA	NORTH SEA	BRITISH ISLES	ATLANTIC OCEAN	MEDITERRANEAN SEA
1993	16.3	6.2	40.4	31.3	10.4
1994	28.0	7.9	73.8	33.2	9.2
1995	7.7	8.7	59.5	40.9	7.3
1996	2.7	7.9	57.1	24.8	5.6
1997	4.1	6.6	80.8	27.6	2.7
1998	4.9	3.7	38.5	18.7	8.9
1999	3.9	8.0	32.8	24.5	4.6
2000	12.2	5.3	20.1	25.7	8.8
2001	1.1	1.0	14.5	8.7	5.9
2002	8.5	2.7	13.1	15.6	4.4
2003	9.6	1.9	26.7	8.2	3.0
2004	1.6	0.9	13.7	8.8	2.8
2005	6.9	1.1	18.9	11.2	0.8
2006	1.5	0.5	9.4	7.8	3.8
2007	2.9	2.3	8.4	7.2	3.8
2008	1.7	0.8	1.0	8.2	
mean 2004–2008	2.9	1.1	10.3	8.6	2.8

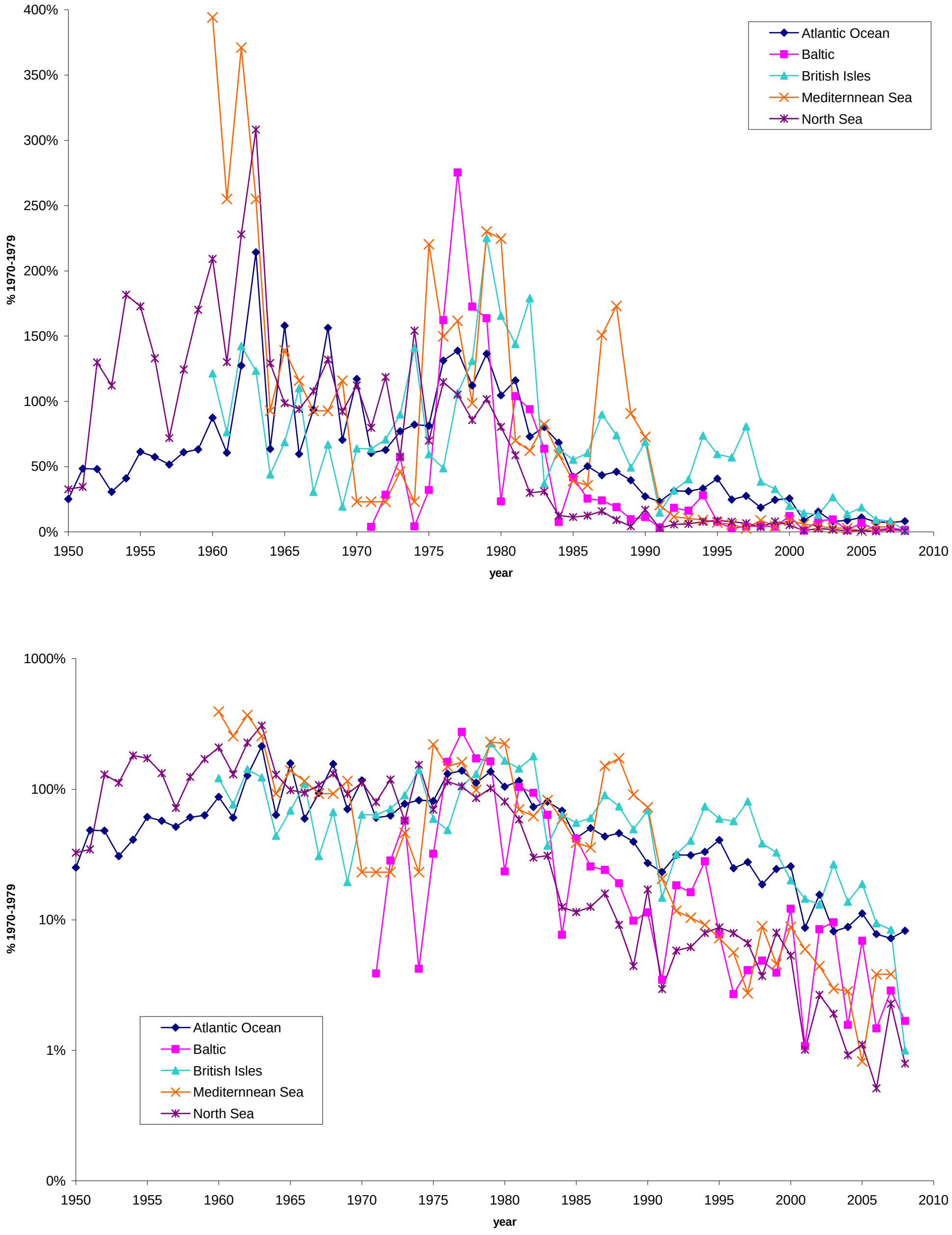


Figure 2.12: Recruitment (glass eel and young of the year) index per area in regular (upper panel) and in logarithmic scale (lower panel). Each series have been scaled to 1970–1979 average.

2.2.2 Sampling type effect on glass eel and young of the year recruitment

This model explains 66% of deviance (Table 2.10) and all effects are highly significant ($p<0.001$). Table 2.11 and Figure 2.13 give results from this model. Recruitment indices per sampling type demonstrate the same trend as recruitment index per area: decreasing trend since the end of 1970s or the beginning of 1980s. Depending on sampling type the present level is between 1% and 11% (2004–2008 average) of 1970–1979 level. Commercial cpue and trapping all, only represented by datasets in the central part of the eel distribution, have the highest present level (11% and 10%). Commercial catch and trapping partial, represented in the central and extreme part of the eel distribution, have intermediate present level (5%), while scientific sampling, only taking place in North Sea, has the lowest present level (1%). The analysis did not suppose any particular distribution pattern of the recruitment; we can thus build an index of recruitment of all Europe. The European index is calculated as the geometric mean of each of the monitoring indices, i.e. the least-squares mean (Table 2.11 and Figure 2.12). This combined index demonstrates that the present recruitment is only 5% of the 1970–1979 level.

Table 2.10: Analysis of deviance of the area effect on glass eel and young of the year GLM.

MODEL	RESIDUAL DF	RESIDUAL DEVIANCE
NULL	1051	1763.27
Site effect	1023	1545.73
Year x monitoring type effect	764	593.15

Table 2.11: Recruitment index per monitoring type and geomean. Each series have been scaled to 1970–1979 average.

YEAR	COMMERCIAL CATCH	COMMERCIAL CPUE	SCIENTIFIC ESTIMATE	TRAPPING ALL	TRAPPING PARTIAL	GEOMEAN
1950	39.5		12.0			21.8
1951	45.7		24.3			33.3
1952	62.8		156.1			99.0
1953	88.4		26.6			48.5
1954	139.0		39.5			74.1
1955	139.9		54.7			87.5
1956	124.8		14.3			42.2
1957	71.5		31.9			47.8
1958	86.6		105.0			95.3
1959	138.1		57.6			89.2
1960	246.6		43.5	56.4	94.9	87.1
1961	130.2	45.7	75.1	28.9	63.2	60.6
1962	186.6	181.2	176.5	113.3	86.3	142.3
1963	198.3	346.7	251.9	19.7	116.2	131.8
1964	135.3		39.8	9.6	40.2	38.0
1965	114.2	201.8	101.3	41.3	48.7	85.9
1966	76.9	73.8	87.6	64.2	79.2	75.9
1967	87.7	90.3	131.6	13.8	24.3	51.1
1968	147.3	145.7	118.3	68.8	32.3	89.2
1969	79.4	88.2	92.0	27.5	5.4	39.5
1970	81.4	113.0	138.9	27.5	51.1	71.0
1971	79.1	67.4	69.3	43.3	29.7	54.4
1972	94.6	70.6	89.5	55.0	41.2	67.0
1973	67.6	87.2	63.9	112.9	61.7	76.5
1974	95.9	92.1	161.5	95.8	40.9	89.0
1975	111.3	65.5	64.9	41.0	55.2	64.0
1976	130.6	149.2	95.0	85.9	147.6	118.6
1977	121.9	112.6	118.9	65.2	260.0	122.6
1978	100.7	119.2	91.3	105.9	169.3	114.5
1979	116.8	123.2	107.0	367.2	143.4	152.0
1980	101.8	107.2	77.7	241.0	34.6	93.3
1981	85.2	105.1	62.0	152.9	151.4	105.1

YEAR	COMMERCIAL CATCH	COMMERCIAL CPUE	SCIENTIFIC ESTIMATE	TRAPPING ALL	TRAPPING PARTIAL	GEOMEAN
1982	63.9	64.1	24.7	235.8	146.1	81.0
1983	65.8	54.1	26.4	67.2	80.9	55.2
1984	51.3	60.6	10.5	53.5	15.1	30.5
1985	31.1	34.7	12.3	69.5	58.0	35.2
1986	37.5	31.3	11.5	75.8	50.7	34.9
1987	51.7	45.1	13.9	118.8	47.0	44.8
1988	51.4	45.0	8.5	74.2	40.6	35.8
1989	32.4	51.1	5.7	46.4	18.5	24.1
1990	27.4	21.0	20.9	72.2	25.5	29.4
1991	16.3	20.2	3.4	18.5	4.4	9.8
1992	18.0	36.7	7.6	36.8	24.4	21.4
1993	18.4	38.0	8.5	43.3	20.9	22.2
1994	22.6	28.6	11.3	91.6	27.6	28.4
1995	25.2	38.6	10.5	66.5	10.4	23.4
1996	19.1	23.3	8.6	39.3	19.7	19.7
1997	17.1	32.5	7.4	109.6	18.2	24.1
1998	15.0	15.8	4.9	31.3	9.5	12.8
1999	14.6	30.2	10.0	24.7	9.1	15.8
2000	12.8	46.0	7.8	22.4	7.2	15.0
2001	5.9	7.8	1.3	22.2	2.5	5.0
2002	8.3	20.5	3.4	16.3	13.7	10.5
2003	6.2	7.9	2.3	29.7	19.4	9.2
2004	6.8	9.1	1.0	10.4	3.5	4.7
2005	7.2	14.3	1.6	17.9	12.1	8.2
2006	5.5	11.7	0.7	6.6	3.6	4.1
2007	4.8	9.9	2.7	8.6	3.4	5.2
2008	0.6	11.7	0.9	4.4	0.3	1.5
mean 2004–2008	5.0	11.4	1.4	9.6	4.6	4.7

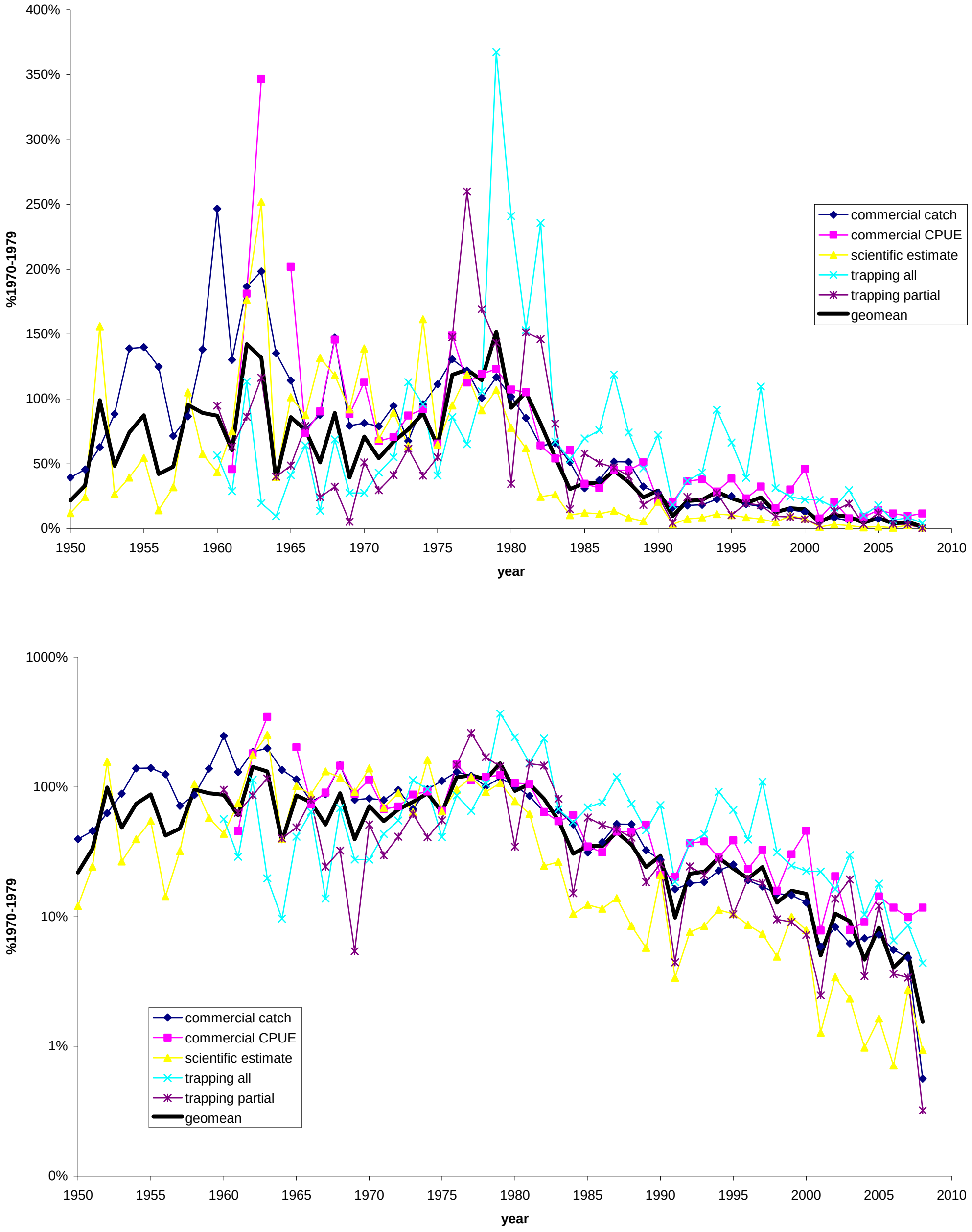


Figure 2.13: Recruitment (glass eel and young of the year) index per monitoring and geomean of these series in regular (upper panel) and in logarithmic scale (lower panel). Each series have been scaled to 1970–1979 average.

2.2.3 Area effect on young yellow eel older than 1 year

Data of two areas only (Baltic Sea including Kattegat, Skagerrak and North Sea) are available to fit this model. It explains 59% of deviance (Table 2.12) and all effect are highly significant (p<0.001). Table 2.13 and Figure 2.14 give results from this model, i.e. a young yellow eel older than 1 year recruitment index per area. The Baltic Sea (including Kattegat and Skagerrak) index demonstrates a continuous decline since the beginning of the period (1950). The North Sea index demonstrates the same trend, at least since the mid 1970s. The current level (2004–2008) is only 25% and 6% of the 1970s level for Baltic Sea (including Kattegat and Skagerrak) and North Sea respectively and the Baltic Sea (including Kattegat and Skagerrak) is at 8% of the 1950s level. None of theses series demonstrates any sign of recovery.

Table 2.12: Analysis of deviance of the area effect on young yellow eel older than 1 year GLM.

MODEL	RESIDUAL DF	RESIDUAL DEVIANCE
NULL	448	886.01
Site effect	438	725.79
Year x area effect	342	363.41

Table 2.13: Young yellow eel older than 1 year index per area. Each series have been scaled to 1970–1979 average.

YEAR	BALTIC SEA (INCLUDING KATTEGAT AND SKAGERRAK)	NORTH SEA		BALTIC SEA (INCLUDING KATTEGAT AND SKAGERRAK)	NORTH SEA
1950	269		1980	122	134
1951	360		1981	38	70
1952	356		1982	60	116
1953	572		1983	62	51
1954	290		1984	42	38
1955	431		1985	68	78
1956	207		1986	32	65
1957	226		1987	72	25
1958	232		1988	82	72
1959	492		1989	38	47
1960	245		1990	30	78
1961	249		1991	62	29
1962	244		1992	27	16
1963	214		1993	17	21
1964	82		1994	94	15
1965	152		1995	14	10
1966	214		1996	17	4
1967	117	213	1997	25	19
1968	245	85	1998	22	7
1969	166	74	1999	27	18
1970	68	100	2000	28	9
1971	92	25	2001	24	11
1972	146		2002	66	11
1973	197	50	2003	31	13
1974	77	90	2004	40	7
1975	155	175	2005	11	5
1976	49	139	2006	21	4
1977	79	152	2007	36	8
1978	73	101	2008		
1979	64	68			
			mean 2004–2008	27	6.2

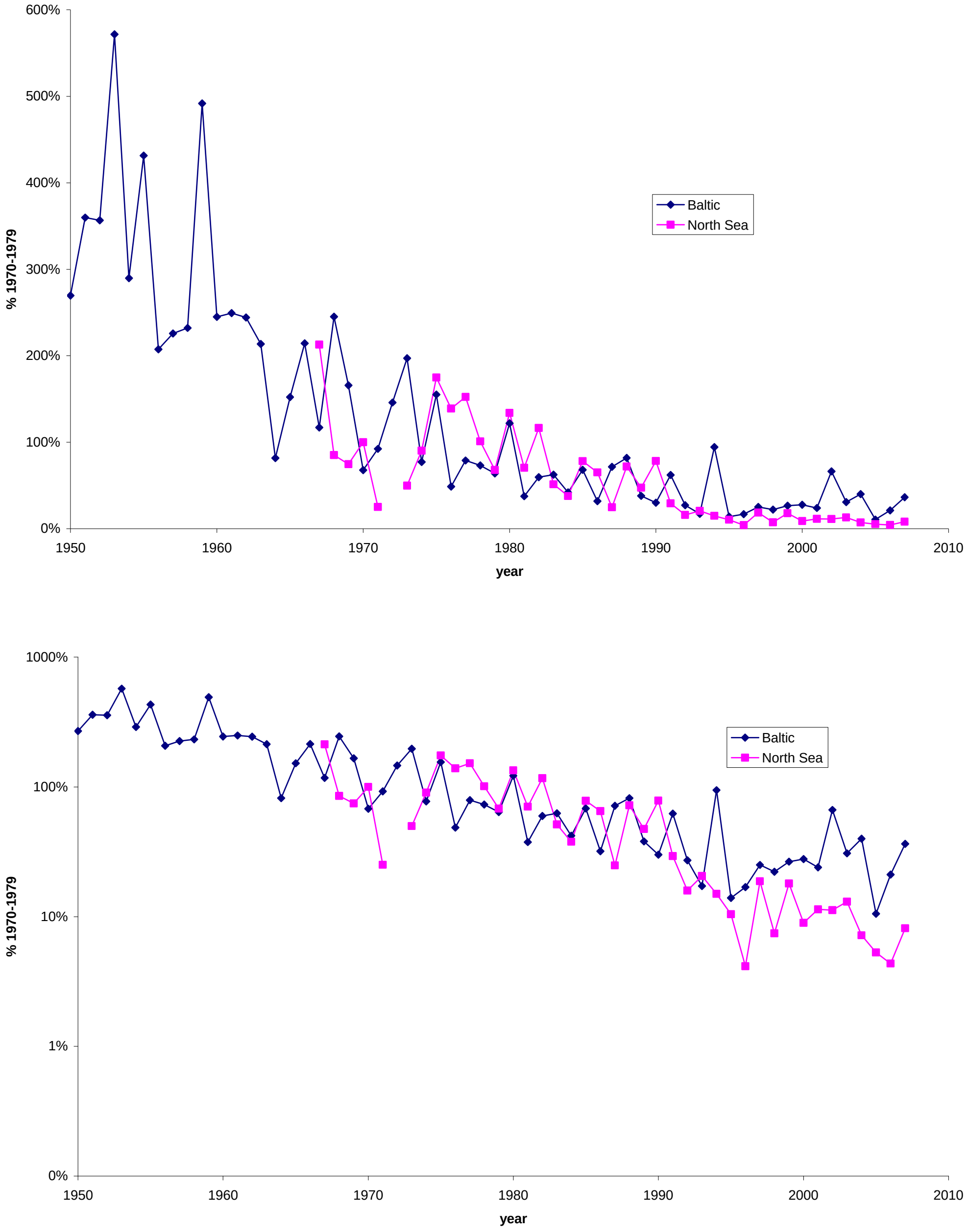


Figure 2.14: young yellow eel older than 1 year index per area in regular (upper panel) and in logarithmic scale (lower panel). Each series have been scaled to 1970–1979 average.

2.2.4 Discussion

Area effect and sampling type effect on glass eel and young of the year recruitment models are fitted on the same data. The area effect model explained more deviance while using fewer degrees of freedom than sampling type effect. On a statistical basis, the geographical pattern seems to fit the data better than the sampling effect, but the difference is not very clear. The geographical pattern can also be explained by the difference found in sampling type. When comparing datasets in different areas with the same sampling type (trapping partial in Baltic Sea including Kattegat and Skagerrak and in British Isles or commercial catches in the North Sea, British Isles, Atlantic Ocean and Mediterranean Sea), the geographical pattern is confirmed. Although sampling biases may exist, geographical pattern (stronger decrease in extreme part of the species distribution area) is the more likely interpretation.

The implementation of the EU Eel Regulation might result in discontinuities in the data on recruitment. First, commercial fisheries might be reduced, affecting the series based on commercial landings and commercial cpues. Second, the Regulation obliges Member States to implement a full registration programme for landings and fishing efforts, probably resulting in more complete coverage of the fishery. The recruitment series based on trapping (all or partial) and the scientific estimates will not be affected. For the (international) analysis of trends, the dataseries suffering from discontinuities will have to be split into "before" and "after", reducing the continuity of the overall analysis. Since this (unwanted but unavoidable) breakpoint will occur in just some sampling methods, it is all the more important to settle the area/sampling problem, i.e. to collect additional unpublished archive dataseries, strengthening the discriminating power of the above analyses.

The Baltic Sea (including Kattegat and Skagerrak) index of young yellow eel older than one year and to a lesser extent the North Sea index for this stage demonstrates a quite different pattern with a decrease starting earlier (at least since 1950 for the Baltic). Unfortunately, the Baltic Sea index for glass eel begins in 1971 only. This index does not differ from other area indices. Two hypotheses can explain these observations;

- the Baltic Sea including Kattegat and Skagerrak glass eel and young of the year index does not start early enough to strongly distinguish from other areas;
- young yellow eel older than 1 year in the Baltic Sea including Kattegat and Skagerrak area started to decline whereas glass eel and young of the year recruitment was constant. The reason for the yellow eel decline is unclear.

The first hypothesis better fits the data, although further information (young yellow eel data in the rest of Europe, or glass eel/young-of-the-year data in the Baltic Sea including Kattegat and Skagerrak area) will be needed to confirm this.

2.3 Conclusions and recommendations for Chapter 2: Trends in recruitment, stocking, yield and aquaculture

2.3.1 Conclusions

All glass eel and young of the year recruitment series demonstrate a clear decline since about 1980 with no sign of recovery. Recruitment is currently at only 5% of the 1970–1979 level. The Baltic Sea, including Kattegat and Skagerrak indices of young yellow eel recruitment, demonstrates a clear decline since about 1950. The decline in recruitment appeared stronger in the more northern and southern parts of the distribution. It is recommended to use recruitment indices per area (Baltic, North Sea, British Isles, Atlantic Coast, eastern and western Mediterranean), and to collect and analyse additional data to confirm the spatial pattern, and to establish the reliability and bias in the different sampling methods.

There needs to be an improvement in the data collected and data reported, particularly on landings and on stocking. Hopefully, the traceability requirements under the EU Regulation and CITES will improve this situation.

2.3.2 Recommendation

The analysis of aquaculture is complicated by the existence of three different datasets. We recommend that the collection of such data are centrally coordinated to provide a single dataset.

The situation is even more complicated for stocking, since in some countries no central databases exist. Therefore, information on stocking is incomplete. This situation should be improved in order to obtain a more comprehensive picture of the stocking activities in Europe.

It is recommended to use glass eel indices per area (i.e. Baltic, North Sea, British Isles, Atlantic Coast, Mediterranean), and to collect and analyse additional data to confirm the spatial pattern, and to establish the reliability and bias in the different sampling methods.

3 International stock assessment and data needs

3.1 Introduction on stock assessment and data needs

The European Union has decided on a protection and restoration plan (Eel Regulation) in 2007, aiming at the protection of 40% of the silver eels, relative to a situation without human influence. At the heart of the Regulation is the obligation for all Member States to develop a (national or river basin specific) management plan for the eel stock and fisheries, aiming at the agreed 40% target. Each management plan should contain an assessment of the current status of the local stock, a description of future monitoring and registration of catch and fisheries for future assessments of the stock and anthropogenic impacts.

The WGEEL considers its tasks (ICES and EIFAC ToRs) to assess and evaluate the overall status of the stock, and the impact of protection measures taken. There is an apparent overlap with the obligation in the Eel Regulation, to report on the status of the stock in individual Eel Management Units, and with the evaluation by the Commission. However, the assessment of the working group will focus on the total population, independent of the split over jurisdictions and management units. Only where the biological processes are inherently spatially diversified, will the assessment of the working group go into disaggregate analyses.

This chapter will elaborate the concepts of an international assessment of a regionally managed stock (Section 3.2), and derive criteria for a minimally required dataset on eel (Section 3.3).

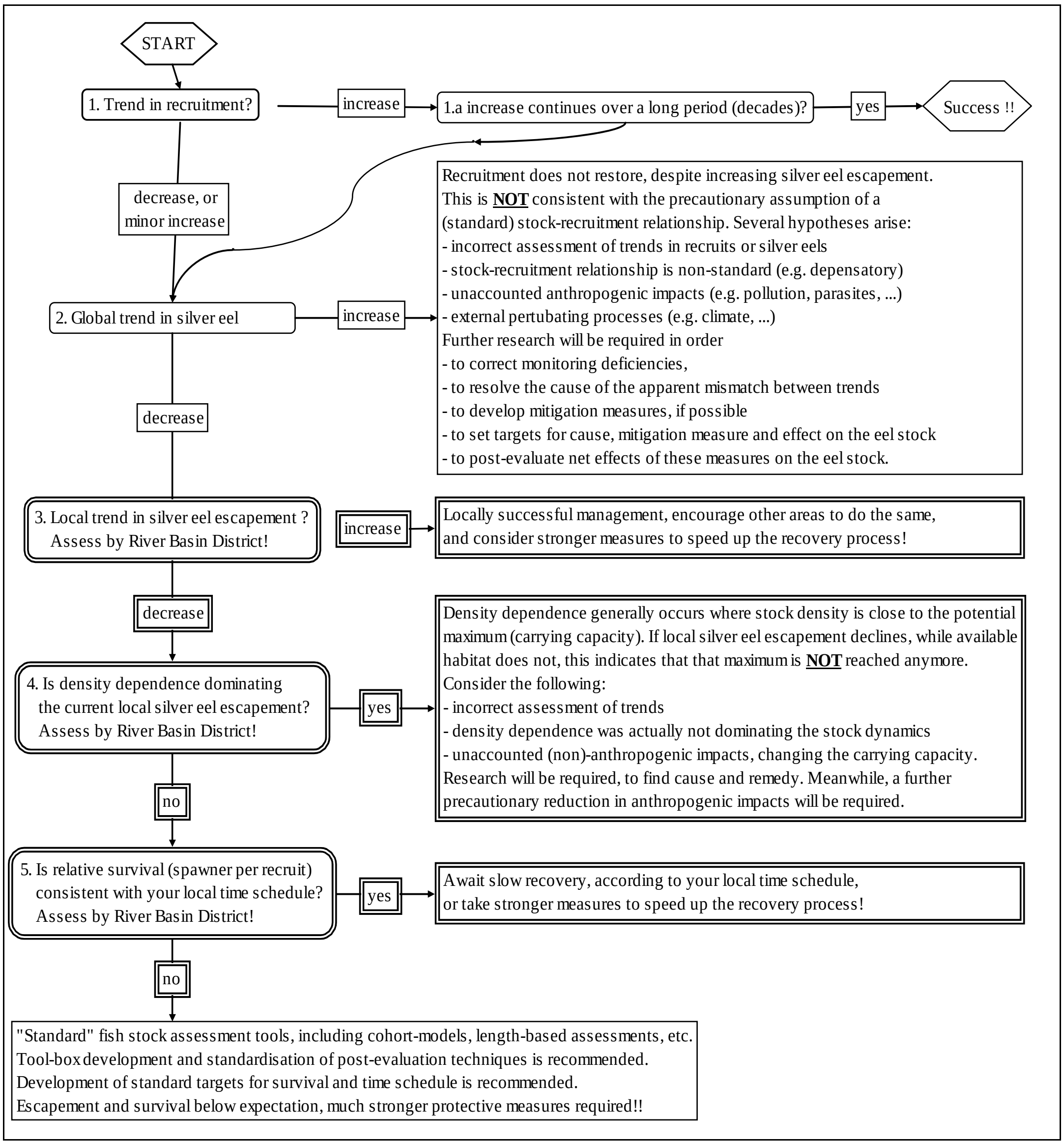
3.2 International stock assessment

3.2.1 International management and stock assessment

The EU Regulation on eel sets a common target for the escapement of silver eels, at 40% of the natural escapement in the absence of anthropogenic impacts. In accordance with the precautionary advice provided by ICES (2002), it is assumed that a stock recruitment relationship exists. Member States are obliged to implement protective measures to achieve the escapement target, and should provide a time schedule for the attainment of this target. This time schedule is certainly much more determined by the slow biological restoration of the stock (decades; Åström and Dekker, 2007), than by the time required to implement the protection measures completely (years?). The Regulation sets no limit on the time frame for restoration. Implicitly, this rules out the hypothesis that the stock–recruitment relationship is determined by depensatory processes, as tentatively found in historical data (Dekker, 2004; ICES 2007). As an alternative to the depensation hypothesis, it has been hypothesized, that the decline of the stock might have been caused by climate factors (Chapter 7 of this report), pollution or parasitism (chapter 6 of this report), and others acting in the oceanic phase.

Noting that the EU Eel Regulation has set targets for the quantity (biomass) of silver eels escaping from the continent, and obliges Member States to take protective measures primarily focusing on the quantities escaping, but has not set targets and does not oblige to take actions with respect to other processes (related to silver eel quality, or climate change) in relation to eel management (if possible), the international assessment of the status of the stock will presently focus on the dynamics of stock in numbers and quantities, and on the effect of protection and restoration measures taken. This does not, in principle, rule out potential effects of other factors, including silver eel quality and/or climate factors. However, since the mechanisms involved have not been cleared up, and the quantitative impact on the stock is unclear, there is no way forward to include these aspects in international stock assessment at this moment in time. Further research will be needed, to elucidate the processes, to quantify the impacts, to find mitigation measures, to advise management targets, and to assess the net effects of measures taken on the eel stock. Until that has been done, prime focus in the stock assessment will necessarily rest with "classical" fish stock assessment, which for the eel case, will be complex enough.

Under the EU Eel Regulation, an international assessment will be required of the population-wide status of the stock, and an assessment of the impact of the management measures taken. The Regulation focuses on stock dynamics in terms of quantities and biomass and thus the assessment leaves aside scientific debates on the impact of spawner quality and/or climate factors. A decision tree diagram for this assessment is presented in Figure 3.1. The indicated steps are elaborated in the text below;



Recruitment does not restore, despite increasing silver eel escapement.
This is **NOT** consistent with the precautionary assumption of a (standard) stock-recruitment relationship. Several hypotheses arise:
- incorrect assessment of trends in recruits or silver eels
- stock-recruitment relationship is non-standard (e.g. depensatory)
- unaccounted anthropogenic impacts (e.g. pollution, parasites, ...)
- external pertubating processes (e.g. climate, ...)

Further research will be required in order
- to correct monitoring deficiencies,
- to resolve the cause of the apparent mismatch between trends
- to develop mitigation measures, if possible
- to set targets for cause, mitigation measure and effect on the eel stock
- to post-evaluate net effects of these measures on the eel stock.

Locally successful management, encourage other areas to do the same, and consider stronger measures to speed up the recovery process!

Density dependence generally occurs where stock density is close to the potential maximum (carrying capacity). If local silver eel escapement declines, while available habitat does not, this indicates that that maximum is **NOT** reached anymore.
Consider the following:
- incorrect assessment of trends
- density dependence was actually not dominating the stock dynamics
- unaccounted (non)-anthropogenic impacts, changing the carrying capacity.

Research will be required, to find cause and remedy. Meanwhile, a further precautionary reduction in anthropogenic impacts will be required.

Await slow recovery, according to your local time schedule, or take stronger measures to speed up the recovery process!

"Standard" fish stock assessment tools, including cohort-models, length-based assessments, etc.
Tool-box development and standardisation of post-evaluation techniques is recommended.
Development of standard targets for survival and time schedule is recommended.
Escapement and survival below expectation, much stronger protective measures required!!

Figure 3.1: Decision tree for international assessment of the impact of protective measures taken under the EU Eel Regulation. International issues are depicted in a single-lined box, whereas River Basin Specific issues are in a double-lined box.

3.2.2 Only recruitment and escapement trends?

Taking a superficial view on first examination of the task of international stock assessment, it might appear that the time-series data on spawner emigration and glass eel recruitment are the only data items of information essential to international assessment of eel stock and recruitment. This view, however, ignores the reality of the current and probable future situation. Only if recruitment were to recover rapidly following measures to increase spawning stock, resulting in confidence that recovery is underway, would these two data items suffice. Such a rapid recovery is an unlikely scenario, given that our ability to increase spawning stock escapement significantly will be limited for at least an eel generation, as a consequence of the past 15 to 25 years of low recruitment yet to feed through to spawner emigration (Chapter 2 of this report). It is quite probable, therefore, that recruitment will continue to decline for some time, and it will be almost unavoidable that silver eel escapement will also decline considerably further for at least some years. The effectiveness of protection and restoration measures taken under the EU Eel Regulation will therefore have to be judged on a relative scale: the relative improvement of survival from recruit to silver eel. This necessitates the analysis of the full continental phase of the life cycle.

3.2.3 Issues of time-scale

The principal objective of WGEEL at its future meetings will be assessment, renewed annually, of the state of the stock and recruitment at an international level. The desired objective of current management is clearly that measures taken to protect and enhance spawner escapement result in increased recruitment. The time-scale for full evaluation of such success is long, and for assured confidence that recovery is underway, any recovery will have to be successfully tracked through the generations, that is: over decades.

3.2.4 If recruitment continues to decline

Should recruitment not respond positively to increased spawner biomass, and continue to fall whereas spawning-stock biomass is rising, then there are other factors operating than those included in the assumptions (that eel will follow classical stock–recruitment relationships).

Where such conclusion is reached, at any point in the assessment and study of eel, it would be evident that unknown factor(s) are acting on the stock–recruitment relationship. This brings in possibilities such as a problem in oceanic processes affecting migration, eel “quality” factors affecting spawning ability, genetic issues, or a new and unforeseen problem resulting in depensation in the S-R process. These scenarios would all force an urgent search through research programmes on possible additional causes of decline, which is of course an option at any stage where new evidence of detrimental factors arises. These “new” problems, however, have always to be researched through a process involving data gathering, correlation, quantification of cause and effect, development, proposal and adoption of mitigation measures, and post evaluation before they can be fully built in to the assessment of S-R or R-SSB processes. It is therefore necessary that the “new” lines of potential impact research are continually progressed through research programmes alongside the annual stock assessment process, so that when and if numerical estimates of their impact are available, these can be taken into account.

If recruitment does not respond to spawner enhancement measures, and spawning stock continues to decline, then the assessment process is required to investigate biological and mortality processes at a spatially disaggregated level. In principle, the analysis could proceed, at a biologically meaningful disaggregated level. In practice, however, the RBD level will be much more easily achievable. At this level, management measures have been taken, and data on stock, fisheries and other anthropogenic impacts have been gathered. Indeed, the probable situation over the coming two decades is at best continued low spawner emigration protected to some degree by measures to be taken under management plans required the eel regulation, with glass eel recruitment at best displaying a slow recovery but perhaps continuing its decline. Management plans may fail to generate any increase in spawners, some through no fault of the plans but simply as a consequence of the history of low recruitment, and some through inadequacy in the plan. In this scenario, it will become necessary to carry out a spawner-per-recruit analyses at the international level (that is probably the simple sum of river basin specific analyses) to distinguishing between these two possible causes of unpredicted low spawner production. This analysis will require access to data to examine processes operating at least at the eel management unit, and preferably the river basin level.

3.3 Data requirement

An internationally coordinated international stock and recruitment assessment for European eel has a minimum data requirement, which is not yet met. The data needed for future international stock–recruitment assessment are a minimum of:

1) Escapement estimates from all Eel River Basins, in absolute terms (biomass and numbers, by sex), combined with

2) Recruitment indices indicative of recruitment strength over the whole distribution area.

3.3.1 River Basin vs. international uses of data

The sum of the escapement estimates over the distribution area provides a proxy estimator of the spawning stock size, whereas recruitment indices quantify the offspring. The combination of spawning stock size and recruitment index facilitates assessments of stock status and analysis of the stock–recruitment relationship and potential effects of climatic factors on the oceanic life phase.

The analysis of the stock dynamics in the continental phase, i.e. a spawner-per-recruit analysis, requires data from the continental phase, which resides within national waters, within Eel Management Units (EMUs). Since the biological characteristics, as well as the anthropogenic impacts on the stock vary from region to region, a single unified assessment of the status of the stock will not be feasible, other than on an EMU by EMU basis.

Neither the Eel Regulation, nor the Water Framework Directive programmes oblige Member States to make the basic data available, though they do contain an obligation to report on the results to the Commission. The Data Collection Regulation, in contrast, does require Member States to make data available upon request, but no central database exists. A future WGEEL might have to specially request these data from the Commission. As indicated above, partial spatial coverage may allow for an analysis of trends in recruitment, but neither the assessment of the trend in silver eel escapement, nor the assessment of the relative survival over the continental life stages, will be feasible. A formal requirement, and a practical procedure to present and store the data, will have to be developed. Development of protocols, exchange procedures and databases will not be feasible within the framework of the international assessment working group.

3.3.2 Use of yellow eel data

Therefore, data on the growing yellow eel phase are not directly applicable to the first level of an international scale stock assessment. They are, however, essential to individual member states, or regions, for example as inputs to modelling silver eel escapement, or for providing interim data check points during the long growth term between recruitment and silver eel production**.** If the national or regional stock assessments are to be checked at an international level, the data on which these are based must be available in an accessible form.

3.3.3 The EU Eel Regulation

The EU eel recovery regulation requires specific national actions including the gathering of some eel data, and the supply of these data to the EU Commission upon request. It does **not** specify or require that this information is directly available to the WGEEL or to any organization except the EU commission. Furthermore, the data to be gathered as part of the management plan and subsequent reporting to EC under the stock recovery regulation is to be supplied to the EC at relatively long intervals of at least three years. The reporting cycle starts with the detail of management plans by the end of 2008, with subsequent reporting every three years, reducing in frequency to every six years after 2021. The Commission itself will make its first report to the EU Parliament in 2013.

Notwithstanding the fact that there is no built-in obligation to report these data to the WGEEL for stock assessment, the intervals in the reporting cycle under the EU Regulation are far too long to enable any rapid progress by WGEEL. For an assessment working group to make significant progress toward bringing eel in line with other international species stock assessments, annually updated data are required. The cross-compliance requirement between the recovery regulation and the CFP fishery data collection regulation obliges countries to make some data available annually. However, the DCR does not (yet) cover all data sources required for an assessment of the status of the stock, either at EMU or wider scales.

3.3.4 Checklist of actions required under the Eel Regulation and associated guidelines

Where data may be useful to international stock assessment this is displayed in **bold text**.

- Establishment of management plans by country or other eel management unit by end 2008, including:
- A list of management units and authorities responsible.
- An inventory or individual basins in each management unit.
- Justification for the use of a national scale plan if this option is selected.
- Maps revealing eel management units in relation to WFD river basin districts.
- **Annual catch, if fished, in Kg for each RBD of glass, yellow and silver eel. (this is not included in the regulation itself but is included in the Commission implementation guidelines).**
- Quantitative and qualitative description of eel fishery units.
- A list of fishers, licences, vessels licensed to local and EU waters, plus auctioneers and licensed dealers.
- **Quantitative and qualitative descriptions of eel fishery effort reflecting local situation and any reductions imposed.**

- A quantitative description of recreational eel fishing, i.e. numbers of fishers and their catches of eels.
- **Statement of which optional method(s) is used to define silver eel escapement of target 40%.**
- **A description of the silver eel 40% escapement target mode of measurement system used including its precision and accuracy.**
- A description of habitat condition, including non fishery mortalities e.g. caused by pollution, migration obstacles (**quantify this mortality if possible**).
- **An indication of the proportion of each life stage affected by contaminants, pathogens, parasites and degree of contamination.**
- **Qualitative and quantitative descriptions of past restocking and any intended as part of the management plan, with stocked areas.**
- **A quantitative estimate of how stocking, if to be used, will contribute to achieving the 40% escapement.**
- The proportion of captured less than 12 cm eel to be used for restocking.
- **Actual or estimated escapement relative to the 40% target, at time of plan submission (2008) with description of estimation methods used.**
- Price monitoring for glass eel markets.
- Description of the sampling system for catches and effort concerning all life stages of eel, with regard to Regulation (EC) No 1639/2001 (DCR).
- Measures to identify origin and traceability of live imports and exports.
- Determination that eel imported and exported from territory are captured within national (EMP) and international (CITES) rules.

In summary, this checklist identifies several items of potential use to future working groups, assuming that the WGs have access to all data, preferably in the year produced, rather than having to wait for the reporting cycle. By far the most relevant data for international use will be the silver eel potential and actual escapement estimates.

There are, however, very significant deficiencies in this data source as an aid to international stock assessment. Perhaps the most obvious gap is the failure of the regulation to secure a fishery-independent glass eel recruitment dataseries. The reliance on catch monitoring focuses the relevant part of the regulation on commercial glass eel fisheries, which may change markedly, resulting in loss of individual dataseries. As outlined above, the reporting cycle of three years is at intervals too long for any rapid progress to be made on international scale stock assessment. Many of the data highlighted, while of supporting interest, are not core requirements. The absence of a requirement for eel quality data are noted.

3.3.5 Data Collection Regulation

The cross-compliance link between the Eel regulation and the DCR process is a useful provision for stock assessment purposes. The DCR driven data provision is, however, dependent on continuation of commercial and recreational eel fisheries. There is no requirement for any fishery-independent eel sampling in the DCR or for any sampling to continue where and when fisheries close. Continuation of commercial eel fishing is far from guaranteed given the continuing downward trends in catches, the possibility of approaching economic extinction, and the probability of widespread cuts in eel fishing activity as a consequence of MS or RBD scale failure to meet the "40%" silver escapement targets required in the eel regulation.

Even while the DCR does apply and forces data collection, the minimum prescribed sampling is unlikely to provide sufficient data to compile a meaningful international scale eel stock assessment, as it does not contain yellow eel surveys. Although there will be some silver eel data where fisheries still exist, most DCR data will be on yellow eel fisheries, and as such will be of indirect value to international stock assessment. Silver eel fisheries are also likely to be the first target for closure when escapement targets are failed.

According to the DCR minimum stipulation for data precision level, the "fallback" option is to measure 100 eels for every 20 t landed. A dedicated workshop on national data collection of European eel (Dekker *et al.*, 2005) concluded that "… one sample per 20 t catch … was found to be inadequate …" and recommended that "15 samples per life stage, per management unit would be more appropriate". This workshop also stated that "The number of individuals per sample for length analysis was examined and there has been no analysis to date determining the precise levels required. Common practice would indicate that 100 individuals per sample may not be adequate for length and this should be increased to 200 per sample. SGRN (STECF) have strongly endorsed this recommendation in its December 2007 meeting. However, for some RBDs with small fisheries, the DCR sampling requirement exceeds the typical annual catch of yellow or silver eel, but as the EU Eel Regulation constitutes an international recovery plan, normal exemption rules do not apply.

The DCR on its own will not provide a framework to estimate the size of the spawning stock as the programme does not provide estimates of eel abundance in small fisheries or in those waters not fished.

3.3.6 Recruitment dataseries are not secured

EU concerted action 98/076 (Dekker, 2002) brought together the Europe-wide dataseries of recruitment sampling which now form the basis of the recruitment data reported annually to this WG. It was concluded at the time that better coverage was needed and proposals were made to establish new sites. Only two of these new sites (research sites in Greece) have been started, and some of the formerly active sites are now effectively stopped as a consequence of their dependence on fisheries now not commercially viable or a lack of glass eel produced for restocking.

3.3.7 Water Framework Directive

The WGEEL has noted on many occasions that the requirement for MS to monitor eels as part of inland fish populations under Water Framework Directive provisions may also aid stock assessment. Such monitoring is likely to gather some data on yellow eel and as such will be a data input to silver eel output models. However, given the broader aims of the Water Framework Directive, there is a high risk that the monitoring related to the WFD will be inadequate for the assessment of the eel stock. Inadequate spatial coverage, low selectivity for eel, underreporting actual eel catches and non-reporting for eel, have been observed.

3.3.8 Data availability for international analyses

Table 3.1 summarizes the assistance that currently active initiatives, including the eel regulation, DCR provisions, and WFD monitoring, may bring to international stock assessment. It is concluded that these, while welcome, will not provide any rapidly available source of data for a full international eel stock assessment. This objective can only be achieved by the establishment of nationally maintained database, made available for international compilation, of the key stock descriptors. These descriptors are emigrating silver eel numbers, biomass and sex ratio, and recruitment in terms of glass eel or young of the year numbers and biomass. The component and compiled data must be annually updated to enable examination of any stock–recruitment relationship. Only when such data exist will it be possible to bring eel population and stock- recruitment assessments to the level given to most other major internationally exploited fish species.

The list of data elements and supply in Table 3.1 includes the EMU or RBD level data as a requirement, over and above the simple need for aggregated total spawner emigration and glass eel recruitment indices. In almost all cases, these data do not currently exist and new dataseries need to be commenced, with international coordination ensuring a compatible approach end allowing future analyses of the disaggregated individual area components of the aggregated spawner production per recruit relationship.

Table 3.1: Summary of potential data provision as required by EU and other international legislative instruments, and WG data requirements for post-evaluation of the Regulation.

Data Element	EC Eel recovery regulation 1100\2007	Guidance document for preparation of EMPs	DCR	WFD	CITES requirement (if international trade exists)	Adequate coverage? Ok Not ok.	Required for stock–recruitment analysis (ocean)	Required for survival analysis (continent)	Not in assessment (further research required).
EMUs and River Basins	Y	Y		Y	(Y)	Listavailable 2009		+	
List commercial Fishermen	Y				(Y)				
Catch by recreational fishers	Y		Y			Tri-annual insufficient		+	
List of primary sellers	Y				(Y)				
Traceability in trade	Y	Y			Y				
Fishing Capacity		Y	Y		(Y)				
Silver eel escapement	Y	Y			(Y)	Tri-annual insufficient	+	+	
Potential SE escapement	Y	Y			(Y)	One off in 2008/9	+	+	
Fishing effort by métier	Y	Y	Y		(Y)	From DCR		+	
Landings, glass eel	Y	Y	Y		(Y)	From DCR		+	
Landings, yellow eel		Y	Y		(Y)	From DCR		+	
Landings, silver eel		Y	Y		(Y)	From DCR		+	

DATA ELEMENT	EC EEL RECOVERY REGULATION 1100\2007	GUIDANCE DOCUMENT FOR PREPARATION OF EMPS	DCR	WFD	CITES REQUIREMENT (IF INTER-NATIONAL TRADE EXISTS)	ADEQUATE COVERAGE? OK NOT OK.	REQUIRED FOR STOCK–RECRUITMENT ANALYSIS (OCEAN)	REQUIRED FOR SURVIVAL ANALYSIS (CONTINENT)	NOT IN ASSESSMENT (FURTHER RESEARCH REQUIRED).
Catch composition -Length			(+)			From DCR		+	
Biological sampling for length, age, sex, maturity			+	(Y)		DCR, but only where fisheries exist		+	
Recruitment surveys						Incomplete, and no obligation!	+	+	
Yellow eel surveys				Y		WFD, low coverage and detail		+	
Silver eel ”surveys”		Y				Tri-annual insufficient	+	+	
Hydropower mortality – No Stations		Y		Y	(Y)	EMP ,WFD Hydromorph data		+	
Hydropower mortality		Y – If info available			(Y)	Not for all sites		+	
Predation Losses		Y – If info available			(Y)	only partial coverage		+	
Eel Quality data1		Y				Only local data		+	

[1] e.g. fat content, contaminants, parasites and diseases.

Y =Required as a primary function; (Y)=Required as cross-compliance; + =Adequately covered; (+) =Partially covered but inadequate; entries in bold indicate data deficiencies, while entries in italics meet requirements. Eel quality includes pollution, parasites, pathogens and fat levels.

3.4 Stock assessment vs. research needs

The EU Regulation on eel aims at the restoration of the spawning stock and recruitment. Implicitly, it assumes that a stock–recruitment-relation (of the standard type) exists for the total stock. In Figure 3.1, a decision tree diagram is presented, in which the international assessment of the state of the stock and of the impact of protective measures under the EU Regulation are evaluated, on the basis of trends observed at the global and local level.

The EU Eel Regulation has set targets for the quantity (biomass) of silver eels escaping from the continent, and obliges Member States to take protective measures primarily focusing on the quantities escaping. No targets have been set with respect to other processes (e.g. related to silver eel quality, or climate change) in relation to eel management (if possible). The international assessment of the status of the stock therefore focuses on the dynamics of stock in numbers and quantities, and on the effect of protection and restoration measures taken.

However, the evaluation process depicted in Figure 3.1 (left hand column), provides diagnostics at several points in the evaluation process, judging the adequacy of the focus on quantities escaping only. When these diagnostics indicate a deviation from expectation, further research will be required to clear up the processes, to quantify their impacts, to find mitigation measures, etc. The right hand column of the decision diagram of Figure 3.1 presents a bare skeleton for the decision processes for these cases.

The final two columns in Table 3.1 reflect the current state of development of data and quantitative knowledge of how they affect processes, separating those data items essential now for database building to feed SPR analyses from those where there may be an impact on eel biology but where current and further research programmes need to be completed to quantify impacts and to allow these to be incorporated into mathematically based analyses of stock and recruitment processes.

3.5 Stock assessment

3.5.1 Mortality based management targets

If and when recruitment continues to decline and silver eel escapement is not improved (which situation is quite likely to occur in the coming years) a critical assessment of the stock status will be required for each River Basin District, indicating whether or not the targets of the EU Eel Regulation have been met. The target of the Eel Regulation has been set in terms of silver eel escapement biomass (40% in relation to a notional pristine production). There are many areas where that target can not be reached in the foreseeable future, as a consequence of the low recruitment in recent years, even if all anthropogenic mortality would have been removed immediately. Additionally, a phased implementation of protective measures might slow down the recovery in the earlier years following implementation of the Regulation.

However, the Regulation also requires Member States to specify a time schedule for the attainment of the target. The Regulation does not specify what time schedules will be accepted. Restoration times are more likely to be in the order of decades or centuries, than in terms of years (Åström and Dekker, 2007); if total anthropogenic mortality remains above a critical threshold (fishery mortality *F* plus other anthropogenic mortality H is 0.08 in that analysis), no long-term recovery is expected. Preliminary re-assessment of the time till recovery for specific parts of the distribution area (notably the southern areas with higher growth rates), presented during the working group meeting, confirms a decadal or centennial recovery period, and a threshold mortality level for long-term recovery, though the results differ in absolute values.

Since the Eel Regulation biomass target is not achievable in the near future in many areas, the mortality threshold for recovery is expected to represent the effective target to which the stocks, the anthropogenic impacts and the protection measures will have to be judged. The implicit character of this mortality threshold (being derived from the time schedule, as an unacceptable "keep steady" limit) pleads for the derivation of an explicit mortality target, corresponding to the time schedule requirement and/or the biomass target of the EU Eel Regulation. A general, area-independent target is recommendable, e.g. %SPR. Whether this index of life time mortality actually suffices for eel, needs to be investigated.

3.5.2 Density dependence and stock assessment

The long continued and widespread decline of the European eel stock has led to adoption of a protection and recovery plan, based on classical concepts in fisheries biology for precautionary reasons. This concerns, first and foremost, the assumption of a classical stock–recruitment relationship in the oceanic phase. In its continental phase, however, the eel is scattered over a multitude of small water bodies (Dekker, 2000), in almost all EU Member States and surrounding areas, often under local management. Biological characteristics of the continental waters vary, both at short distance (e.g. from the coast, via rivers and lakes, to headwaters, marshes and ditches) and between geographical areas (from productive lagoons in the Mediterranean, via densely populated rivers in the Bay of Biscay, to extensive cold waters in the Baltic, producing low densities of large old females). Because of the wide variety of ecosystems in the continental phase, no single uniform approach to protection and assessment will suffice. Some local stocks will be adequately represented by classical population models such as life table models, but others will not. Perhaps the most conspicuous deviation is found in places where density-dependence dominates the local stock dynamics. Where this occurs, an increase in recruitment, as strived for by the recovery plan, will not result in a (proportional) increase in the stock and in the silver eel escapement. Where and when this occurs, the classical models of (density independent) stock dynamics will not be applicable. Loss of production potential can occur in these waters as a consequence of habitat loss, or loss of accessibility (migration barriers). Otherwise, the presence of density-dependence indicates that the stock is at or, close to, its maximum density (carrying capacity), and restrictions of anthropogenic impacts will probably not increase silver eel escapement very much. Consequently, management actions should primarily focus on mitigation of habitat loss. However, we do not know in how many rivers density-dependence is evident, and the continued decrease in recruitment will decrease their number over the years. Where and when density-dependence is insignificant, classical concept in fish stock dynamics, such as life time survival, spawner per recruit, and maximum sustainable yield can be applied. Derivation of (standardized) criteria for density-dependence, and adaptation of (standard) fish stock assessment models to the peculiarities of the eel for density independent cases is required.

3.5.3 Assessment tools

The EU Eel Regulation obliges Member States to assess the current state of their stocks, and to assess the expected impact of proposed management actions. The international stock assessment, as discussed here, will post-evaluate the status of the stock, and the net effect of management measures taken. That is: the focus is on the actual state of the stock, rather than on expected impacts. The field of fish stock assessment is particularly well developed for marine fish stocks, including techniques such as cohort analysis, length frequency based assessments, survey based assessments, etc. Existing experience in post-evaluation assessment techniques for eel fisheries is extremely limited (see Dekker *et al.*, 2006 for an overview). Taking advantage of the experiences in marine fish stock assessments, the construction of adequate post-evaluation techniques for eel stocks is an achievable challenge. In contrast with "standard" marine fish stock assessment techniques, anthropogenic impacts other than fisheries (e.g. predation, hydropower, eel quality), the spatial distribution of local stocks within river systems, migration and migration barriers should also be taken into account. It is recommended to develop these tools internationally, making optimal use of available expertise and funding, and involving data and experts from various geographical areas.

The adoption and implementation of the EU Eel Regulation will set an unprecedented breakpoint in eel stock management, and will it is to be hoped lead to a major breakpoint in stock trends. Consequently, the application of the above mentioned post-evaluation assessment techniques will have to cope with unprecedented datasets. It is therefore suggested to explore the use of constructed reality, that is: to apply the tools being developed on data derived from (other) simulation models.

3.6 Conclusions and recommendations for Chapter 3: International stock assessment and data needs

The absence of any internationally driven requirement to maintain a recruitment dataseries needs to be corrected, with reference to the recommendations of the EU contract 98/076: Establishment of a recruit monitoring system for glass eel.

Internationally coordinated eel recruitment monitoring should be included in the requirements for the DCR.

The WGEEL notes that for future meetings it will need:

- The means to compile data on spawner emigration and glass eel recruitment,
- The means to assess RBD level spawner output per recruit relationships with the full access to EMU level data that entails.

The WGEEL further notes that:

- Current legislative instruments including the Eel Regulation, DCR, CITES and WFD do not, either individually on in combination, contain sufficient provisions to ensure adequate data supply for such assessments.
- There is an urgent need to develop assessment and post-evaluation tools adapted to the eel case.

4 Assessing stocks and management actions

4.1 Background theory on population dynamics

4.1.1 Introduction

The reproductive process is one of the main mechanisms that controls and maintains fish populations. In fisheries science, the phase from adult spawning stock to new-born recruits contributing to the stock is known as Stock-Recruitment (S/R) relationship. It is the evolutionary mechanism by which fish stocks "buffer" the effect of varying food and spatial resources. The S/R relationship is most often explored by examining the empirical relationship between the spawning stock size (or its proxy) and the subsequent recruitment output which results from a complex chain of events through spawning, ova deposition and larval and juvenile growth and survival. In fish stocks, the S/R relation is often the main resilient mechanism buffering the exploitation mortality.

The mechanisms that determine the S/R relationship can be categorized as density-dependent and density independent. Density independent mechanisms imply that the individual chance of survival for a youngster is independent of its parent's stock size and the number of eggs produced, giving rise to a linear relationship between the spawning stock size and the number of recruits produced across the range of spawning stock sizes. This model must have limits since no population can increase indefinitely given that resources are finite, and fully density independent relations are not observed in practice. At high spawning stock size, compensatory mechanisms ultimately limit population size by maintaining some ceiling on the level of recruitment, i.e. density-dependence becomes dominating. Several mathematical models have been used to describe the shape of S/R models (i.e. Beverton-Holt, Ricker) but these all take a similar general shape at low stock sizes and largely only differ in the upper ranges of stock size, which is of little concern for depleted stocks.

Figure 4.1 describes a theoretical S/R relationship of the Beverton-Holt type. The solid line describes the relation between the number of spawners and the subsequent number of offspring (recruits). This has an almost density independent phase (nearly linear) at low stock density (spawning stocks of 0 to 10, recruitment of 0 to 40) and an upper density-dependent phase, when the curve levels off (see above).

It is relatively simple to understand this relationship for local stocks such as salmon or sea trout where the spawning effort and juvenile production takes place in individual catchments and where density-dependent factors such as space for spawning and food availability are clearly finite resources. It is much more difficult to envisage how this might operate for eel which has an oceanic spawning and larval phase, given the lack of knowledge of the spawning and early life history of the eel in the Sargasso.

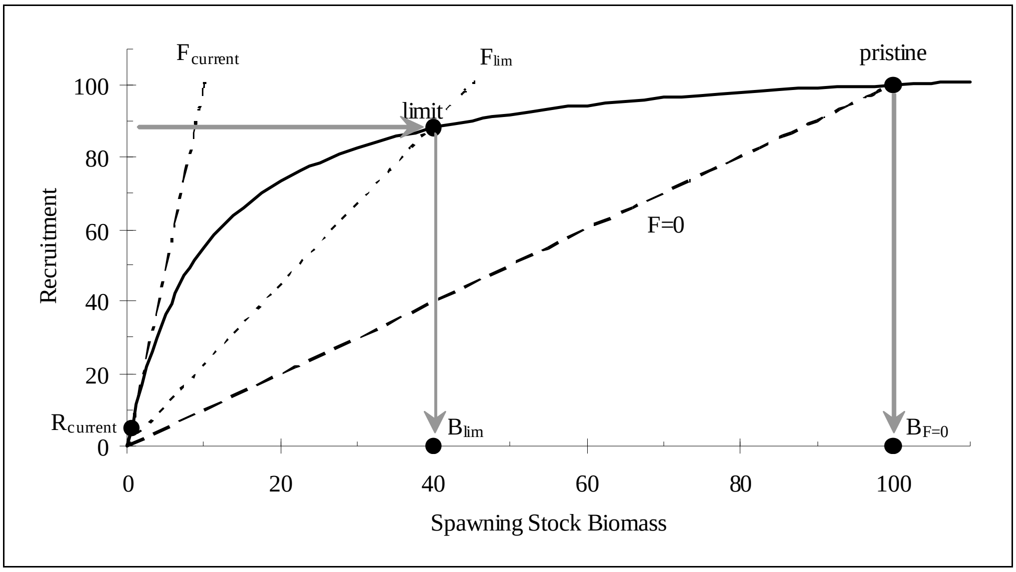


Figure 4.1: Hypothetical Stock-Recruitment relationship, showing a Beverton and Holt-type relationship, the solid line indicates what recruitment is produced at what spawning stock size; the broken lines indicate what spawning stock can be derived from a given recruitment, at no fishery (F=0, dashes line), at maximal, just sustainable fishery (F_{lim}, dotted curve) and current non sustainable fishery (and other anthropogenic sources of mortality) ($F_{current}$, dot-dashed curve). Both Recruits and Spawning Stock Biomass are given in arbitrary units. The EU Regulation sets the minimum target at 40% of the pristine spawning-stock biomass, which will keep recruitment close to its maximum, but on the brink of impaired recruitment. The intersections between the two types of curves determine equilibrium biomasses (densities).

So, population dynamics and resulting equilibrium levels can be analysed through the use of curves for SSB->R (from Spawning Stock Biomass to Recruitment) and R->SSB (from Recruitment to Spawning Stock Biomass) (see Figure 4.1) where:

- Recruitment in this context is assumed to be the biomass (or number) of glass eels that successfully arrive to continental waters after having survived juvenile density-dependent mortality in the oceanic phase. An alternative could be to define recruits as a somewhat later stage like: glass eels settling (or elvers) in continental waters, and thus include the possible local density-dependence in the early processes when glass eels arrive at the continent.
- Spawning stock biomass is the magnitude of the effective spawners, i.e. the ones that are successfully reaching the Sargasso Sea and actually spawning.

Equilibrium points correspond to intersections points between the two types of curves.

The SSB->R curve depends upon oceanic factors such as spawner, success, currents, food availability, etc, whereas the R->SSB curve depends upon mortality cumulated during continental lifespan. Particularly, mortality rates *F+M* (anthropogenic and natural) cumulated in the lifespan (from glass eel to spawner) determines the slope of the R->SSB relationship and consequently the equilibrium level. Higher levels of mortality rates determine equilibrium points corresponding to lower values of both R and SSB.

Note that spawner quality might be explicitly included in the SSB->R relationship as an additional mortality considered that "bad spawners" die before spawning, but after leaving the continent, or simply produce less offspring.

4.1.2 Eel stock and stock decline

In recent years[1], the development of the precautionary approach in fisheries management and the exploitation of stocks have received much attention along with the development of fisheries management tools and the provision of scientific advice. The precautionary approach dictates a risk-averse strategy, in which no fish stock is exploited at a rate higher than one that generates maximum yield, and no spawning stock is reduced to low levels, at which recruitment impairment occurs. In the absence of pertinent knowledge to the contrary, a S/R relationship should be assumed to exist, even for eel. The existing trends in eel landings and recruitment indices support this view, although the exact form of the S/R relationship has not been possible to determine so far.

Recruitment of European eel has been in decline since the early 1980s, and is below 5% of the historical level, since 2000. Total landings have revealed a gradual decline since the 1960s, down to approx. 25% of the former level (Dekker, 2003). The causes of the decline in recruitment are not well known, but might well be related to a low spawning stock. Given the continuously declining trend, data suggest that the present equilibrium point corresponds to extinction or very close to extinction. The ecology of eels makes it difficult to demonstrate a stock–recruitment relationship. However, the precautionary approach requires that such a relationship should be assumed to exist. Therefore, ICES (1999) advised to restrict fisheries and other anthropogenic impacts to the lowest level possible, in order to ensure that the spawning stock returns to then remains above the critical level B_{lim}, above which recruitment is not impaired by the size of the spawning stock. Classical fishery management set the critical spawning-stock biomass level (B_{lim}) at 30% of that in absence of fishery. Due to the fundamentally different biology of the eel (semelparous with high longevity, panmictic and scattered over the whole continent), the WGEEL suggested a higher B_{lim} of 50% for eels, and EU Regulation opted for a 40% objective.

As an alternative strategy to setting SSB target at an uncertain (30, 40 or 50%?) percentage of the notional pristine SSB (which is not easily estimated), with an unknown corresponding level of recruitment, another approach might be the following: In the 1970s, recruitment of glass eel was still at historically high levels. This indicates that SSB was not limiting the production of recruits at that time. Quantification of the pre-1980 spawner escapement therefore is the simplest derivation of a reference level. Note that in this case, the full escapement (100%) of the silver eels in the 1970s (given the anthropogenic mortality of that time) then is assumed to correspond to the escapement level advised by ICES (2002). That is, one could either set this interim reference threshold at 100% pre-1980 silver eel escapement where the data are available, or in the absence of data, at a percentage of the notional pristine state.

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[1] United Nations Convention on Law of the Sea (1982).

UN Conference on Environment and Development (Rio de Janeiro, 1992).

FAO, Code of Conduct for Responsible Fisheries (1995).

4.2 Targets

In general it can be expected that achieving the target defined by the European Council (council regulation No 1100/2007) through management actions will take a very long time. Åström and Dekker, 2007 estimated the time to full recovery of recruitment (the ultimate goal of the management of the eel) to be at least 80 years, if all eel fisheries were closed and none of the other mortality issues addressed. The long-term target defined by the EC then becomes hard to apply in practical management terms. So, for practical reasons short-term, management unit based, interim targets (here called interim targets) need to be defined in connection with management measures to be taken (Figure 4.2).

These interim targets need then to be translated into sub-targets for action on the local scale, which can range in geographical scale from a point source such as a hydropower plant or fishery to the catchment or the scale of the Eel management Unit. This is required as the efficiency of management action has to be evaluated in a short term compatible with the time-scale of the responsible managers and this is shorter than the expected time span for the recovery of the eel stock. Therefore short-term, subtargets are needed to optimize regional management according to the long-term objective of full stock recovery (Figure 4.2). The sub-targets will be split into management sub-targets directly linked to the set-up of management and into eel sub-targets aiming at increasing the production of eel on a local or regional scale. Management sub-targets may be defined as the number or magnitude of actions taken, i.e. number of dams with passes installed, reduction of fishing mortality, number of habitats and amount of eel stocked. In contrast an eel sub-target could, as an example, be related to the abundance or density for 0+ eel in predefined sections of a catchment.

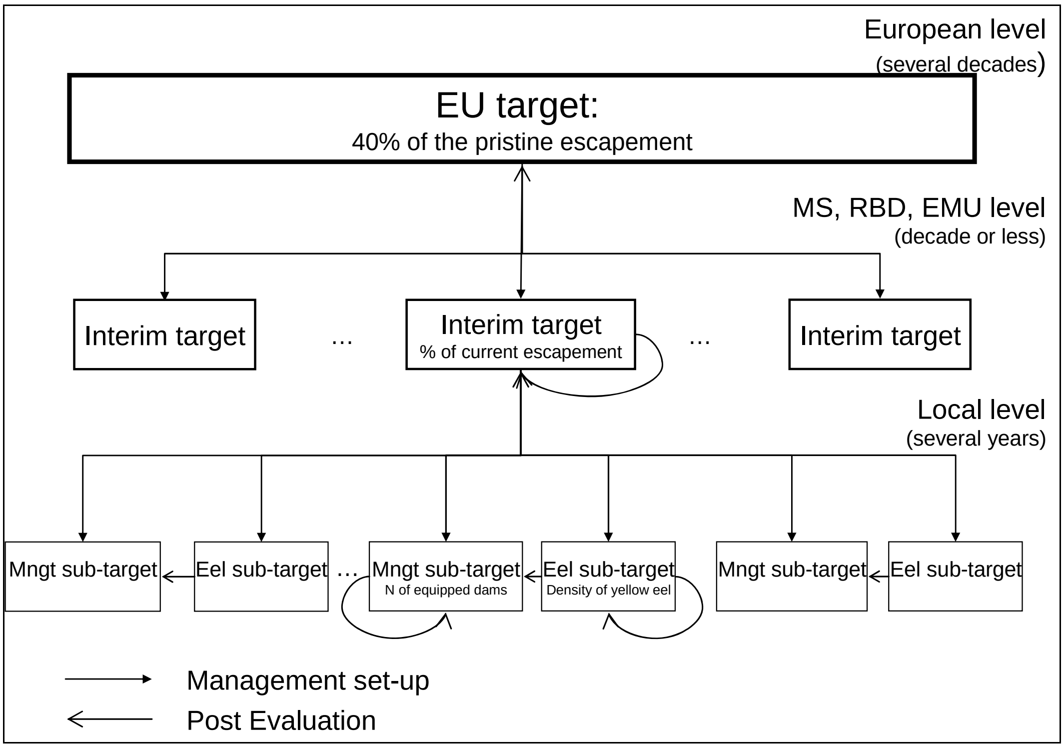


Figure 4.2: Schematic representation of different targets, interim targets and eel and management sub-targets.

Both types of target (eel life stage sub-target; management sub-target) should be possible to post-evaluate, i.e. it should be possible to empirically measure the outcome of the management effort relatively soon after it has been applied, and member states are required to collect relevant data to achieve this. For each type of management measures different time-scales for the response in the relevant eel life stage can be expected.

A link between the outcome of the post-evaluation and future management restrictions should be established. In principle, one could use a qualitative link; i.e. whenever the spawner production is below the sub-target, the managers increase their restrictions. However, a quantitative link is preferable, if not a prerequisite as the EC target is defined in quantitative terms; i.e. the post-evaluation method should indicate what level of restrictions is required to achieve the sub target.

The level of the interim and sub targets should be defined so that the long-term target defined by the council regulation No 1100/2007 ("… reduce anthropogenic mortalities so as to permit with high probability the escapement to the sea of at least 40% of the silver eel biomass relative to the best estimate of escapement that would have existed if no anthropogenic influences had impacted the stock. "), (or other relevant, stricter, targets), has a high probability of being reached, in reasonable time. The expected differences in time until different measures result in increased spawner escapement have to be considered in this context.

If reaching the long-term target is not possible, based on the current eel stock within an Eel Management Unit (EMU), and the time schedule for the attainment of the target level of escapement cannot be calculated (although such a time schedule is required by the council regulation No 1100/2007), managers might consider using a stepwise approach with increasingly more ambitious interim targets in sequence over time. This could mean starting out with interim targets and short-term measures based on currently achievable improvements in the eel stock, given the current low recruitment (e.g. a high % of current possible escapement) then moving to an interim target related to escapement of pre-1980 (e.g. 40% of possible (without anthropogenic impact) escapement of the pre-1980), then increasing the required percentage of pre-1980 escapement (e.g. 100% of escapement pre-1980) to finally be able to aim directly for 40% of pristine escapement.

It will need to be remembered that when calculating expected spawner escapement from each RBD/EMU, in response to management measures, it must be emphasized to consider information on the recent recruitment decline, which in most cases will impose a decreasing local stock of eels in the near future, and consequently a declining spawner escapement, which need to be counteracted by the level of the management measures. This also raise the risk of getting a situation where an escapement target might be reached one year, just to drop below the next year being in the risk of a continued decline despite the management measures taken.

4.3 Estimation of spawner escapement

The Regulation suggests three options for determining the target level of escapement (Article 2.5):

(a) using data collected in the most appropriate period prior to 1980 to estimate silver eel escapement, provided these are available in sufficient quantity and quality;

(b) a habitat-based assessment of potential eel production, in the absence of anthropogenic mortality factors;

(c) extrapolating with reference to the ecology and hydrography of similar river systems.

4.3.1 Estimation of silver eel escapement pre- and post-1980

The definition of silver eel needs to be standardized for escapement estimates. The difference between silvering and silver eels has to be clear and the adoption of the same criteria all over Europe is therefore required. These distinctions have been made clear by some authors (e.g. Acou *et al.*, 2005; Durif *et al.*, 2005) and following them we propose three criteria, which include eye diameter, state of lateral line (presence of black corpuscles) and body colour contrast. It is essential that a standardized method of silver eel identification is adopted for escapement studies.

Estimations of silver eel escapement are available from a number of studies; these are summaries in Tables 4.1a and b for assessments pre and post 1980, respectively. The geographical distribution of the studies data are shown in Figure 4.3. Silver eel escapement is defined as the total number or weight of silver eel that left the catchment, expressed per unit wetted area available to eel for comparison between catchments. Potential silver eel escapement is defined as the number, or weight, of silver eel that would leave the catchment, without anthropogenic mortality, and for Tables 4.1a and b, this has been calculated as the sum of silver eel escapement and the catches of silver and yellow eel and any mortality from other causes (hydropower, illegal fishing, etc).

Pre-1980 data are available from 25 locations (Table 4.1a). For river systems where lakes are a small proportion of the available habitat for eel production estimates ranged from 1.9–49 kg/ha (n=4). For catchments where there is a sizeable lake component to the overall wetted area (>50%) the estimates ranged from 0.3–17.4 kg/ha (n=4). For lakes, with the exception of the Ijsselmeer where production was estimated at 40 kg/ha only minimum estimates based on silver eel yields from fisheries suggest a range of 0.1–11.7 kg/ha (n=14). For marsh type habitat there is a minimum estimate of 43.7 kg/ha and for lagoons one estimate of 20 kg/ha.

Post-1980, the number of assessments of production has increased, but remains dominated by lake studies from Sweden; 66% of the 50 studies (Table 4.1b). Estimates of potential silver eel escapement for rivers varied from 2.7–16.4 kg/ha (n=3), for lake dominated catchments from 0.2–6.4 kg/ha (n=4) and for lakes from a minimum (based on silver eel yield) of 0.04–4.4 kg/ha (n=35). Of the 35 lake studies, two the Shannon and Ijsselmeer provide an estimate of potential silver eel production of 2.7 and 4.4 kg/ha, respectively. There are three lagoon studies with estimates ranging from 6.2–30 kg/ha.

Table 4.1a: Estimated silver eel yield and production (in kg/ha wetted area), pre-1980.

Years	Country	River	Latt.	Long.	Catchment surface area	wetted area available to eel	Waterbody type	Trophic status (*mg P per l)	Catchment geology	Stocked	Silver eel yield (kg/ha)	Potential spawner escapement (kg/ha)	Method of calculation of potential spawner escapement	Reference or contact
pre-1980	Sweden	Mälaren	59.5	17.0		87200	Lake	0.026*		Yes	0.30		minimum estimate	Håkan Wickström
pre-1980	Sweden	Hjälmaren	59.2	15.8		47691	Lake	0.026*		Yes	0.50		minimum estimate	Håkan Wickström
pre-1980	Sweden	Vombsjön	59.0	15.4		1197	Lake	0.082*		Yes	7.40		minimum estimate	Håkan Wickström
1975-1982	Norway	Imsa	58.9	6.0	12800	1160	Lake/River	meso/oligotrophic	Siliceous	No		2.27	Direct count	Maria Korta
pre-1980	Sweden	Ringsjön	58.9	17.4		3918	Lake	0.06*		Yes	2.70		minimum estimate	Håkan Wickström
pre-1980	Sweden	Vänern	58.9	13.3		269100	Lake	0.008*		Yes	0.10		minimum estimate	Håkan Wickström
pre-1980	Sweden	Ången	58.8	17.2		242	Lake	0.092*		Yes	0.40		minimum estimate	Håkan Wickström
pre-1980	Sweden	Glan	58.7	16.0		7390	Lake	0.033*		Yes	0.20		minimum estimate	Håkan Wickström
pre-1980	Sweden	Ymsen	58.7	14.0		1310	Lake	0.073*		Yes	3.40		minimum estimate	Håkan Wickström
pre-1980	Sweden	Roxen	58.5	15.7		9500	Lake	0.031*		Yes	0.70		minimum estimate	Håkan Wickström
pre-1980	Sweden	Sommen	58.2	15.0		13035	Lake	0.011*		Yes	0.10		minimum estimate	Håkan Wickström
pre-1980	Sweden	Fardumeträsk	57.8	18.9		340	Lake	0.042*		Yes	1.20		minimum estimate	Håkan Wickström
1988	Denmark	Bjørnsholm å	56.9	9.2			River	Meso/Eutrophic	Sand/gravel	no		19-36 (range)	Mark recapture	Bisgaard and Pedersen, 1990
pre-1980	Sweden	Åsnen	56.6	14.7		14753	Lake	0.022*		Yes	0.61		minimum estimate	Håkan Wickström
pre-1980	Sweden	Ellestadsjön	55.5	13.7		264	Lake	0.061*		Yes	6.34		minimum estimate	Håkan Wickström
pre-1980	Sweden	Krageholmssjön	55.5	13.7		205	Lake	0.114*		Yes	11.65		minimum estimate	Håkan Wickström
1965-1979	UK Northern ireland	Bann	55.1	-6.5	494277	40,000	lake with minor river	Eutrophic	Siliceous	Yes	5.8	17.4	Fishery Yield plus mark -recapture	Derek Evans/ Robert Rosell
1981	Denmark	Brede aa	55.0	8.5	42500	65	River	Meso - Eutrophic	Sandy/muddy	No	19.7	49.0	Mark recapture	Nielsen 1982
1965-1979	Ireland	Erne	54.5	-8.3	437500	33 000	Lake/river	Eutrophic	Calcareous	no	0.2	1.3	fishery yield plus mark-recapture	Derek Evans/ Robert Rosell
1942-1944	England	Leven	54.2	-3.1	25400	1546	Lake/river	Oligotrpohic	Siliceous	No		0.3	Large scale experimental trapping (minimum estimate)	Lowe (1952)
pre-1980	Germany	Elbe	53.9	8.8	14826800	239130	River			Yes		5.1	Model estimate	Uwe Brämick
1971-1979	Ireland	Burrishoole	53.9	-9.6	8400	474	Lake/river	Oligotrphic	Siliceous	No		0.9	Direct count	Russell Poole
Pristine	Netherlands	Ijsselmeer	52.8	5.4		175000	Lake	0.1*	Mud and sand	No	0.2	40.0	Cohort model	Dekker pers. comm
1950	Netherlands	Polders	52	5			Polder		Mud/sand	No	14.1		minimum estimate	VanDrimmelen 1953
1950	Netherlands	Lakes	52	5			Lake		Mud/sand	No	21.2		minimum estimate	VanDrimmelen 1954
1905-1941	France	Certes Marshes	44.7	-1.0	150		marshes				43.7		minimum estimate	Aubrun 1987
pre-1979	Italy	Comacchio	44.6	12.2	10000		Lagoon					20.0	Total count	Rossi 1979

Table 4.1b: Estimated silver eel yield and production (in kg/ha wetted area), post-1980.

Years	Country	River	Latt.	Long.	Catchment surface area	wetted area available to eel	Waterbody type	Trophic status (*mg P per l)	Catchment geology	Stocked	Silver eel yield (kg/ha)	Potential spawner escapement (kg/ha)	Method of calculation of potential spawner escapement	Reference or contact
post-1980	Sweden	Vigdansystemet	63.5	16.8	-	58	Lake	0.009*		Yes	0.60		minimum estimate	Håkan Wickström
post-1980	Sweden	Storsjön	63.1	14.4	-	147	Lake	0.034*		Yes	0.64		minimum estimate	Håkan Wickström
post-1980	Sweden	Mälaren	59.5	17.0		87200	Lake	0.026*		Yes	0.41		minimum estimate	Håkan Wickström
post-1980	Sweden	Hjälmaren	59.2	15.8		47691	Lake	0.026*		Yes	0.42		minimum estimate	Håkan Wickström
post-1980	Sweden	Öljaren	59.1	16.0		1791	Lake	0.051*		Yes	0.04		minimum estimate	Håkan Wickström
post-1980	Sweden	Hasselforssjöarna	59.1	14.7		1884	Lake	0.012*		Yes	0.18		minimum estimate	Håkan Wickström
post-1980	Sweden	Sottern	59.0	15.4		2780	Lake	0.018*		Yes	0.36		minimum estimate	Håkan Wickström
post-1980	Sweden	Tisnaren	58.9	16.0		3785	Lake	0.017*		Yes	0.16		minimum estimate	Håkan Wickström
1983-2007	Norway	Imsa	58.9	6.0	12800	1160	River	Meso/oligotrophic	Siliceous	No		1	Direct count	Maria Korta
post-1980	Sweden	Ringsjön	58.9	17.4		3918	Lake	0.06*		Yes	2.49		minimum estimate	Håkan Wickström
post-1980	Sweden	Vänern	58.9	13.3		269100	Lake	0.008*		Yes	0.08		minimum estimate	Håkan Wickström
post-1980	Sweden	Bondsjön	58.8	16.0		33	Lake	0.024*		Yes	0.60		minimum estimate	Håkan Wickström
post-1980	Sweden	Ången	58.8	17.2		242	Lake	0.092*		Yes	0.25		minimum estimate	Håkan Wickström
post-1980	Sweden	Glan	58.7	16.0		7390	Lake	0.033*		Yes	0.33		minimum estimate	Håkan Wickström
post-1980	Sweden	Ymsen	58.7	14.0		1310	Lake	0.073*		Yes	2.50		minimum estimate	Håkan Wickström
post-1980	Sweden	Roxen	58.5	15.7		9500	Lake	0.031*		Yes	0.13		minimum estimate	Håkan Wickström
post-1980	Sweden	Vättern	58.3	14.7		56600	Lake	0.005*		Yes	0.00		minimum estimate	Håkan Wickström
post-1980	Sweden	Sommen	58.2	15.0		13035	Lake	0.011*		Yes	0.04		minimum estimate	Håkan Wickström
post-1980	Sweden	Fardumeträsk	57.8	18.9		340	Lake	0.042*		Yes	1.23		minimum estimate	Håkan Wickström
post-1980	Sweden	Högvadsån (Nydala K	57.3	12.9		2338	Lake	0.017*		Yes	0.06		minimum estimate	Håkan Wickström
post-1980	Sweden	Rusken	57.3	14.3		3396	Lake	0.02*		Yes	0.20		minimum estimate	Håkan Wickström
post-1980	Sweden	Tjärnesjön	57.2	12.9		318	Lake	0.017*		Yes	0.20		minimum estimate	Håkan Wickström
1980- 2007	Latvia	Daugava	57.0	24.2		3871	Lake/river	Eutrophic	Calcereous	No	0.03*		minimum estimate (brown & silver)	Janis Birzaks
post-1980	Sweden	Bolmen	56.9	13.7		17319	Lake	0.015*		Yes	0.38		minimum estimate	Håkan Wickström
post-1980	Sweden	Unnen	56.9	13.5		1686	Lake	0.015*		Yes	0.24		minimum estimate	Håkan Wickström
post-1980	Sweden	Åsnen	56.6	14.7		14753	Lake	0.022*		Yes	0.03		minimum estimate	Håkan Wickström
1980- 2007	Latvia	Barta	56.5	21.1		3797	Lake/river	Eutrophic	Calcereous	No	0.1*		minimum estimate (brown & silver)	Janis Birzaks
post-1980	Sweden	Ivösjön	56.1	14.4		5017	Lake	0.01*		Yes	0.12		minimum estimate	Håkan Wickström
post-1980	Sweden	Råbelövsjön	56.1	14.2		630	Lake	0.031*		Yes	0.48		minimum estimate	Håkan Wickström
post-1980	Sweden	Vombsjön	55.7	13.6		1197	Lake	0.082*		Yes	2.85		minimum estimate	Håkan Wickström
post-1980	Sweden	Snogeholmssjön	55.6	13.7		247	Lake	0.061*		Yes	2.16		minimum estimate	Håkan Wickström
post-1980	Sweden	Sövdesjön	55.6	13.7		272	Lake	0.061*		Yes	0.92		minimum estimate	Håkan Wickström
post-1980	Sweden	Ellestadsjön	55.5	13.7		264	Lake	0.061*		Yes	3.90		minimum estimate	Håkan Wickström
post-1980	Sweden	Börringesjön	55.5	13.3		277	Lake	0.109*		Yes	2.25		minimum estimate	Håkan Wickström
post-1980	Sweden	Fjällfotasjön	55.5	13.3		173	Lake	0.109*		Yes	3.33		minimum estimate	Håkan Wickström
post-1980	Sweden	Krageholmssjön	55.5	13.7		205	Lake	0.114*		Yes	3.87		minimum estimate	Håkan Wickström
2003-2007	UK Northern ire	Bann	55.1	-6.5	494277	40000	lake with minor river	Eutrophic	Siliceous	Yes	3.2	6.4	Fishery Yield plus mark -recapture	Derek Evans/ Robert Rossell
1989-1999	Ireland	Erne	54.5	-8.3	437500	33 000	Lake/river	Eutrophic	Calcareous	no	0.3		fishery yield plus mark-recapture	Derek Evans/ Robert Rosell
1994-1995	England	Leven	54.2	-3.1	25400	1546	Lake/river	Oligotrpohic	Siliceous	No		0.3	Resistivity fish counter	Knights et al., 2001
2000-2007	England	Leven	54.2	-3.1	25400	1546	Lake/river	Oligotrpohic	Siliceous	No		0.2	Resistivity fish counter	Miran Aprahamian
2005-2007	Germany	Elbe	53.9	8.8	14826800	239130	River			Yes		2.7	Model estimate	Uwe Brämick
1996-2006	Ireland	Burrishoole	53.9	-9.6	8400	474	Lake/river	Oligotrphic	Siliceous	No		1.3	Direct count	Russell Poole
2001-2007	Ireland	Corrib	53.5	-9.3		28869	Lake/river		Calcareous	No	0.5	1.7	Catch plus escapement plus estimated unreported catch	Lughaidh Ó Néill/ Russell Poole
2001-2007	Ireland	Ennell	53.5	-7.4		1433	Lake	Mesotrophic	Calcareous	Upstream transfer		2.7	Catch plus escapement	Kieran McCarthy
1992-1994	Ireland	Shannon Lakes	53.0	-8.3		42465	Lake/river			Upstream transfer		4.2	Catch plus escapement	McCarthy et al. 1994
2001-2007	Ireland	Shannon	53.0	-8.3		42465	Lake/river		Calcereous	Upstream transfer		2	Catch plus escapement plus estimated unreported catch	Lughaidh Ó Néill/ Russell Poole
2000	Netherlands	Ijsselmeer	52.8	5.4	175000		Lake					4.4	Length structured cohort analysis	Dekker 2000
2000-2002	France	Oir	48.6	-1.3	8700	22.9	river	meso		no		6.3	Direct count	Eric Feunteun
2000-2003	France	Frémur	48.6	-2.1	6000	59.9	Lake/river	eutro		No		1.9	Direct count	Eric Feunteun
2001-2005	France	Loire	47.2	-2.3	16600		River	Eutrophic		No		16.4	mark recapture	Eric Feunteun
1989-1990	Italy	Commacchio lagoon	44.6	12.2	10000		Lagoon					6.2	Total count	De Leo and Gatto 1995
2007	France	Camargue	43.5	4.4	11000		Lagoon					25.0	Direct count and validated model	Bevaqua et al. in prep
2007	France	Bages Sigean Lagoor	43.0	3.1			Lagoon		Calcereous	No	6.0	30.0	mark recapture	Elsa Amilhat
pre-1984	Sardinia, Italy	Porto Pino Lagoon	39.0	8.6	10000		Lagoon					19.0	Total count	Rossi and Cannas 1984

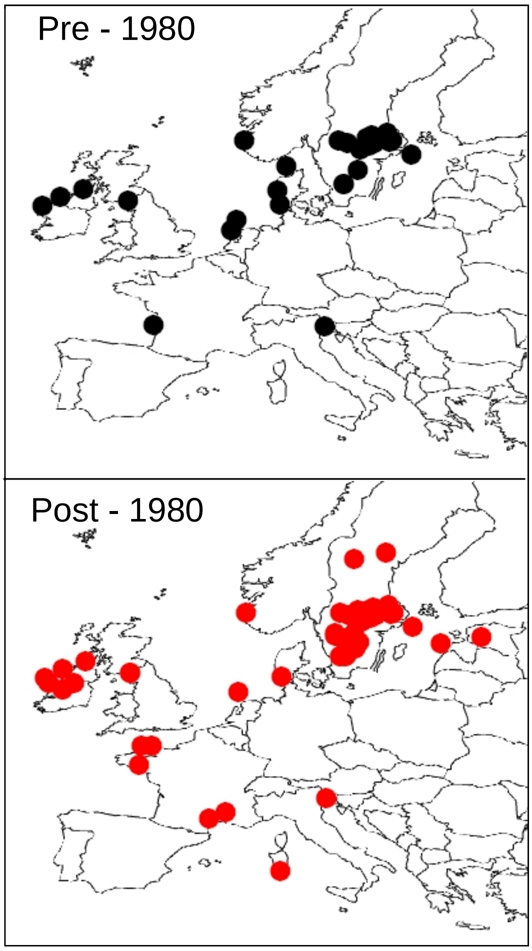


Figure 4.3: The location of the catchments for which historical (pre-1980 black) and recent silver eel production estimates (post-1980 red) are presented in the Tables above.

4.3.2 Modelling approaches

A number of modelling approaches have been made to estimate escapement or a reference condition to assess compliance with the EU escapement target.

The models are:

- Reference Condition Model (RCM)
- Eel Length Structure Analysis (ELSA)
- Scenario-based Model for Eel Populations (SMEP)
- Global Anguille (GLOBANG)
- Length-based Virtual Population Analysis (LVPA)
- Swedish Analytical Models (SWAM)
- Demographic Model of the Camargue (DEMCAM)
- Glass eel model to assess compliance (GEMAC)

These models and their potential to support the EMPs have been described by EIFAC/ICES WGEEL and Dekker *et al.*, 2006. In addition during the meeting a number of other approaches have been presented to the WGEEL as non peer-reviewed worked examples.

4.3.2.1 Elbe population dynamic model (Oeberst *et al.*, submitted)

An age based model has been developed by Oeberst *et al.*, submitted to examine the population dynamics of eel in the River Elbe (Germany) and estimate the number of eel emigrating from the catchment. The model inputs are quantity of immigrating young eel, number (and weight) of eel stocked, natural mortality and mortality caused by commercial and recreational fishing, cormorants, and hydropower plants. The structure of the model allows the sensitivity of the parameters to the overall estimate to be examined. The model may be used to develop management strategies and to assess the effectiveness of different management options to meet the EU target. It has the advantage of simple adjustment by being modular constructed and can be further developed using MS-EXCEL.

The model assumes that eel remain in fresh water for a maximum of 20 years. The available data for describing the different factors which influence the stock dynamics have different quality. Total catch (kg) per year is estimated for the commercial fishers and angler. The mean weight of the catch (g) and age–length based samples are only available from some areas of the Elbe and short periods. Length based estimates exist for the transformation of yellow eel to silver eel and for the eel which are taken by cormorants based on stomach samples. To combine the different data types a procedure is necessary for transferring length based data into age based data.

For the model it was assumed that eel age >8 were fully recruited to the fishery, this is based on a minimum size limit of 45 cm for commercial and recreational fishers. Recruitment is composed of natural immigration of glass / yellow eel based on monitoring estimates and stocked eel from published reports. Natural mortality is assumed to be constant at 13% (M=0.14) per year (Dekker, 2000). For recreational anglers the total weight of eel caught was the product of the total number of anglers and the mean weight of the catch. The amount of eel consumed by the cormorant population was estimated based on the number of cormorants, their residency time, the daily food intake and the average proportion of eel in their diet (Brämick and Fladung, 2006). The total catch of the commercial and recreational fishers and the consumption of eel by cormorants were converted from a weight based estimate to a number per age using weight to length conversions and a von Bertalanffy growth model. A length based logit-function was used to estimate the proportion of silver eel in the catch of eel by fishers and in the eel consumed by cormorants.

In addition, some general assumptions were used for estimating the catch in number by age group and year because appropriate data are lacking: The age frequency of the catches by fishers and anglers is similar to the age frequency of the stock combined with the requirement that eel younger than eight years are not landed; silver eel are not landed by fishers or the landings can be neglected.

Even though the model is adjusted to the conditions in the river system and to the availability of data, it also includes several assumptions and uncertainties. Therefore, the results of the model will have to be validated by monitoring the stock, especially by silver eel monitoring.

4.3.2.2 Irish model to estimate silver eel escapement (Ó'Néill and Poole, in prep.)

Catch based estimates of historic/pristine escapement

The calculation of pristine productivity for exploited catchments requires estimates of silver eel escapement along with historic silver and brown eel catches (Figure 4.4). Historical catch records for silver eel fisheries were available for the five catchments of the Corrib, Moy, Garavogue and Erne. The efficiencies of the fisheries had been previously estimated for the Shannon, Corrib and Erne silver eel fisheries. Where fishery efficiency was not measured an approximately average value of 33% was used to calculate escapement. In addition to the catch at the recording station and escapement past the recording station the brown eel and silver eel catches made upstream were included to estimate pristine productivity. In the absence of historical data for these latter parameters (brown and silver eel catches upstream of the recording station) it was assumed that the yields were equal to those currently observed (2001–2007).

Brown eel yield was assumed to be equivalent to the same weight of potential silver eel. This assumption was based on the logic that in a system subject only to natural mortality, migration would only be delayed such that fecundity (related to weight) would be maximized. Consequently, it is unlikely that there would be a net loss of weight in subsequent years from a cohort. Finally, the productivity estimates were corrected by the level of unreported and illegal fishing. Unreported yield was derived as the ratio of unreported licences to licences issued within the relevant River Basin District between the years 2001–2007. The proportion of the fishery yield taken illegally was assumed to be equal to that estimated for the Shannon by the DEMCAM (SLIME) model (Dekker *et. al.*, 2006). For those catchments with hydropower, an estimate of the impact was derived by imposing a 28.5% mortality per turbine passage (WGEEL, 2002). Therefore, the probability of surviving passage through ‘n’ number of hydropower installations is $(0.715)^n$.

The estimated pristine spawner escapement ranged from 0.9–5.4 kg/ha with a mean of 3.9 kg/ha (Table 4.2).

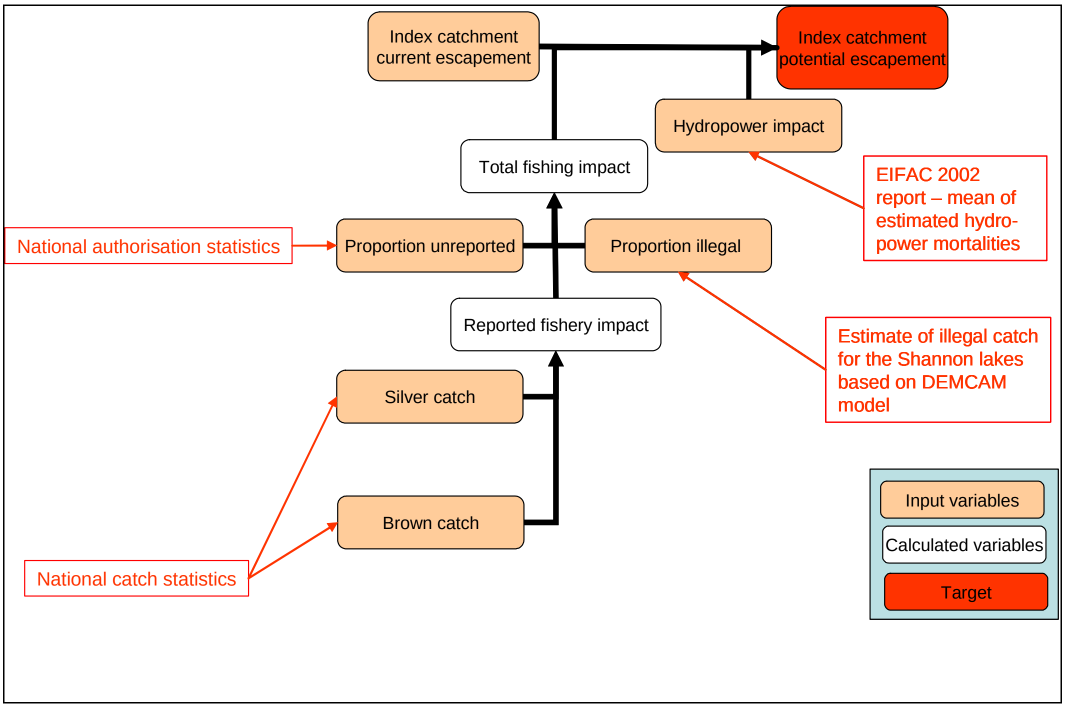


Figure 4.4: Description of how potential production (escapement) was derived from the current escapement of catchments where estimates of silver eel escapement, fishery yield and the impact of hydropower are available.

Table 4.2: Estimated pristine spawner productivity from five Irish catchments based on either direct measurement and/or catch data.

		MOY	GARAVOGUE	ERNE	CORRIB	BURRISHOOLE
		1942–1952	1962–1975	1955–1982	1976–1982	1971–1980
Silver eel catch at recording station (t)		3.4	0.9	9.2	19.4	0.0
Escapement past recording station (t)		6.8	4.4	51.3	38.8	427.5
Brown eel yield upstream (t)	Reported	4.0	1.7	13.4	9.0	0.0
Brown eel yield upstream (t)	Unreported	3.0	1.2	23.4	6.5	0.0
Silver eel yield upstream (t)	Reported		0.0		18.6	0.0
Silver eel yield upstream	Unreported	29.1	1.2	9.2	13.4	0.0
Hydropower impact (t)		0.0	0.0	25.4*	0.0	0.0
Wetted area (ha)		8418.0	1783.0	25.9	28869.0	475.0
Productivity (kg/ha)		5.3	5.4	4.5	3.4	0.9

***occurs following recording station.**

Potential production based on habitats of similar characteristics

The method involved determining the relationship between productivity and the geological characteristics of the catchment.

Growth rate of eel were available for 17 catchments (Moriarty, 1988, Central Fisheries Board). The wetted area within each catchment was quantified using a geographical information system and classified according to the proportion of the catchment area comprising non-calcareous geology. For 17 catchments growth rate was found to be closely negatively related to the proportion of the catchments comprising non-calcareous geology (Figure 4.5) ($r^2=0.67$; $p<0.0001$).

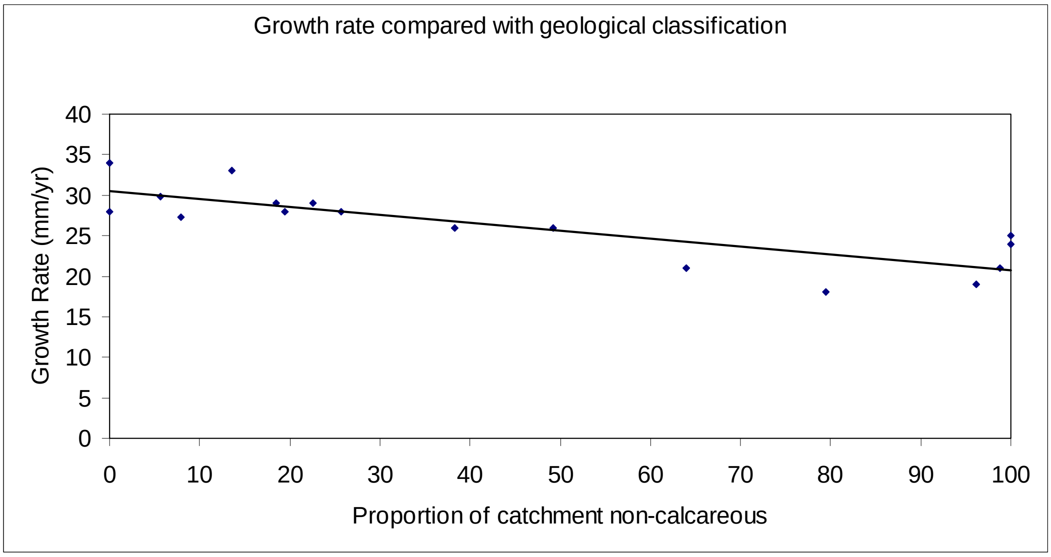


Figure 4.5: The relationship between growth rate and the proportion of the catchment comprising non-calcareous geology.

The four catch-based production estimates along with the direct estimate for the Burrishoole (Table 4.2) were plotted against the proportion of non-calcareous geology within the catchment (Figure 4.6). These historic estimates suggest that in exclusively non-calcareous catchments silver eel productivity was approximately 0.9kg/ha whereas in predominantly calcareous catchments silver eel productivity averaged about 4.5kg/ha.

An obvious weakness in the relationship presented in Figure 4.6 is the distribution of the data, with very few data for intermediate or non-calcareous catchments. To increase the robustness of the model the 5 available productivity estimates were used to convert the growth-rate estimates for 17 catchments into pristine production estimates.

Potential silver eel productivity was regarded as a product of recruitment, natural survival and average silver eel weight. Natural mortality was imposed at a constant rate of 14% per annum. This rate was chosen because the average age of Irish silver eels is approximately 18 years and the cumulative natural mortality over the continental life stages is approximately 2.5 (Dekker, 2004). The residence time was the time required for glass eels (70 mm) to grow to the Irish average silver eel length of 480 mm (sexes combined).

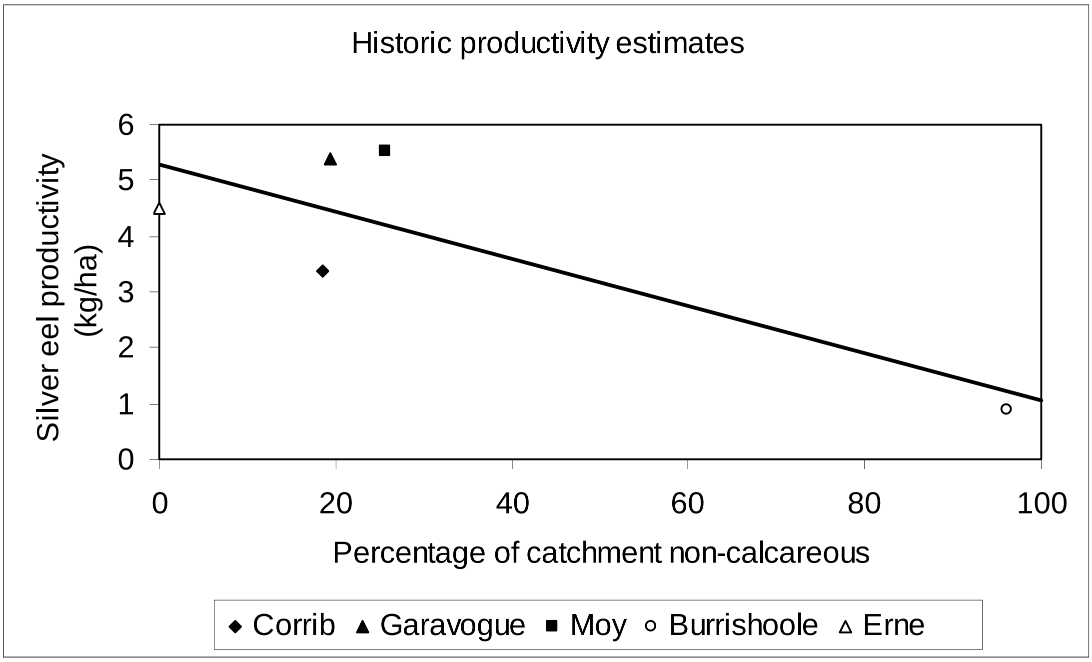


Figure 4.6: Catch based productivity estimates plotted against the percentage of catchment with siliceous (non-calcareous) geology.

For each of the 17 catchments the proportion of fish surviving (S) was thus estimated as follows:

$S = (1\text{-}0.14)^{((480\text{-}70)/G)}$

Where G = growth rate (mm/yr)

For those five catchments data on silver eel production was also available (Table 4.2) and these where used as index catchments to estimate potential spawner escapement as follows:

Spawner production$_x$ = (Survival$_x$/Survival$_i$) * Spawner productivity$_i$

Where i= "index" river; x = river where no estimate of spawner production is available.

This calculation was repeated using the survival and spawner productivity for each of the five "index" catchments and the mean computed. The relationship between the estimated productivity and geology for the 17 catchments is shown in Figure 4.7 together with the estimate for those five catchments where productivity had been measured either from catches of by direct measurement.

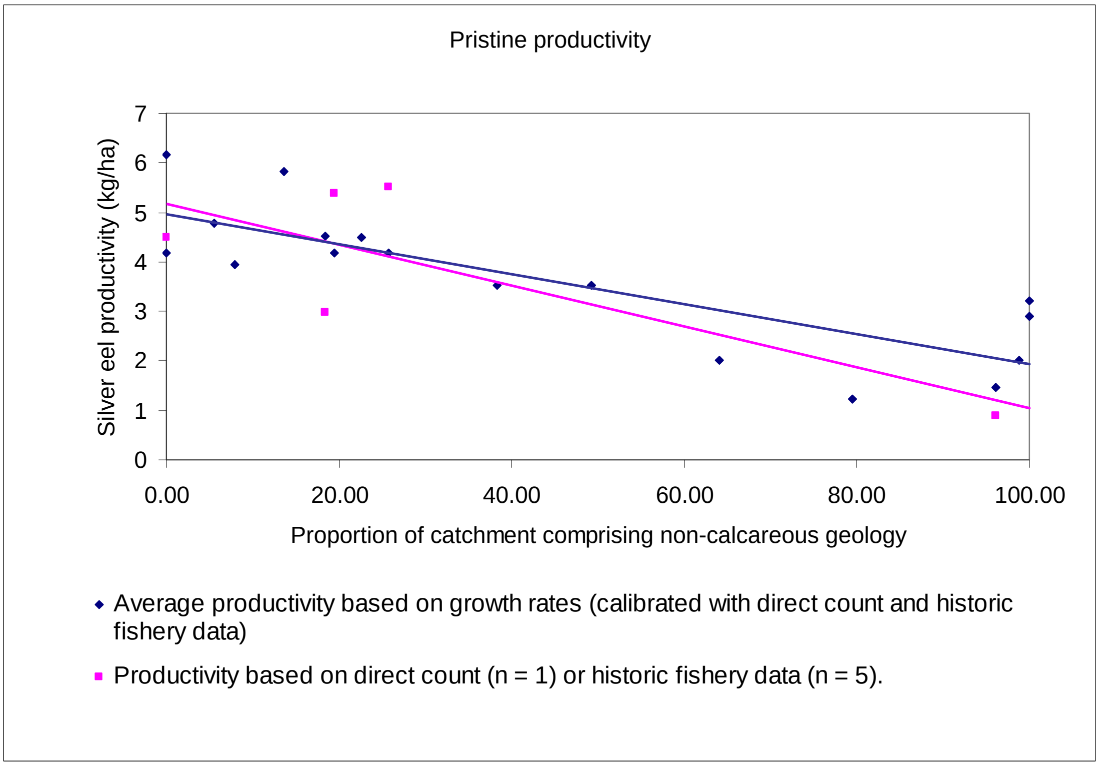


Figure 4.7: Relationship between silver eel productivity (kg/ha) and percentage of catchment with siliceous (non-calcareous) geology. The pink points are based on catch based or direct estimates of productivity. The blue points are based on the relative productivity of the catch based estimates but these are not included in the regression.

These data now allow for calculation of pristine productivity (kg/ha) based on either:

1) The relationship between silver eel productivity (based on four historic catch records and one historic total count) and the proportion of non-calcareous geology in the catchment using the regression equation:

Productivity (kg/ha) = -0.041*(percentage of catchment non-calcareous) + 5.18

2) The relationship between silver eel productivity (based on 17 growth rates calibrated with four historic catch records and one historic total count) and the proportion of non-calcareous geology in the catchment using the regression equation:

Productivity (kg/ha) = -0.030*(percentage of catchment non-calcareous) + 4.97

For Ireland pristine spawner production is estimated at 641 928 kg (4.17 kg/ha) using the regression based on historical catch or total count data and 651 092 kg (4.23 kg/ha) using the regression based on growth rates calibrated with historical catch or total count data.

As reliable data becomes available this approach will be taken to extrapolate from data rich to data poor situations where applicable. This approach is well established for salmon management in Ireland. The regression approach, as described, allows the transfer of data from index catchments with production estimates to catchments where little or no data exists on the basis of geological proxy for production.

4.3.2.3 French methodology to estimate silver eel production (Hoffman, unpublished)

The evaluation of the biomass of silver eel produced in continental waters at the French scale is based on modelling the yellow eel abundance. 20 000 electrofishing operations were used to fit the model. They corresponded to 9000 stations and cover the period 1980–2005. The model describes presence absence and abundance of total densities and densities per class size of 15 cm.

Four categories of variables were used: environment (distance to the sea, temperatures, altitude, geographical area), temporal (month, year), variables linked with anthropogenic pressure (habitat quality, obstacles, glass eel and yellow eel fisheries) and variables associated with electrofishing (fishing method).

The work is based on a GIS database of the French river network, which has been analysed to extract some environmental parameters (distance to the sea, cumulated river length upstream, river width, Strahler rank). Environmental parameters are extracted and densities are predicted in all points of the network. Setting anthropogenic parameters to zero, it is possible to predict the actual pristine productions. Temporal variables allow the prediction of past densities. The combination of both provides a figure of past pristine productions. Densities are converted into numbers by multiplying by the water surfaces.

The aim is to compare the estimated "pristine" 1989 densities with those determined during the 1960s and 1970s and if the latter are higher adjust the pristine 1989 estimate by a factor. This density would then be compared with current estimates (Figure 4.8).

The yellow standing stock will then be compared with actual estimates of silver eel production.

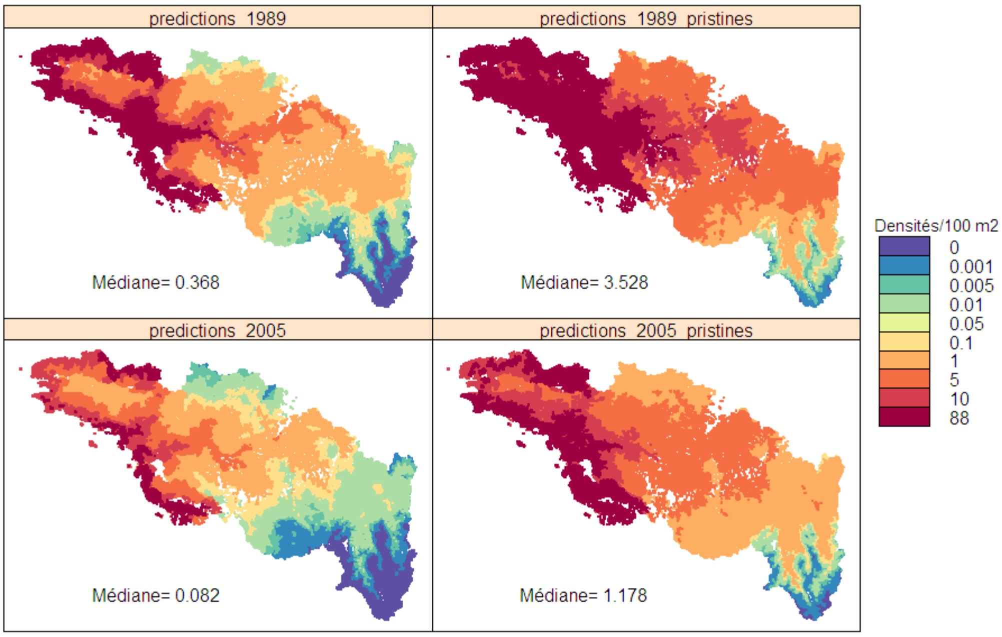


Figure 4.8: Model prediction in Loire Bretagne of the spatial variation in yellow eel densities (nb/100 m²). Surfaces are not yet calculated so the median of eel densities is shown on each graph. Pristine correspond to predictions without dam and with no glass eel fishery.

The predicted temporal trend in yellow eel densities estimated at the mouth of the river in the absence of dams for the period 1982–2005 is shown in Figure 4.9. After 1989 there is a steady decline in density. It should be noted that prior to 1989 the method of data collection differed, and the difference may reflect the lower density estimates.

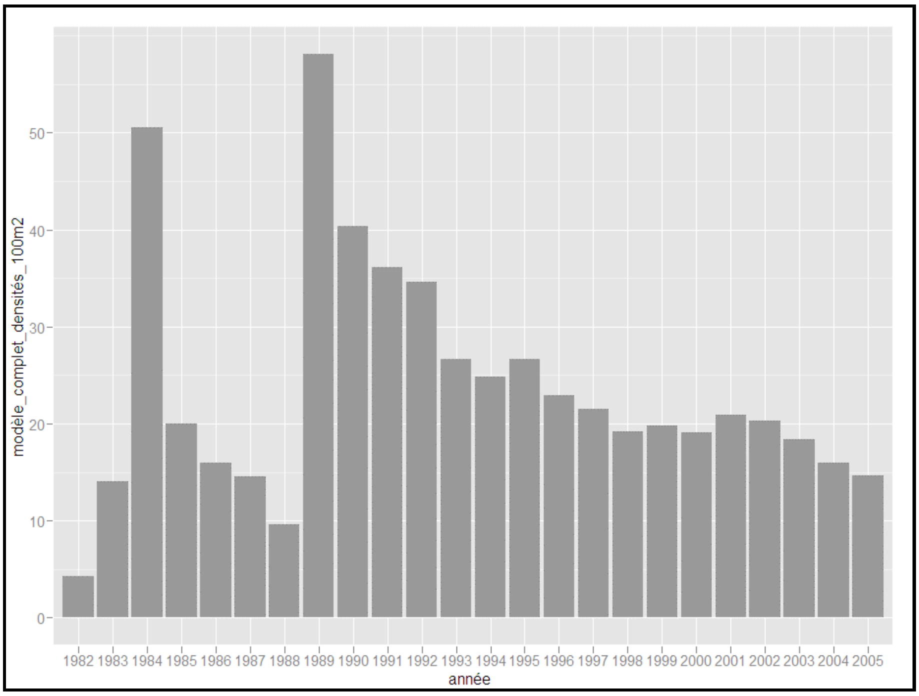


Figure 4.9: Model prediction of the temporal trend in yellow eel densities (nb/100 m²) in Loire Bretagne. The year effect was classified as category in both presence-absence and abundance when present models, the densities are those predicted at the mouth of the river, in the absence of anthropogenic impact.

For each obstacle the severity of the obstruction was estimated on a scale of 0–5 and for obstacles in series the impact was estimated to be cumulative. Obstacles have the effect of reducing the density of eel upstream (Figure 4.10). There is a rapid decline in density with an increase in the number and severity of the obstruction falling to approximately a third at a cumulative obstruction score of 50.

The model also predicted that eel density declines with distance from the sea (Figure 4.11).

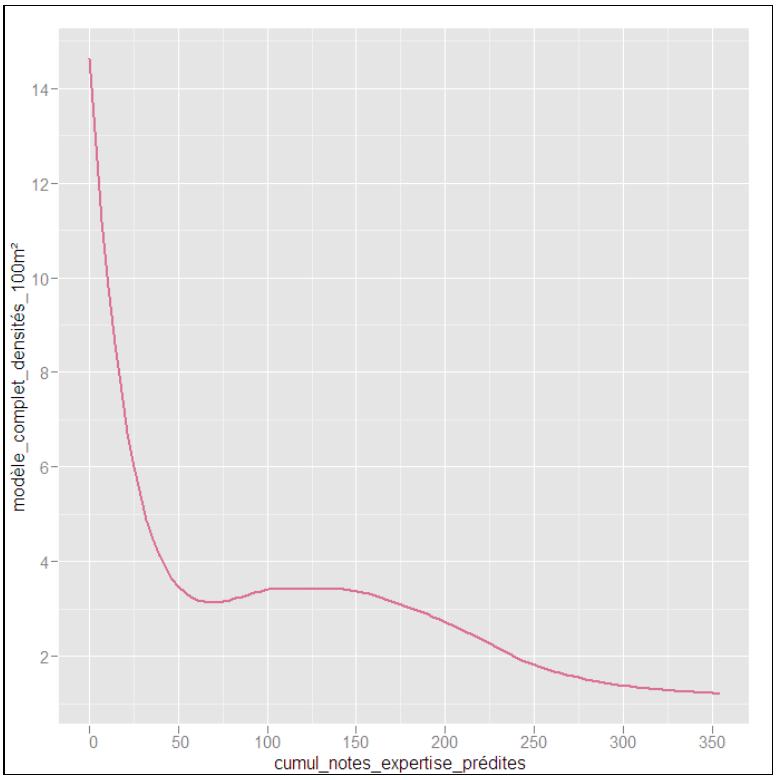


Figure 4.10: Model prediction in Loire Bretagne of the cumulated effect of obstacles. The effect of obstacles is expressed as a scoring (from 0 to 5 impassable). Densities (nb/100 m²) are predicted at the sea, in 1995, in the Loire, without anthropogenic impact.

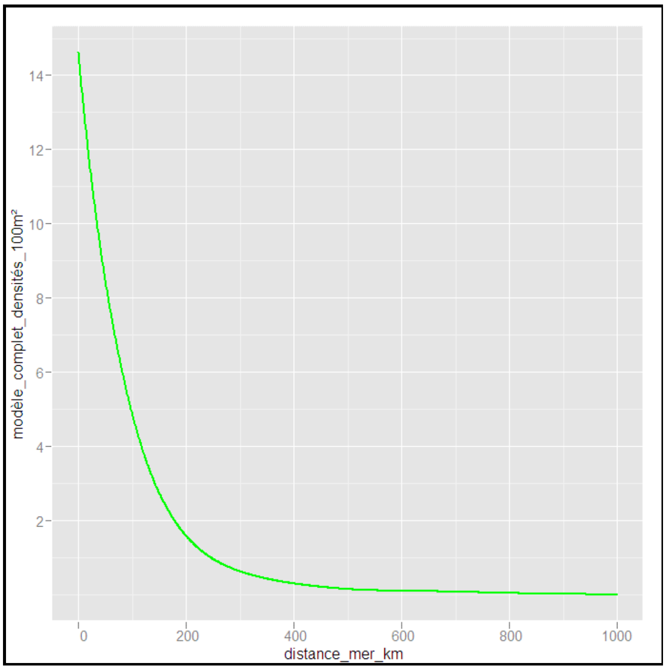


Figure 4.11: Model prediction in Loire Bretagne of the effect of the distance to the sea. Densities (nb/100 m²) are predicted in 1995, in the Loire, without anthropogenic impact.

4.3.2.4 Silver eel production in Danish streams (Pedersen, pers.comm.)

Silver eel production in Koge Lellinge stream was estimated to be 105 kg/ha river (wetted area) (Rasmussen and Therkildsen, 1979). The estimate was based on the density of resident yellow eels, observed growth (derived from age reading) and mortality with data collected during the period 1965–1968. The estimate is therefore based on glass eel recruitment during the period the late 1950s and early to mid-1960s. The population consisted mostly of males with mean weight of 100 gramme. The experiment was undertaken in the lowest part of the stream and downstream of a weir, the estimate therefore can not be taken as representative of silver eel escapement for the catchment as a whole but only the lower part of the river.

Silver eel production in River Brede was estimated to be 49 kg/ha river (wetted area) (Nielsen, 1982). The silver eel were caught in autumn 1981 using fykenets with the escapement estimated using mark-recapture and is thus based on the recruitment of glass eel during the period 1965–1975. The population of silver eel was 82% males and 18% females. Average weight was 120 grammes.

Silver eel production in the River Bjornsholm was estimated in 1988 to be in the range 9–39 kg/ha river (wetted area) (Bisgaard and Pedersen, 1990). Densities of resident yellow eel, observed growth rate (derived from age reading) and mortality produced an estimate of 39 kg/ha river (wetted area). This compares with an estimate of 9 kg/ha river (wetted area) from mark-recapture on silver eel carried out in August and September and therefore should be considered a minimum estimate of escapement. Sex ratios of silver eel were 40% males and 60% females with an average weight of 280 grammes.

In Denmark, it is proposed that 50 kg/ha (wetted area) represents “pristine” escapement for the fresh-water environment. This translates into the EU escapement target of 20 kg/ha (wetted area).

4.3.2.5 Quebec approach (Verreault and Lambert, pers. comm.)

A Canada-France-Québec research project was set up to evaluate impacts of barriers opening in terms of escapement and net productivity gain in the fresh-water habitats of the St. Lawrence watershed. This GIS decision tool will be based on eel habitat surface and eel distribution in a watershed. More precisely, the model is based on the exponential decrease of potential yellow eel abundance with distance from marine waters. Then the potential yellow eel density for every river stretch is modulated by the cumulative mortality and passiblity of downstream barriers then converted in absolute abundance of silver eel escaping the system. The model final output will be an estimate of potential production of oocytes by using a size-fecundity relationship.

4.4 Future methods for silver eel escapement (yellow eel proxies)

It is essential to adopt standardized methods to estimate escapement, potential biomass (*e.g.* biomass available in the river system) and also effective biomass (that will escape and that has reasonable probability to reproduce) derived from silver eel quality and mortality within the river catchment. Possible methodologies are outlined below and in the INDICANG methodological guide (Adam *et al.*, in press) not yet seen by the WGEEL.

Silver eels biomass production is a primary management target to be urgently achieved for starting the restoration of the European eel (*Anguilla anguilla*) population. An assessment of the proportion of individuals actually escaping from catchments-and able to reproduce-compared to a theoretical pristine production under no human intervention, is of critical importance for preserving this resource, and the EU obliges Member States to implement measures. However, there is currently very little information on silver eel escapement and even less information on silver eel quality (e.g. defined by parasite burdens, metallic and organic contamination of tissues, fat content). In order to estimate effective breeding biomass in data-poor catchments, research is required to develop and implement methods and protocols describing reliable proxies. Such research has recently started during the EU programme INDICANG that proposes to clarify some of the basic concepts needed to implement assessment tools for a characterization of the production of spawning biomass in a catchment. These concepts rely mostly on the influence of the catchment context (conditions for the eel growth) on the silver eel population characteristics (biomass and numbers, sex ratio, size and age structure, condition indices) before migration. The effective breeding biomass (escapement of high quality future spawners) is then estimated by attributing anthropogenic mortality rates (fisheries, hydroelectric turbines, dams and reservoirs). Risk analysis is also needed to define the proportion of eels that are healthy enough (low parasite burdens, high condition and fat content as well as low chemical contamination levels) for successful migration and to contribute to the gene pool. As a first step, this effective breeding potential should be estimated at the catchment area level from the sources to the sea. Then, regional approaches need to be developed and implemented to model relations between catchment characteristics and silver eel population characteristics (Acou *et al.*, in press).

Here we review different approaches which have been implemented or proposed to estimate silver eel escapement. The methods will soon be available and translated in four languages (French, English, Castillano, Portuguese) in Chapters 8 and 9 of a "Guide book for European eel monitoring" produced from INDICANG project (website references). Parts of the results are also presented in Robinet *et al.*, 2008. In addition to being able to quantify the status of the stock information is also needed on processes, particularly growth and mortality, as such there is a requirement to ensure standardization of the method(s) used to estimate age.

4.4.1 At the catchment level

4.4.1.1 Estimating silver eel biomass escapement

Direct estimates intercepting silver eel runs

a. Commercial silver eel fisheries can, depending on their location and scale, provide good opportunities for direct estimation of the numbers and biomass of silver eels escaping from hydrosystems, by analyses of annual variation in either yield or cpue provided that it is possible to determine the efficiency (proportion of run captured) of the eel capture systems involved. Examples of such investigations, of population dynamics and seasonal patterns of seaward migrating eels, include those undertaken on the River Loire, River Shannon and Corrib, River Bann (Lough Neagh outlet), the River Imsa, the Baltic basin and the St Lawrence. Difficulties can occur when the fishing season does not cover the full migration period or when there is significant eel production downstream of the fishery area. Use of mark/ recapture methods for estimation of fishery capture efficiency allows for estimation of the numbers and biomass of migrating eels at the fishing sites. This can involve use of a variety of tags and marks (see Concerted Action for Tagging of Fish: www.hafro.is/catag). Experimental fisheries could be established in data poor areas and used to improve fishery monitoring methodologies. (Vollestad and Jonsson, 1988; Caron *et al.*, 2000; Feunteun *et al.*, 2000; Feunteun *et al.*, in press; Allen *et al.*, 2006; WGEEL Baltic sea; and McCarthy *et al.*, 2008).

b. Wolf traps, or related systems, or use of winged nets deployed for research purposes can provide precise estimates of migrating eel population dynamics and under some circumstances all silver eels can be counted and weighed. However, this is usually only possible in smaller river systems where discharge patterns allow for silver eel trapping throughout the migration season. Examples of this type of silver eel escapement estimation include the studies undertaken on the Norwegian River Imsa (Vollestad and Jonsson, 1988), the French Rivers Frémur (Feunteun *et al.*, 2000) and Oir (Acou *et al.*, in press), the Burrishoole (Poole *et al.*, 1990; 1994) and the outlet of Lough Ennel in the River Shannon, Ireland (McCarthy, unpublished data).

c. Counters and various acoustic technologies can allow for the estimation of silver eel escapement in locations where eel capture is not possible. For example, hydroacoustic methods, such as were used by McCarthy *et al.*, 2008 to investigate variations in numbers of silver eels migrating downstream in the headrace canal of the Ardnacrusha hydropower plant in the River Shannon, and resistivity counters and Didson acoustic cameras trialled for counting emigrating silver eel in the UK (M.A. Aprahamian, pers. comm.). Such eel counts, and linked data on size frequencies of the migrating eels, are only possible in locations where other fish species (with target strengths in the same range as the silver eels) are not also migrating downstream at the same time as eels. Work is in progress in Ireland, UK, Poland and other European countries that should lead to improved sampling protocols and to more widespread use of this method for estimation of eel escapement rates.

Indirect estimates using yellow eel proxies

In many water basins, lack of data concerning silver eel estimates, requires the use of alternative approaches to meet the demands of Council Regulation 1100/2007 for estimating silver eel escapement. The use of proxy indicators from sedentary eels and habitat population models seem to be the most promising approaches (Feunteun *et al.*, 2000; Aprahamian *et al.*, 2007; Lobon-Cervia and Iglesias, 2008; Feunteun *et al.*, in press,). These procedures should nevertheless be standardized so that methodologies used can provide representative estimates of silver eel production, e.g. sampling at the beginning of the migratory season (late summer in southern latitudes and middle summer in northern latitudes).

Mark-recapture or other more locally adequate methods could be used to estimate density of yellow and silver eels. Several habitat types representative of each catchment should be evaluated in order to be able to extrapolate for the whole catchment and include it in habitat population models.

Eel mortality rates need to be determined throughout the river basin including the estuary as well as fresh-water habitat (see also Chapter 3).

In some countries, lack of data on both yellow and silver eels requires a different approach in which, habitat data collected within the WFD should be used in conjunction with eel population data from similar regional areas. However, EMPs based on this provisional approach should also include details of sampling programmes to provide a basis for future determination of spawner escapement.

Estimating effective silver eel biomass escapement

Effective silver eel biomass {proportion of the potential silver eel biomass * mortality (Fishery, Hydropower, Natural) * quality} estimation is essential if the actual contribution made by particular rivers, river basin districts or larger scale European regions is to be evaluated now and during post evaluation of EMPs. This integration of data on population dynamics and eel quality has not been subject to the detailed level of discussion to which other elements of the EU eel recovery plan have been subjected. However, a more standardized approach to this topic is required if results of ongoing studies on contaminants, parasites and diseases of silver eels are to be integrated at a European level.

4.4.1.2 Quality

Monitoring quality of silver eels should aim to establish the proportion of migrating eels that have sufficient quality to reach the spawning grounds, breed and produce adequate numbers of viable larvae. In analyses of silver eel populations the extent of quality monitoring will be more limited for eels released following capture and measurement. For released eels, the life-history stage determination, and the usual length and weight measurements, must be recorded for representative subsamples.

Observations of significant decreases in fat levels in yellow eels over 15 years in Belgium and the Netherlands raises serious concerns about their reproductive potential (Belpaire *et al.*, in press), and warrant the inclusion of eel quality estimates within the quantitative targets for escapement.

Considerably more parameters should be requested on a subsample of silver eels. These can involve data on contamination levels of metals and organic (for methods refer to quality section), fat content and condition factor, otolith age reading, *A. crassus* and EVEX and other viral diseases. Information on life-history traits and population characteristics should also be provided for sampled silver eel populations and this can involve sex ratio estimated from size frequencies (with calibration using sacrificed eels). There is a need to establish a size-age relationship and also an index relating eel quality to breeding success.

4.4.2 At the regional level

It is anticipated that the EMPs are developed under the River Basin District (RBD) level. The success of EMPs depends on a good coordination and consistency between measures taken under Regulation 1100/2007 and European Directives having impact in the river basin. Therefore, to make EMPs more effective, it is desirable that catchment based models are also developed at a regional level (involving each RBD), aiming at predicting silver eel escapement.

4.5 Methods for evaluation of management measures

A close link between both management and eel sub-target will be established in the following sections with regard to selected management measures (Table 4.3). The relationship between management and eel sub-targets will allow for a direct feedback to management if measures are not achieved and/or the locally targeted eel population responded, or failed to respond, in the predicted manner (e.g. an increase in yellow eel density). The methods to evaluate management measures and the response of the targeted eel life stages should be applied locally and therefore give a feedback to the authorities in the eel management units. By this feedback loop local managers will be able to adapt their management approach without regard to the delayed response of the whole eel stock (e.g. changes in recruitment). However the proposed management- and eel-targets are not intended to be an exhaustive list of all possible management measures. It should be taken as a first step in filling the gap between local management and the long-term recovery.

It is also recognized that methods for evaluating the outcome of management measures on the population level (eel sub-targets) are not always fully available and need further research. The same holds true for the definition of different quantitative levels of eel sub-target. The levels have to be related to the actual status of the eel population with respect to the global objective of full recovery (e.g. 40% of spawner escapement without anthropogenic impact). The level of the management action finally depends on how far a certain management unit is away from the objective (refer to Figure 4.2).

4.5.1 Management measures and methods for evaluation

4.5.1.1 Commercial fishery

EMP´s will involve fisheries regulation measures throughout the distributional area and across all continental life stages. A range of different measures can be identified and applied to the different life stages. Evaluating the effects may require different approaches and time frames.

Management sub-target 1.1: Effort restrictions. For all life stages, the regulation and limitation of the access to the fishery is a common measure that can be applied.

4.5.1.2 Glass eel fishery

Quotas and partial or total closure of fishing activities are the most plausible methods in managing a glass eel fishery.

Management sub-target 1.1; Achievement of Quota. A defined proportion of the recruits to a management unit is excluded from the local fishery. Evaluation should be based on knowledge of variation in abundance/catchability over time in the season and monitoring of landed quantities.

Management sub-target 1.2; Total or part time closure. A given degree of closure results in a predetermined reduction of fishery mortality. This target must be based on the knowledge of glass eel abundance over time in the fishing area and may be monitored by field control of fishing activities.

4.5.1.3 Yellow eel fishery

Quota, total or part time closure, size limits and closed areas are measures applicable in regulating most fisheries, including fishing for yellow eel. Technical regulations of the fishery for yellow eel may have different effects depending on where they are imposed in a catchment. If they are imposed downstream, in an estuary or near the area of primary recruitment, they may have an effect on density-dependent migration and thus proliferate upstream in the river basin. On the other hand, if they are introduced upstream in a system, where the subpopulation has a higher degree of residence, the expected effect will primarily concern demography and mortality. The statements above suggest different designs of monitoring and short-term evaluation.

Management sub-target 1.3; Quota. A defined proportion of the yellow eel stock in a management unit is excluded from the local fishery. Evaluation should be based on knowledge of the local production in the area and effects of a regulation can be monitored in landed quantities.

Management sub-target 1.4; Total or part time closure. A given degree of closure results in a predetermined reduction of fishing mortality. Evaluation of this target needs stock assessment models, which are often dependent of an existing fishery. A total closure thus is easier to evaluate.

Management sub-target 1.5; Size limits. Imposing size limits is targeting reduction of fishing mortality. Evaluation of this target needs stock assessment models, which are often dependent of an existing fishery.

Management sub-target 1.6; Protected areas. A management target for protected areas could be evaluated as the proportion of the available habitat or productive potential that is taken out of fishery. In this case, as in most other cases, the proper management target is a certain reduction of fishing mortality in the management unit.

4.5.1.4 Silver eel fishery

The most plausible tools to manage a silver eel fishery are total or part time closure and size limits. Protected areas may also be considered.

Management sub-target 1.7; Total or partial closure should fulfil the target to reduce mortality by a predetermined value. Evaluation must be based on a good estimate of the number of eel that would be caught if fishing was open and the total catch in the open season. This target may be monitored using landings and historical information on distribution of catches over the entire season.

Management sub-target 1.8; Legal size limits may include exclusion of the smallest as well as the biggest individuals from the landed part of the catch. This target should be set bearing in mind the total effect on effective SSB. Egg production may not be/is not linearly related to body weight (Verreault, 2002). Compliance with the target must rely on sampling of the size distribution in the total catch, discards included.

Management sub-target 1.9.; Protected areas. The effect of protected areas should target a certain proportion of the silver eel production in a management unit and should be restricted/closed for all types of fishing activity, i.e. F=0 for x% of the potential production.

4.5.1.5 Recreational fishing

In parts of Europe recreational fishery generates a major part of the fishing mortality. This kind of fishing is to a great extent focusing on the yellow eel stage but capturing silver eel may also occur (Staas, 2006). The measures available for managing this sector of fishery are primarily the same as those for the commercial fishery. Thus the biological targets are similar to those presented above under yellow eel fishery. All management actions described in the same section could be applied to recreational fishery. The presence of poaching though, may introduce the need for official control.

Management target 1.10.; Control of effort. This target should be the control of effort taken in a management unit or in predefined parts of a management unit.

4.5.1.6 Actions to make rivers passable and enhance habitat quality

Upstream migration

Management sub-target 2.1; number of dams where eel ladders will be installed, especially in and near the zone of active colonization:

Management sub-target 2.2; surface area of river channels and lakes in a catchment or a percentage of lost habitats that could become recolonized by eels.

Evaluation of management sub-target 2.1 and 2.2 could be achieved annually by listing of the recently equipped dams combined with GIS techniques of upstream surface measurement.

The conversion of the management targets into an eel sub-target assume that all habitats within a river system are equally productive per unit surface area and eels were totally excluded upstream of man-made obstacles (Verreault *et al.*, 2004; ICES 2007).

Management sub-target 2.3; number of fish passing over the obstacles. To determine these numbers an eel ladder should be equipped with a fish counting device (trap, video camera etc.). However, passage of fish may fluctuate a lot with several peaks during the migration period. For example, in the River Couesnon, 75% of the fish trapped occurred within four weeks whereas 17 weeks contributed to less than 10% of the total catch (Legault, 1994). The target in absolute numbers could be difficult to achieve in the short term especially when a decreasing recruitment trend is observed. It is probably better to define a relative target i.e. percentage of fish that succeed to migrate upstream. Briand *et al.*, 2005a undertook a survey of arrival near the obstacle by using a mark and recapture technique but this kind of application is difficult to execute and repeat for a long period.

Downstream migration

Current practice of stocking and the (recent) construction of fish passes have led to the establishment or maintenance of yellow eel population in habitats situated upstream of hydropower plants. In many cases these areas will be included into the natural eel habitat. But when reaching the silver eel stage a fairly large proportion of these eel are lost as a consequence of turbines passages and or impingement. Possible mitigation measures consists of installing bypass systems, switching off hydropower turbines temporarily and capturing downstream migrating silver eels (and incidentally yellow eels) before entering hydropower turbines.

Management sub-target 2.4; number of obstacles where appropriate bypass systems will be installed, or where hydroelectric power turbines should be switched off temporarily, or where trap-and-transport measures will be carried out.

Evaluation of this management target could be achieved annually by listing the recently equipped dams.

4.5.1.7 Reduction of environmental contamination

Management sub-target 2.5; reduction of pollutant discharge until total prohibition of use for the most dangerous contaminants.

The direct evaluation of such target is not simple because it is difficult to estimate the quantity of pollutants being input to the river, especially when sources of pollutant are diffuse.

4.5.1.8 Increase of habitat quality

Management sub-target 2.6; Wetted surface area of river where eel habitat quality is improved.

As with contaminants the direct evaluation of such a target is not simple because it is difficult to estimate the habitat quality and the relationship with the quantity of eel.

4.5.1.9 Stocking of glass eel or pre-grown (farmed) yellow eels

If stocking is to be used as a management measure according to the EU-Regulation, it has to be assumed that stocking is performed at the actual state-of-the-art (decision tree and stocking protocols are available; see Chapter 5) with respect to carrying capacity and sufficient quality of the chosen habitats (see relevant data collected under the WFD). The health status of material used for stocking with special regard to parasites, viruses and other pathogens has to be checked. Additionally silver eels produced from such stockings should be able to escape from the habitats without major losses as a consequence of pumping stations or hydropower turbines.

Management sub-target 3.1 Defined proportion of habitat with low recruitment in the management unit for supplementation of eels and number of eels stocked per surface unit (ha) according to available eel surplus for stocking.

Management sub-target 3.2 Defined proportion of natural eel habitats without recruitment and number of eels stocked per surface unit (ha) according to available eel surplus for stocking.

Stocking activities will in future rely on the assumption that a surplus of glass eel from at least some European estuaries is still available. In view of high prices for glass eel the locally available budget may limit stockings more than biological or logistical aspects.

4.5.1.10 Measures related to aquaculture for stocking

A great proportion of glass eel captured in Europe is currently used for eel production in aquaculture. This proportion is assumed to diminish in the next years as according to the EU-Regulation up to 60% of all eel below 12 cm should be reserved for stocking. On the other hand stocking, as a conservation measure, can include eels up to 20 cm in length. This is in accordance with current stocking practice using pre-grown eels from aquaculture for release in natural eel habitats. As prices of glass eel tended to be high in recent years and glass eel are assumed to face a high natural mortality in the first years this practice will probably continue in coming years. As a consequence of rearing conditions there is a concern about the quality of such eel released after a time in conventional eel aquaculture with regard to health status and genetic diversity (see Chapter 5.4.2.3).

Management sub-target 4.1 Ensure the production of sufficient numbers of eels (for stocking) with a good health status with respect to parasites (*Ang. crassus*), viruses (HVA, Eve, EVEX) and other pathogens.

Management sub-target 4.2 Ensure the production of eels from aquaculture with a minimum genetic selection and avoid stocking of slow growing individuals sorted out from aquaculture.

4.5.2 Eel sub-target

4.5.2.1 Glass eel sub-target

Eel sub-target 1.1; Density target for wild (and stocked) 0+ in predefined sections of a catchment.

This can be monitored in ladders and/or by electro-fishing and to be evaluated against historical data. A short-term response is expected (few months).

Time frame for revision management action: 1 year.

Indicators; n/ha, absence/presence, front of colonization.

4.5.2.2 Yellow eel sub-target

Eel sub-target: Profile of eel occurrence according to longitudinal position in the catchment. More precisely, this target can be expressed in distance from the sea where the probability of eel presence is 50%.

No information on time-scale of response, probably few years depending on latitude.

Example of application

This methodology is based on an analysis electro-fishing data with logistic regressions. Lasne and Laffaille, 2007 estimated that study of temporal trends of "eels' logistic profiles along the longitudinal gradient" allow the assessment of the improvement of colonization after mitigation of local impacts.

Eel sub-target: Density of yellow eel in the upstream reaches.

A short-term target could be set as a specific increase in density on a certain level in a river system after a certain period of time. Compliance can be monitored by mark-recapture, counting in ladders, by electrofishing, with fykenets or other kinds of fishery-independent methods (ICES 2007) and can be evaluated referring to historical data or expected densities from models.

No information on time-scale of response, probably few years depending on latitude.

Indicators

Numbers passing, n/ha, cpue.

Example of application

An illustrative example is given by the reopening of the Vilaine watershed (Briand *et al.*, 2005b). The construction of the eel ladder resulted in high densities (>1 eels/m^{-2}) in the downstream and middle stream areas after two or three years after. These changes remain clear and the examination of five years of data has changed little of the conclusions expressed after only two years. Number of glass eels climbing the fish ladder led to the colonization of the entire basin and a possible saturation in the downstream and middle stream areas. But decrease of glass eel arrival and density-dependant mortality could complicate the interpretation of the results, by inducing a decrease in density in some parts of the catchments (Briand *et al.*, 2005b). A similar approach was performed on the Fremur River and stressed again the importance of maintaining longitudinal connectivity in rivers.

Eel sub-target; Degree of habitat saturation of yellow eel.

Response in distribution/habitat saturation level in the entire catchment can vary in time frames according to latitude, altitude, climate, etc. A reasonable estimate is that a sub-target like this could be set to 3–5 years in the central area of distribution. The target fulfilment can be evaluated against historical data or densities from models.

Indicators

Ratio between saturated and unsaturated surface, ration between actual density and carrying capacity.

Eel sub-target: Sex distribution.

An increase in density induced by a reduced fishing mortality may result in a density-dependent change in sex ratios. Evaluation of the appropriate target level will be difficult, but may be based on historical data.

Example of application

The Baltic eel stock declined sharply in the 1960s and the 1970s following a preceding decline in recruitment of young yellow eel into the Baltic Sea. The hypothesis was raised that the reduced recruitment was due density-dependent processes in the areas of primary recruitment, i.e. the Kattegatt and the Danish straits (Svärdson, 1976).

Following this male eel almost completely disappeared in SW Sweden. An effect of density on sex ratio was also observed in Lough Neagh in Northern Ireland (Rosell *et al.*, 2005).

The time frame for a response in density-dependent sex differentiation is uncertain, as there is a period of time between recruitment and sexual differentiation.

Indicator

Proportion of sexes per size group.

Eel sub-target: Short term response in mortality rate.

Local estimate of global mortality (fishing mortality, other source of anthropogenic mortality) rate can inform on pressure on the stock.

Example of application

The LVPA assessment models quantify the population state and the impact of fishing, for the data years Dekker, 1996 #865}. A minimum of assumptions and a maximum of data ensure a close tracking of the true population state in recent years; in particular, estimates of both the population number and the fishing mortality by length class are updated annually. The Beverton and Holt methodology easily allows for simulation of alternative fishing regimes, and derivation of reference points. Application on the yellow eel fisheries in Lake Ijsselmeer demonstrated that this fishery overexploit the local stock of eel. Current fisheries reduce male spawner escapement to one in seven parts and reduce female spawner escapement to one in seven hundred parts of the unexploited situation (Dekker, 2000).

ELSA is a modelling approach based on eel length taken into account relative change in recruitment, sex ratio, growth, natural and fishing mortality and rate of silvering. It is useful to estimate total mortality rate from a simple length structure above 30 cm (Lambert *et al.*, 2006). The information about eel stock status provided by an application on the Gironde estuary present analysis urges to implement management actions in fresh-water part of the estuary.

Time frame for revision management action

Two to five years (should be revised).

4.5.2.3 Silver eel sub-target

Eel target: level of mortality rate for each obstacle, maximum delay for migration. For global river management, cumulative mortality and delay can be targeted.

An approximate estimate of turbine mortality can be obtained using empirical formula from literature (Larinier and Travade, 1999). More accurate estimations of eel mortality rates can be obtained by telemetry procedure although they are difficult to obtain as a consequence of the uncertain behaviour of eels during their downstream migration (ICES 2007).

Evaluation of such target should take into account the variability induced by environmental fluctuations and therefore a multi-annual survey is advised.

Time frame for revision management action

Two or three years.

Eel target: Number of silver eels escaping

This can be monitored by catch statistics, direct counting methods, or mark–recapture experiments (ICES 2007).

The potential production of silver eels can be deduced by converting the re-established yellow eel population or production (data from electro-fishing) into silver eel using simple population models. Where downstream dams are present, escapement estimates should be adjusted to account for cumulative mortality from dam passage.

Time frame for revision management action

One to five years.

4.5.2.4 All life stage sub-targets

Eel sub-target 4.1: Level of contaminant load in eel. Measurements in fish are possible for many contaminants, especially for lipophilic ones since eels are particularly sensitive to bioaccumulation of such contaminants. Eel measures give better responses (% of detection) than measurements in water or in sediment (Belpaire and Goemans, 2007a) and an adaptation of the Flemish survey (Belpaire and Goemans, 2007a) to the relevant scale of the studied source of pollution should be advised.

The time response of these management actions depends mainly on the persistence of the contaminant in the field. For example, in Flanders lindane load decreased rapidly after its ban in 2002, whereas DDT continues to slowly decrease 30 years after prohibition (Maes *et al.*, 2008).

Eel sub-target 4.2; Level of quality index. An index of (yellow or silver) eel quality is important for evaluating the net effect of silver eel escapement on reproduction.

Fat content could also be good proxy indicator of the contamination level and a subsequent decrease in yellow eel fat content has been tentatively linked to the capability of silver eels to perform the migration to the Sargasso (Belpaire *et al.*, 2008). Health status of eels used for stocking especially with regard to *A. crassus* and viruses such as HVA, EVE and EVEX can complete this index.

Table 4.3: Linking management sub-target and eel sub-target. Relation in a short term between management sub-targets (level or magnitude of action in local management) and eel sub-targets (response of the eel population to management) (GE: glass eel YE: yellow eel; SE silver eel).

			Eel sub-target									
			GE	YE					SE			
			1.1; Density	2.1 Occurrence	2.2 : Density	2.3.; Habitat saturation	2.4. Sex Distribution.	2.5 Mortality rate	3.1; Obstacle mortality	3.2 Escapee number	4.1 Contaminant load	4.2; Quality index
Management sub-target	Fishery	1.1 ; GE Quota	✓	✓								
		1.2; GE time closure	✓	✓								
		1.3; YE Quota		✓	✓	✓	✓	✓				
		1.4; YE time closure			✓	✓	✓	✓				
		1.5; YE Size limits			✓	✓	✓	✓				
		1.6; YE Protected areas		✓	✓	✓	✓					
		1.7; SE time closure								✓		
		1.8; SE size limits								✓		
		1.9. SE protected areas								✓		
		1.10. Control effort						✓				

Table 4.3: continued.

			Eel sub-target									
			GE	YE					SE			
			1.1; Den sity	2.1 Occur-rence	2.2 : Density	2.3.; Habitat saturation	2.4. Sex Distri-bution.	2.5 Mortality rate	3.1; Obstacle mortality	3.2 Escapee number	4.1 Conta-minant load	4.2; Quality index
	Upstream migration	2.1; Equipped dam number		✓	✓	✓	✓					
		2.2; Opened surface area		✓	✓	✓	✓					
		2.3; Fish passing number		✓	✓	✓	✓					
	Down-stream mig.	2.4 N^o. of obstacles							✓	✓		
	Pollution	2.5; Pollutant reduction								✓	✓	
		2.6; Improved habitat surface			✓	✓						
	Stocking	3.1 Surface of habitat with low recr. and N^o. of stocked		✓	✓	✓	✓					
		3.2 Surface of habitat without recr. and N^o. of stocked		✓	✓	✓	✓					
	Aquaculture	4.1 N^o. of produced eels with a good health status						✓				✓
		4.2 N^o. of produced eels with minimum genetic selection						✓				✓

4.6 Conclusions and recommendations for Chapter 4: Assessing stocks and management actions

4.6.1 Conclusions

It is suggested that managers define interim targets for the management measures in order to integrate local action efficiently to the aim of long-term recovery of the European eel stock. For this purpose management sub-targets defining the magnitude of actions (e.g. number of dams removed) will be linked with eel sub-targets reflecting the expected short-term response of the local eel population. Eel sub-targets should therefore allow a fairly rapid evaluation of the management measures taken but sensitivity and time response of some of the proposed eel sub-targets would need further investigation before their application would be operational.

Eel sub-targets should finally be integrated into the evaluation of the status of the whole eel stock. However it has to be recognized that adequate methods or modelling approaches for doing this exercise are still lacking.

Implementation of EMPs requires the development of methodologies to obtain those data. They can include either direct (*e.g.* mark-recapture) or indirect measures (yellow eel proxies to determine silver eel production and eel habitat modelling production). It is important to ensure standardization and quality control of the method(s) used to estimate age.

Use of direct methods, though preferable in many respects, will be severely restricted by: uneven distribution of silver eel fisheries within and between regions; limited fishery monitoring resources; and in extreme fluctuations in large river flows. However, where possible, use of direct methods should be prioritized.

A variety of indirect methods, mostly dependant on yellow eel proxies and modelling, are available for areas where direct measurements of silver eel escapement are not possible and should be extensively used to estimate regional and national silver eel escapement. Selection of models should take account of SLIME conclusions and advice given elsewhere in this report (Dekker *et al.*, 2006). Validation of indirect methodologies should be undertaken on an ongoing basis for a network of river systems where reliable direct estimation of silver eel escapement biomass is possible.

Estimation of effective spawner biomass should be undertaken in all EMPs (*i.e.* at local, regional and national levels) and this will require quantification of adverse effects of contaminants, low fat levels, non-lethal turbine damage, viral diseases, along the lines previously proposed for *A. crassus* as well as other anthropogenic mortality rates along the river catchment. Local management decisions should then be made by reference to effective silver eel escapement rather than total spawner biomass estimates.

There are very few quantitative estimates of pristine (pre-1980) and current silver eel production to allow comparisons to be made between systems and there is very few data on the importance of estuarine and coastal populations to overall production. Modelling will be needed to transfer estimates from data rich to data poor systems. Some approaches have been outlined by this Working Group which complements those from presented in previous working Group reports and in Dekker *et al.*, 2006.

4.6.2 Recommendations

- well defined sub targets for short-term, local management efforts should be used, and that data should be collected so that they can be post-evaluated both regarding the fulfilment of the management efforts and the anticipated effects on eel;
- population model(s) should be used to assess the status of stock, compliance with (sub) target(s), to evaluate management actions and to evaluate the influence of biotic and abiotic factors on the stock at a range of geographical scales;
- adaptive feedback links are established between post-evaluation results and resulting changes in management efforts;
- care should be taken so that locally established (short-term) sub targets ensure long-term recovery, eventually leading to the restoration of the spawning stock so that the eel reach full recruitment capacity.;
- since short time evaluation of management actions urges for a list of monitoring activities, fishery dependent as well as fishery-independent, methods for monitoring in connection to the sub targets presented by the WGEEL in this report and in the report of 2007 should be implemented ASAP within the DCR and elsewhere and that where possible these activities should be coordinated nationally with related monitoring activities, i.e. regarding biodiversity within the WFD;
- the concept of effective spawner biomass escapement should be adopted for all EMPs and comprehensive protocols for integration of standardized eel quality data should be developed for application of this concept;
- standardized terminology, and identification criteria be adopted, for use in all European eel programmes;

5 Stocking and aquaculture

5.1 Introduction

Stocking and transfers of juvenile eel have been discussed at length by the Working Group (most recently ICES, 2006 and 2007). These discussions have covered the principles and extent of stocking, stock transfer practices and their contributions to fisheries. Their effect on escapement has been discussed mainly in conceptual and theoretical frameworks as a consequence of a lack of hard data. The WG 2007 recommended that "guidelines, or best practice manuals, should be established for methodologies for ……. stocking of eel".

ToR b) develop methodologies for the assessment of the status of the eel stock, the impact of fisheries and other anthropogenic impacts and of implemented management measures; this might include, for example, support for EMPs on the determination of "pristine" spawner production levels and **relative contribution of stocking.**

Extract from 2006 WGEEL report-the changing scientific advice regarding stocking.

"Scientific advice on re-stocking has changed over the years, from clearly in favour (Moriarty and Dekker, 1997), to against on precautionary grounds (ICES, 2000). In our previous report (ICES, 2005b), the risks involved were discussed, balancing potential genetic effects against the risk that the current stock might suffer from depensatory effects in the reproductive phase, for which re-stocking might be one solution.

Clearly, arguments both pro and contra re-stocking remain valid, and no final and scientific advice can be derived. However, the previous advice was based on the potential for depensation occurring in the reproductive phase. All arguments pro and con being as they are a more practical and nearby argument has come to the fore in this report: that seed stock areas might progressively become depleted as a consequence of a continued decline in glass eel immigration. Options for potentially successful restoration of the stock by glass eel restocking are fading. Re-stocking of glass eel, either in southern areas rapidly contributing to silver eel production, or in northern areas with a long postponed and long lasting contribution to silver eel production, therefore needs urgent consideration."

The Working Group revisited this topic in 2008 in order to provide updates on stocking figures and practical information to support stocking best practice and will provide support to EMP's and the EU Commission.

5.2 Methods to assess the relative contribution of stocking to the regeneration of the European stock, and for EMPs

5.2.1 Source of glass eel

Advice from ICES to the EU commission (ICES, 2005a) was that the recent glass eel catch (ca. 100 tonnes) is less than that required (150 to 1000 tonnes) to supply the total potential productive habitat (about 40 000 km2), and ACFM further concluded that full-scale restocking alone is unlikely to achieve the EU objectives in the medium term (ICES, 2006).

Therefore, the advice remains that there are likely to be insufficient glass eel available from the fishery to meet the demands for stocking at the European level. However, the Regulation EU: 1100/2007, requires that fisheries make at least 35% of eel <12 cm available for stocking in 2009, rising to 60% by 2013. The implementation of EMPs in 2009 may effect the reduction in some glass eel fishing effort, either as part of local

Management Plans or as a consequence of the 50% cut required where plans are not submitted and approved. This outcome will not be known until the EMPs are published. Here, we consider the potential effect (benefit) of this stocking material.

5.2.2 Yield potential

The yield potential can be calculated from Yield/Recruit (Y/R) estimates. Most of the data on Y/R available are obtained from stockings in lakes and an Italian lagoon. The data for lakes range from 5–72 g.stocked eel^{-1}, but most are in the range 20–50 g.stocked eel^{-1}. The yield-per-recruit in the Italian lagoon appears to be more than twice as high. If the total catch of glass eels in Europe is in the region of 100 tonne (ICES, 2005) of glass eels, with 3000 glass eels per kilo, and 35% (minimum requested by the Eel Regulation) provided in 2009 for stocking, this would have a production potential for approximately 2000–5000 tons of silver eel after one eel generation time. When 60% of the catch becomes available in 2013, it will have a lifetime potential for 3500–8500 tons of silver eels given no anthropogenic mortality. ICES 2006 produced comparable results (10 000 tons of silver eels when stocking 100 tons of glass eels) when using population dynamic calculations and data from Moriarty and Dekker, 1997. The above estimates are maximum estimates, based on the assumption that the catch of glass eel will be in the region of 100 tons. There is of course the possibility that there may be no surplus of glass eels in the near future (ICES, 2007).

Glass eel are caught using moving and stationary fishing gears. There is evidence that handling mortality of some of these gears, e.g. trawls may be up to 40%. Reduction of these mortalities would lead to the more efficient use of the limited and declining resource of glass eels.

5.3 Review of stocking activity across Europe

Before the WG meeting, a simple questionnaire was sent to the WG members in order to obtain additional information. The responses to this questionnaire are briefly described in the following section. Information from 17 countries is included. For this purpose, UK and Northern Ireland were considered as two countries, since there is a considerable transfer of glass eels from the "UK" to Northern Ireland.

A. Does your country buy eels for stocking?

Yes: 11 (DE, PL, N.Irl, SE, NL, BE, FI, EE, LT, LV, DK)

No: 6 (FR, ES, PT, UK, IE, NO)

A clear geographical pattern can be seen. Countries at the Atlantic coast do not buy eels whereas countries further east of the Atlantic, and in particular around the Baltic Sea, usually purchase eels for stocking.

It has to be noted that this is a dynamic picture, which may change from year to year depending on several factors (availability and price of glass eels, situation of the fishery in the respective country, political and administrative decisions).

B. If so which life stage, glass or yellow eels? (only countries with "Yes" under question 1)

Glass eels:	6 (DK, LT, EE, FI, SE, N.Irl)
Yellow eels (elvers, pre-grown eels):	1 (LV)
Both:	4 (BE, NL, PL, DE)

Clear changes in the stocking strategies have occurred in the past and will probably re-occur in the future depending on several factors, in particular the availability and price of glass eels *vs.* pre-grown eels from farms. New scientific results may also influence the decision for one of the stocking types (e. g. survival and growth rates of glass eels vs. pre-grown eels, gender selection based on farm densities and risk of infection with diseases from the farms). There are risks and benefits for each type, which are considered in another section of this report, and which should be considered in the stocking strategy.

C. How much stock was purchased in 2008?

The data for 2008 were not complete and did not allow a useful analysis. Therefore, the data for **2007** were considered here.

Total glass eels 2007:	5.7 Million individuals
Total yellow eels 2007:	5.6 Million individuals

There are uncertainties in these numbers and the data are not complete for all countries (but all 11 countries which answered “yes” under question A, are included). Therefore, these numbers must be considered as minimum values. The calculation is difficult, since some countries buy glass eels and rear them in farms for a while before stocking. In some of these cases, the original numbers of imported glass eels are not available (just the numbers of young yellow eels stocked).

A rough estimate was made about the total amount of glass eels finally used for stocking. For that purpose, yellow eel numbers were translated into glass eel numbers (glass eel equivalents) by correction factors usually used in Denmark (1 farmed eel equals 1385 glass eels; M. I. Pedersen, pers. comm..) and Germany (1 farmed eel equals 3 glass eels; e. g. Knösche *et al.*, 2004).

Based on these factors, the total numbers of glass eel (equivalents) used for stocking ranged from 13.5 Millions to 22.5 Millions. If a mean weight of 0.3 g for glass eels is assumed, these numbers translate into biomasses of 4.5 t to 7.5 t. Even though these are rough estimates, they may indicate the order of magnitude of glass eels used for stocking of natural waters in Europe. If this is compared to the total glass eel catch in Europe, which was between 50–60 tons in 2007, a proportion of 7.5–15% of the total glass eel catch was used for stocking. This is in the same order of magnitude as previous estimates. These figures may be influenced by incomplete recordings of stocking as well as of glass eel catches.

D. From where or whom?

It does not appear possible to provide very clear analyses about the trade paths of glass eels since the situation is very dynamic or poorly reported (Figure 5.1). Glass eels are mainly purchased from France or from the UK. However, even glass eels bought from the UK, may previously have been imported from France. When pre-grown eels from farms are used for stocking, they are either imported as glass eels and reared in farms within their own country (e. g. DK, NL, partly DE, LT) or directly imported as young yellow eels (mainly from NL, DE, but possibly also DK and in smaller amounts from other countries). The information is probably incomplete.

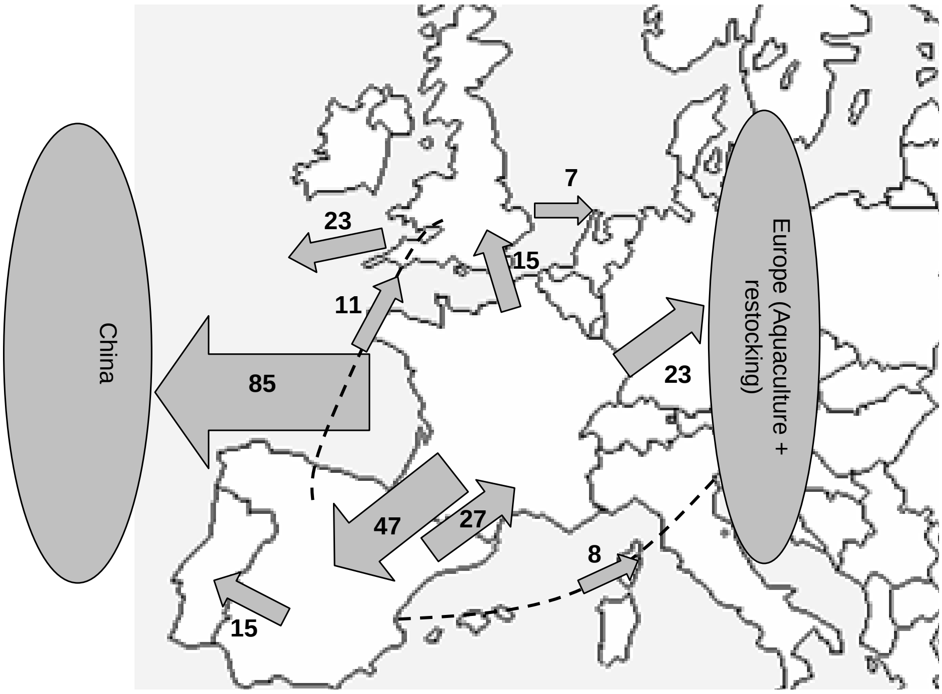


Figure 5.1: Mean trade volumes of glass eel (T) 1996–2006 in Europe analysed from EUROSTAT database.

The analysis of the questionnaire demonstrated that at present it is not possible to trace the origin and trade paths of glass eels and young yellow eels. However, as a consequence of the obligations in 2009 from CITES and from the EU Council Regulation (1100/2007-the "Eel Regulation"), Member States have to develop systems for the traceability of traded eels. Consequently, the availability of information on numbers/biomasses of eel traded and their trade paths are expected to improve in the future.

E. Does your country have a protocol in place by which it stocks its waters?

Yes:	6 (DE, ES, SE, UK, EE, DK)
No:	7 (PT, PL, LT, LV, IE, NO)
Will be developed:	1 (BE, NL)
No info/unclear status:	3 (FR, FI, N.Irl)

The information shown here contains some uncertainties. The type of protocol may be very different between countries. It may contain just rules on were to place the eels and at what density whereas in other cases a screening for diseases or parasites may be included. Other countries are at the stage of developing protocols at present. The situation may even differ within one country if regional authorities or government are responsible for fisheries issues as is the case in Germany. A considerable number of countries do not have protocols in place suggesting room for further improvement in this area.

F. Does your country intend using stocking as a tool in its eel management plans?

Yes:	12
No:	1 (NO)

Still in discussion:	2 (IE, FR)
Unclear/no information:	2 (PT, FI)

The majority of countries intend to use stocking as an option in the Eel Management Plans. This raises the question if, given the possibility of a further decline in glass eel catches and the obligation to achieve the management targets also in the donor catchments, sufficient numbers of glass eel will be available to reach the stocking targets. However, the decision whether the export of glass eel from those catchments (mainly in France and the UK) to other countries for stocking will be permitted, includes an economic and political dimension, which is difficult to assess.

5.4 Decision framework

The WG has presented and made use of various decision frameworks in our earlier reports (ICES 2006 and 2007; Williams and Aprahamian, 2004; Symonds, 2006; Montreal report (Williams and Threader, 2007)).

5.4.1 Management policies

5.4.1.1 Objectives

"Whenever stocking of fish is to be considered, the aims and specific objectives of the exercise must be clearly defined and adhered to" (Cowx, 1999).

Only more recently has stocking been done to mainly enhance local stocks in order to improve or provide the basis for a profitable fishery. In some circumstances stocking was done to mitigate or compensate for depleted stocks, as a result of upstream dams related to hydropower. Such stocks may be depleted as a consequence of dams as migration obstacles for young ascending eels and as turbine-induced mortalities in silver eels.

Concurrently with the awareness of the serious decline in the European eel stock and in connection with the preparation of eel management plans, stocking has become one measure to improve the stock. This time stocking is done with the main purpose of increasing the production of silver eels leaving the managed unit and contributing to the spawning biomass, i.e. not to support a fishery.

COM has proposed stocking in waters with free access to the sea as one measure among others to enhance local stocks with the ultimate goal aim to increase the biomass of spawners to produce a sufficient number of recruiting glass eels (COM 1100/2007).

Stocking as part of management plans may also occur in new water bodies, or areas where eel are absent, in order to produce additional potential spawners where access to the sea is open.

Another objective might be to restore local stocks in order to improve or preserve biodiversity (Verreault, pers. comm.) and this also might be beneficial if there is an olfactory cue to upstream migration. Alternative strategies to stocking have to be considered and analysed. Improving the possibilities for eels to migrate upstream might be a sufficient measure where dams are obstructing upstream migration, given that the emigration route is secured. Improved environmental conditions in eel growing waters, thus increasing survival and growth, may also be an alternative or addition to stocking.

As there is a general lack of stocking material (glass eels) there is no room for a misuse of this restricted resource. Therefore stocking should only be done as part of a management plan ensuring a significant escape of silver eels. The potential availability of central funding through the European Fisheries Fund (EFF) to support stocking for enhancement purposes, may ensure parity with other competitors for seed stock (e.g. aquaculture, fisheries enhancements).

5.4.2 Ecological considerations

5.4.2.1 What size of eel should be stocked?

There are three main options; stocking of glass eel, young yellow eels and ongrown eel from aquaculture. Apart from that there is the option of moving eels "over the dam" in cases of migration obstructions (assisted migration). The latter option is not dealt with here.

The risks concerned with diseases, parasites, biased sex-ratios and genetic selection may best be avoided by stocking with eels that are as young as possible from a natural state. Stocking with yellow eel caught in the wild poses the additional risk of their being contaminated. If ongrown eels from aquaculture are considered for stocking, there are risks of disease spread, reduced genetic fitness (Section 5.4.2.3) and skewed sex ratios. When purposely infected with herpes virus in aquaculture, as seems to be widely practised, when these eels are stocked the spread of disease is a certainty, not a risk. However, stocking of healthy ongrown eels will result in comparable growth rates and mortalities compared to the stocking of glass eels (ICES, 2007).

Another risk associated with using ongrown eels, is the stocking of *Anguilla rostrata.* Stocking of *A. rostrata* seems to have occurred in the past (German Country Report, 2008; Ubl and Frankowski, 2008), *A. rostrata* is grown in European aquaculture and discrimination between *A. rostrata* and *A. Anguilla,* when grown up, is not possible in practice.

5.4.2.2 Contaminants

One of the potential ecological and environmental risks which stocking programmes should consider is contamination as a potential risk to produce (in stocked systems) reproducers not able to reach spawning grounds at the Sargasso Sea and/or produce enough gametes of high quality.

Consideration should be given to pollution with PCBs, flame retardants, pesticides and heavy metals. Priority should be given to those sites where such contaminants are absent or at permissible levels (information available through the European Eel Quality Database Chapter 6).

Detrimental effects of pollution on fitness and fecundity have been suggested earlier on (Larsson *et al.*, 1990), but recently, there are indications that poor quality of the spawners, namely the silver eels migrating to the oceanic spawning grounds, might be a key factor in the decline, e.g. decrease of body fat content. Palstra *et al.*, 2006 argued that gonadal levels of dioxin-like contaminants, including PCBs, in eels from most European locations impair embryonic development. Pollution might also impact reproductive success through effects on genotype: a significant negative correlation between heavy metal pollution and eel genetic variability was reported by Maes *et al.*, 2005. Insufficient condition and energy resources (Svedäng and Wickström, 1997), high bioaccumulation of persistent organic pollutants (especially polychlorinated biphenyls-PCBs) (Larsson *et al.*, 1990; Robinet and Feunteun, 2002; Palstra *et al.*, 2006) and pathological agents (Palstra *et al.*, 2007) have been reported as potential restrictive factors, disabling long distance migration and successful reproduction with prime quality gametes.

Where spawner quality is poor and lipid content low, silver eels may not contribute to the overall spawning and recruitment of the European stock. Accumulation of energy through lipid storage may be affected by different environmental factors such as disease agents, changes in food availability, other global changes in the environment, changes in (density-dependent) sex ratios even life-history characteristics, i.e. restocking itself and pollution pressure as a consequence of disruption of the endocrine processes.

5.4.2.3 Genetics, diseases and health issues

Genetics

The importance of maintaining genetic diversity can be divided into a short-term impact (in the order of few generations), by avoiding inbreeding and fitness decrease (population survival) and a long-term impact (over decades or even centuries), and by conferring the possibility to adapt to changing conditions (species survival). Genetic data may help to assess species integrity within the North Atlantic, evaluate the genetic stock structure of the European eel, clarify the spatio-temporal stability of the genetic structure, define the influences of oceanic conditions on genetic variability, monitor and guide the stocking policy in Europe, and evaluate the effect of population decline and habitat degradation on genetic variability and the overall fitness of eels (see also **Annex 4** for a more detailed review).

Genetic consequences of stocking practices

Below are listed some important points to consider in regards to genetics when planning stocking measures and provide some advice for sustainable stocking.

1) Deciding on mass stocking practices to supplement populations can lead to the rapid introduction of non-native genetic material from non-indigenous eel species. Monitoring the correct species identity (tracing) is therefore crucial to preserve genetic integrity of the European eel. Examples of this phenomenon have already been observed, mainly in Germany (Trautner *et al.*, 2006), where *A. rostrata* were found, prompting for up to date molecular identification methods for species discrimination (Maes *et al.*, 2006a). The European eel has been listed under CITES, potentially leading to increased importations of other eel species. Such exotic eel introductions have been a major problem in Asia, where European eels were introduced to supplement Japanese eel stocks (Okamura *et al.*, 2002; 2004).

2) Aquaculture grown glass eels (grown from glass eels to 10 cms) are often used for stocking purposes. Although at first sight no significant problem is expected from the genetic diversity point of view (glass eels are natural recruits), potential consequences could be other than expected. Indeed, keeping glass eels too long in such facilities will adapt them to aquaculture conditions (such as artificial food and temperature regimes), and will lower their competitiveness in the natural environment. Currently juvenile eels are deliberately exposed to water contaminated with the highly virulent Herpes virus *anguillarum* (HVA) in order to induce a limited infection which, although causing some mortality, will autovaccinate the fish prior to them meeting the infection at the most vulnerable fast growing stage. This process causes a significant drop in food intake and growth rate but is considered the lesser evil by the industry at present in the absence of an approved commercial vaccine. As such, ongrown eels used for stocking which have been reared under such practices pose an epidemiological

threat given that they can infect natural populations. Additionally, such practices create a high selective pressure on glass eels, reducing total genetic diversity and directionally selecting at the functional level for specific disease resistance genes (such as MHC). This has been revealed to have a very detrimental effect in salmonids when such individuals are released in the wild, as a consequence of a lower fitness for natural pathogens. Timing of stocking should be carefully considered in order to optimize survival. Stocking material should not be composed of the slow growers of aquaculture, which have been revealed to exhibit a lower functional genetic diversity and could demonstrate lower survival rates and skewed sex ratios.

3) At the population level, stocking practices can have major consequences on intraspecific biodiversity, as a consequence of the mixing of genetically differentiated populations. No stable geographical differentiation has been detected to date (Wirth and Bernatchez, 2001; Dannewitz *et al.*, 2005; Maes *et al.*, 2006). However, given long-term stocking practices since the 1950s, it is possible that these might contribute to a homogenization of populations as a consequence of massive translocations. Indeed, the presence of only a small level of geographical genetic differentiation at neutral genetic markers may lead to seriously underestimating of quantitative and adaptive differentiation between populations. From recent studies on marine fish populations we know that adaptive differences might be present but not detectable with the current molecular markers. Indeed, apart from analysing neutral genetic variation to assess the demographic independence and stability of fisheries stocks, knowledge of geographic and temporal scales of adaptive genetic variation is crucial to species conservation (Conover *et al.*, 2006; Maes and Volckaert, 2007). If distinct populations exist, the introduction of genetically different glass eels can potentially break up any existing adaptation in local stocks and have major fitness consequences on life-history traits, such as migration duration and timing, temperature resistance and size at maturation sizes. The homogenization of these traits can lead to a decrease in diversity and the loss of important traits for survival. However, given these concerns and the absence of data the following advice for different levels of natural recruitment is therefore precautionary.

Regions with no recruitment: stock with glass eels in high quality habitats originating in if possible the same main hydrographical region (Northern Europe, West Atlantic, Southern Europe, Mediterranean).

Regions with low recruitment: Preserve natural recruits, while preferably stocking glass eels from estuaries or neighbouring river basins in high quality upstream habitats.

Regions with high recruitment: care should be taken not to overfish glass eels for stocking purposes, as this will weaken the donor region and deplete the rivers from escapees.

If neither neutral nor adaptive differences can be detected in the European eel, stocking practices may have a beneficial effect. However, the question remains, whether stocked individuals will find their way to the Sargasso Sea and ultimately contribute to the spawning stock. The most important issue is then to preserve the total genetic diversity to allow adaptation to a changing environment. Keeping the highest level of biodiversity in phenotypic (quantitative) and genetic traits is crucial to the survival of the entire species.

Pathogens and parasites

The occurrence of diseases and parasites in eels has been recorded for some time. Up to now, consequences on the ability of eels to carry out their long-distance migration and reproduction were unknown, although these have been suggested as potential causes for the decline in eel populations. Available information on the introduction and spread of *A. crassus* in Europe illustrates how through live-transport of eels, within and between countries, and through stocking programmes the parasite has been rapidly dispersed to all major spawner producing areas.

In the proceedings of a recent workshop held in Montreal (Canada) in 2007, the risk of disease transfer when stocking eel was specifically addressed (Williams and Threader, 2007) because eel transfers increase the risk of pathogen introduction. In her review, Symonds, 2007 described several parasites, viruses, bacteria and fungi that have been found in eel communities in North America. In Europe, many studies on eel parasites and diseases indicate that stocking and transfers have been responsible for rapid spreading of their fellow travellers (Szekely, 1994; Van Ginneken *et al.*, 2004; EELREP 2005). The rapid spread of *A. crassus* throughout Europe indicates that eel transfer or stocking done without screening is a practice that can be detrimental for the population and aquatic community.

In Canada eel stocking and transfers must be done under "The National Code on Introductions and Transfers of Aquatic Organisms" to avoid risks to aquatic animal health from the potential introduction and spread of pathogens and parasites that might accompany eels being moved. Screenings are routinely done for elvers before their stocking in fresh-waters locations. Screenings for viruses (IHNV, ISAV, IPNV and EVH) and *A. crassus* in individuals prior to stocking were negative since the initiation of the stocking programmes, four years ago.

In spite of warnings concerning viruses and diseases issued from WGEEL in 2006, there is still no common protocol for parasite and disease screening prior to stocking. Each country applies its own regulation and screening procedure for stocking. For example, Sweden practises quarantine for imported glass eel prior their stocking in brackish and fresh-water areas whereas no specific procedures are in place for other countries. Table 5.1 shows what is done for each European country prior to glass eel and/or elver stocking to prevent the introduction of parasites, viruses and pathogens.

It appears that few countries have put in place procedures to prevent the introduction and spreading of parasites and diseases when stocking young eels. This could be very detrimental for the future of eel populations since stocking will presumably be part of many national Management Plans. A robust protocol for screening stocked stocks should be put in place as soon as possible.

Table 5.1: Current procedures for stocking glass eel/young eel to European countries.

COUNTRY	STOCKING	SCREENING FOR PARASITES, VIRUSES AND PATHOGENS	QUARANTINE
Belgium	Yes	No	N0
Denmark	Yes	Yes	Yes
Estonia	Yes	Yes	No
Finland	Yes	Yes/No	Yes
Poland	Yes	No	
France	Yes	No	No
Germany	Yes	Yes/No	No

COUNTRY	STOCKING	SCREENING FOR PARASITES, VIRUSES AND PATHOGENS	QUARANTINE
Ireland	Yes1	No	No
Italy	No	-	-
Latvia	Yes	No	No
Lithuania	Yes	No	No
Netherlands	Yes	No	No
Norway	No	-	-
Portugal	No	-	-
Spain	Yes	Yes	-
Sweden	Yes	Yes	Yes
UK	Yes	Yes*/No	No

[1]Stocking restricted within the same water catchment.

*** For England and Wales only.**

5.4.3 Fisheries considerations and considerations for other users

Generation times of eels decrease with temperature and increase with latitude and may be 2–3 times lower in the most Southern parts of the distribution range as compared to the Northern parts of Scandinavia. Growth of eels varies between 14–62 mm.year^{-1} within its distribution range (ICES, 2006) and this means that for male silver eels of 37 cm it will take then 5–21 years to reach that size. For female eels of 67 cm it will take twice as long, while for longer females it will take even longer. If the glass eels were stocked in 2009, the effects on silver eel escapement could be expected from 2014 (at the earliest) to approximately 2050, depending partly on stocking location and partly on sexual differentiation and eel growth. Therefore this is a measure that might be valuable over a longer time-scale. If the stocked eels are not hampered by anthropogenic factors, they could contribute significantly to silver eel escapement after 10 years or more. Eels stocked in suitable habitats may well grow faster than if left *in situ* and, therefore, mature earlier (Aprahamian, 1988).

5.4.3.1 Effects on recipient eel populations

The surface area of available habitats in Europe is estimated at 5–10*10^{6} ha (ICES, 2005). A possible stocking of 60 tonne (at most) when well spread over the available habitat, will have no significant negative effect on the growth of the existing eel populations. However, if high stocking rates are applied locally, this will be different because of density-dependent growth rates (reviewed by ICES, 2007).

Effects on existing populations may occur when stocked eels are diseased. Change in sex ratios (as demonstrated on Lough Neagh under differing recruitment and stocking patterns (Rosell *et al.*, 2005)), in favour of males, potentially affecting the yearly production of the non-stocked eels. Effects on the whole stock may occur if the genetic fitness of the stocked eels is further reduced. The latter might occur when stocking eels from aquaculture without additional care for reducing possible genetic effects.

5.4.3.2 Effects on the remainder of the exploited fishery

The effects on the fishery depend largely on the total quantity of eels to be stocked. If the aforementioned 35–60 tons would be stocked, it has a yield potential in the same order of magnitude as the eel aquaculture production in Europe or the current eel landings in Europe. This potential would be fully realized after one generation time. If not fished at all, this would increase the production of silver eels (ICES, 2006). The quantity of 35–60 tons of glass eels is more or less equal to, or more than the historical maximum of stocking rates (40 tons).

5.4.3.3 Effects in mixed-stock fisheries

There are no additional effects expected in mixed-stock fisheries.

5.4.4 Implementation constraints

5.4.4.1 Introduction

Cowx, 1999 recognized a number of potential constraints associated with any stocking programme, and posed these as a series of checks for managers, regarding the availability of:

- sufficient quantity and quality of fish;
- suitable methods of the transportation and expertise;
- sufficient funds; and,
- have the access rights been defined.

The issues of funding for stocking programmes, and access to donor and recipient waters are political rather than scientific issues, and so we will not consider them here. The first two bullet points have been considered previously by ICES (2006, 2007) and others (Williams and Aprahamian, unpublished; Symonds, 2007; Montreal, 2008). Here, we summarize the outcomes and update supporting materials where they have become available since the 2007 report was compiled.

5.4.4.2 Are sufficient quantities of eel available for stocking, at the local level?

At the local or catchment level, there may be a surplus stock of glass eel, arising as a result of density-dependent mortality being higher in the absence of fishing (ICES, 2006). The prime assumption for a local surplus of eel is that removing the eel has no impact on the donor population (on silver eel output). That is, reductions in density-dependent mortality (or other limiting effects such as growth rates and gender determination) result in enhanced production of silver eel in the stocked population exceeding the putative loss (from fishing elvers) in production from the donor population.

Lobón-Cerviá and Iglesias, 2008 studied long-term variations in the density of eels in the Rio Esva (northwestern Spain) at an estuary site and at nine sites distributed among three tributaries (1986–2006). Mortality rates calculated for age cohorts revealed a consistent positive trend, with 53.3% of the variation in cohort mortality rate explained by variation in glass eel abundance. Note, however, that this population is characterized by fast growing and early maturing eels, almost all of which become male.

Although the Regulation (1100/2007) does not specifically require that eel for stocking are sourced only from catchments where such a surplus exists, it is prudent to focus collection on such catchments. However, previous ICES reports and other reviews have provided little guidance on how managers could assess whether a surplus exists, and thereafter, quantification of this surplus.

The direct means for this assessment is to quantify the size of the donor population, typically glass eel, and compare this with estimates of the amount of settled elver required to produce the target silver eel output. The EU InterReg programme, Indicang, considered methods for the absolute quantification of glass eel in estuaries, recommending flux quantification (filtration) or mark recapture exercises, but noting that these methods are difficult in large and stratified estuaries (Feunteun, pers. comm.). Alternatively, an indirect assessment can be made based on studying the associated yellow eel population under conditions of varying glass eel exploitation to establish lack of impact of said fishery. For example, a glass eel fishery in the Severn estuary, England, does not yet seem to have had any measurable negative impact on upstream stocks of eel (See UK country report 2006).

ICES, 2006 discussed the concept of the carrying capacity of eel in relation to deciding whether to stock eel in a water body, but it should be considered also in deciding whether a potential donor water body can sustain the loss of eels to be stocked elsewhere.

There are two considerations; immediate effects of loss to the estuary, and subsequent effects to the yellow eel population and silver eel output from the river basin.

A method of calculating carrying capacity of a river or lake for eel has not been identified; in part as a consequence of the difficulty in assessing density and/or biomass of eel accurately in a given body of water (Williams and Aprahamian, 2004). Whether a site is at carrying capacity is linked to ease of access for colonization and the productivity of the water.

In tributaries of the lower Severn, Aprahamian, 2000 found eel density ranged from 0.12-1.14 m^{-2} and biomass from 2.56–25.24 gm^{-2}. The absence of any relationship between growth and either density or biomass, suggests that the sites were limited by their productivity and may indicate that they were close to or at their carrying capacity, defined as the maximum density or biomass that the habitat can sustain under average conditions.

In the southern part of their range the carrying capacity is likely to be higher as a consequence of higher temperatures and productivity resulting in a shorter generation time, even if extremely variable among sites. No recent evaluations are available, but given the potential for spawner production of those environments, the enhancement of evaluation studies on this aspect is recommended. Greater importance should be given to biomass when trying to assess whether a site is or is not at carrying capacity. This is because there is a smaller variation in biomass when compared to density both within and among river systems (Aprahamian, 1986) and it is more related to carrying capacity (Knights *et al.*, 2001).

The analysis of eel fishery ‘outputs’ from L. Neagh in relation to glass eel stocked (ICES 2007) suggests a density-dependent relationship with a negative exponential between input stock and eventual output. That is, outputs are maximal for inputs in the range of 150 to 200 glass eel per hectare.

Similarly, Knösche *et al.*, 2004 give a formula, how to estimate the recapture rate in the fishery after stocking for a range of common stocking densities for German waters (50–00 glass eel equivalents per hectare).

Recapture rate (%) = 611 * stocking density $^{-0.81}$

Thus, at a stocking density of 50 glass eels/ha, this would result in a recapture rate of 26%, whereas at 500 glass eels/ha it would decrease to 4%.

However, the general lack of information on carrying capacity in eel populations noted by ICES 2006 continues to this day.

A method of calculating carrying capacity of a river or lake for eel has not been identified, in part as a consequence of the difficulty in assessing density and/or biomass of eel accurately in a given body of water (Williams and Aprahamian, 2004). Whether a site is at carrying capacity is linked to ease of access for colonization and the productivity of the water and recruitment. However, the general lack of information on carrying capacity in eel populations noted by ICES 2006 continues to this day. The most likely sources of eel for stocking (and seeding ongrowing facilities) are glass eel fisheries in estuaries, and traps where upstream migrating eel are concentrated, such as eel passes on weirs and dams. In considering the effects of removing glass eel from estuaries and lower reaches of rivers, the carrying capacity of the estuary may be important. There is, however, no information currently on this, and it is an area that should be addressed. A study group to address this area has been proposed to the Diadromous Fish Committee 2008.

5.4.4.3 Potential indirect impacts on donor stock

ICES, 2006 noted that under the current situation of critically low stock levels, removal of glass eel from any site to stock another should only be done with a full assessment of the effect on recruitment into the growing areas dependent on that donor site. In addition to the direct effects on the size of the local population, there are two other potential risks with removing glass eel from the donor site, a reduction of dispersal of juvenile eel to upstream habitats, and possible alterations to sex ratio of silver eel.

Upstream migration may be driven by intraspecific competition and higher densities downstream. For example, the construction of an estuarine dam on the Vilaine prevented recruitment of eels for 25 years, but the installation of an eel pass resulted in a density-dependent migration behaviour; 1+ groups being forced into the periphery of the high-density area (about 0.8 eels m^{-2}), which extended further upstream in successive years (Feunteun, 2002). Note, however that this “wave” type migration, is in contrast to that reported by Ibbotson *et al.*, 2002 for eels colonizing the River Severn where upstream migration was mainly through diffusion. Removal of stock from downstream areas may reduce the propensity for colonization of upstream areas.

Although the physiological mechanisms for gender differentiation in eel (reviewed by Davey and Jellyman, 2005) are still unclear, evidence supports the concept that it is density driven. There is a risk that removing glass eel from estuaries will affect subsequent gender differentiation and sex ratio of yellow eel (and hence silver eel). Transporting undifferentiated eels from high to relatively low density habitats may well influence ultimate sex ratio of the silver eel output, and by association, the weight of output and distribution across time.

5.4.4.4 Issues of ownership

In considering where to stock, managers must evaluate the subsequent potential exploitation and other mortalities of the eel, e.g. fisheries, turbines, etc. There may be a number of users who potentially benefit from the stocking, and therefore, they should all contribute to funding of the stocking.

5.5 Artificial reproduction of eel

5.5.1 Introduction

Summary of the main findings relevant to WGEEL from the *European Aquaculture Society Thematic Group Workshop on European Eel Reproduction* (October 24th, 2007, Istanbul).

Given the complex nature of the eel life cycle and that maturation occurs during the oceanic phase there is very little information on natural maturation and reproduction.

Consequently much of this work is derived from laboratory studies which examine the environmental effects, endocrine control and artificial reproductive techniques on the production of larval European eel. Details of abstracts on this work can be found at http://www.easonline.org.

The onset of sexual differentiation in eels:

Studies from Israel into the hormonal development in young farmed eels <25 cms found a difference in the hormones released from the pituitary gland depending upon the density of eels held in tanks. Those with fewer eels in them, developed into female eels associated with the hormone release of the female hormone estradiol, while those in higher densities became male associated with the release of the male hormone 12 Keto-testosterone.

5.5.2 Silver eels

Several studies presented evidence that silver eels leaving continental Europe should be considered as being in a pre-pubertal state given that swimming appears to be a strong natural trigger for the development of advanced maturation. During the swimming phase lipid stores in the eel are utilized for the production of energy to fuel their migration and to produce gametes through a variety of hormonally induced metabolic pathways. Research into the thermodynamic influence of hydrostatic pressure on swimming ability found that the metabolism of the eel's fat stores was much more efficient at depth thus optimizing their energy expenditure during migration. Once they have arrived at the spawning grounds several studies into the olfactory capabilities of silver eels and their reactions to specific eel odours suggested that olfaction maybe crucial to synchronizing final maturation in both sexes.

5.5.3 Embryo and larval development

The natural development of embryos appears to be influenced by hydrostatic effects (that had not been used previously during artificial attempts at fertilization) which induce a slower egg cleavage rate and thus embryo development period. It's likely that this may be caused by the pressure influence on thermodynamics and or mechanical stress on egg membranes and water transfer through them at these depths.

Despite many previous attempts to artificially breed European eel the hatching of larvae has only been achieved on a few occasions with a maximal larval life of 3.5 days. The main obstruction has been the intricate hormonal control mechanisms that inhibit gonadal maturation at the onset of puberty. Repeated hormonal treatments to produce gametes have been successfully applied to produce viable eggs and larvae of the Japanese eel. Similar methods have been applied to the European eel, but deficiencies in genitor quality causing fertilization failure had hampered the ability to produce larvae in the past. Investigations into the failure found that an essential fatty acid was missing from the feed given to the broodstock which when included produced fertile eggs. Mass hatchings from these eggs have been achieved and the larvae were fully developed and ready to feed 12 days post-hatching. However further development of the larvae past this stage failed as a suitable feed has yet to be found/developed.

5.5.4 Artificial reproduction techniques

The hormonal induction of maturation is a fundamental requirement for artificial reproduction but this presents difficulties in terms of synchronizing the development of males and females. To aid this cryopreservation techniques have now been developed for eel sperm which yielded viable eel sperm several months after deep freeze storage. Prior to storage the hormonal induction of the males yielded sperm after four weeks the quality and quantity of which increased up to eight weeks after induction. Developments in the maturation of females have found that low initial temperatures increase the sensitivity of the female and that temperatures <17°C during gonadal maturation produced better results.

5.5.5 The Japanese Experience

Japanese glass eel were successfully produced in captivity in 2005 (Kagawa *et al.*, 2005), and since then this work has progressed to produce hybrid larvae of European (male) and Japanese eel (female). The success of this work has relied heavily upon the production of a suitable feed for the larval stage, details of which are currently contained in a Japanese Government registered patent.

5.6 Conclusions for Chapter 5: Stocking and aquaculture

5.6.1 Potential benefit of stocking to regenerate the stock

At present, it is estimated that around 7.5 to 15% of the glass eel catch is used for stocking, either directly or as on-grown eels. Estimates suggest an insufficient supply of glass eel from the total fishery for stocking to full capacity at the European level. Nevertheless, the Regulation 1100/2007 requires that 35%, rising to 60%, of glass eel catches are made available for stocking to enhance the stock. If these percentages were applied to recent annual catches of glass eel, the potential lifetime effect of this increased level of stocking, in the absence of anthropogenic mortalities, could be in the same order of magnitude as current fisheries or eel culture. However, there is a continuing and urgent requirement for robust evidence of the extent to which stocking and transfers on local, national and international scales can increase silver eel escapement and spawner biomass.

The general lack of information on carrying capacity in eel populations noted by ICES 2006 is still an issue hampering management of eel.

5.6.2 Identifying local surplus

It is anticipated that assessments conducted for EMPs will decide whether or not there is a local supply of eel sufficient to meet demands for stocking (either within catchment, RBD, nation or elsewhere in Europe). However, there is a limited understanding on methods by which to make assessments of a local surplus on a quantitative, biological basis.

5.6.3 Post-evaluation of the net benefit of stocking

The assessment post-evaluation of the contribution of stocking to silver eel production is still hindered by the limited quantitative information available on survival/mortality rates (stage specific and glass eel to silver eel), both for stocked eel and wild/natural eel for comparative purposes, for habitats representing the variety available across Europe, and especially for stocking in rivers.

5.6.4 Risks of stocking

It appears that few countries operate procedures to prevent the introduction and spreading of parasites and diseases when stocking young eels and this could be detrimental for the future of eel populations since stocking will presumably be part of many national Management Plans. The risks remain of disease and parasite transfer via stocked material, potentially both from the 'wild' and on-grown in aquaculture. For example, the practice of aquaculture in terms of viral inoculations needs to be addressed. A robust protocol for screening stocked stocks should be put in place as soon as possible.

New techniques are currently used for genetic analyses of the eel stock and results are expected in a few years. These results may prompt a re-assessment of the potential risks associated with stocking.

There is a clear need for assurance that donor populations are not impaired by the removal of glass eel. Notwithstanding the potential risks to the donor population, it is anticipated that assessments conducted for EMPs will determine whether or not there is a local supply of eel sufficient to meet demands for stocking (either within catchment, RBD, nation or elsewhere in Europe).

5.6.5 Aquaculture/on-growing to support stocking for enhancement

Spawner quality in terms of levels and composition of lipids and contaminants appears to be a key issue for the success of both natural and artificial reproduction. Given the future requirements for stocking glass eel or deciding to stock on-grown eel, the implications of the findings on hormonal release and subsequent gender development depending upon stocking densities must be considered.

Spawner quality in terms of lipid levels and contaminants appears to be a key issue for the success of both natural and artificial reproduction.

5.7 Recommendations

5.7.1 Methods to support the basis of stocking for enhancement purposes

The WG recommends that developing methods to make assessments of local surplus of stocking material on a quantitative, biological basis is a priority for research in the near future. Data to post-evaluate the relative contribution of stocking to silver eel production can only be supplied by experimental studies, and although acknowledging that some studies are ongoing, we recommend concerted action to address this area, especially with regard to stocking in rivers, and the relative performance and yield-per-recruit of stocked cultured eels compared with glass eels.

A study group to address eels in saline habitats has been proposed to the Diadromous Fish Committee.

5.7.2 Risks associated with stocking

The eel should be included in the European fish disease prevention policy in order to minimize the risks of transfer of diseases associated with stocking.

A robust protocol for screening stocked stocks should be put in place as soon as possible.

Purposely infected eels in aquaculture with pathogens (viruses, etc.) should not be used for stocking purposes.

The culture of *A. rostrata* in European aquaculture will make it impossible to discriminate between stockings of *A. anguilla* and *A. rostrata* and should be avoided; the same applies to possible growing of other eel species in the future. The improved systems to trace glass eel trade, for CITES and the Regulation (EU 1100/2007), should facilitate this, and the WG strongly support these developments also to address the risks highlighted here. Besides the Eel Regulation and CITES, the following EU Council Regulation (EC) N° 708/2007 concerning the use of alien and locally absent species in aquaculture is also likely to allow better control of farmed alien species like *A. rostrata.*

Despite limited evidence and a complicated variety of possible impacts of environmental factors, such as contaminants, on silver eel quality, conservative advice remains that stocking for stock enhancement purposes should not be conducted in waters heavily polluted with substances that might pose risks for spawner quality.

6 Eel quality

6.1 Introduction

In recent years (e.g. ICES, 2006) the Working Group has described the risks of deteriorated biological quality of eels. In 2005 the EU-EELREP programme (Estimation of the reproduction capacity of European eel) concluded that contamination with PCBs impaired fertility while infections with pathogens and parasites were devastating for swimming eels.

The recommendations of the WG EEL 2006 highlighted the need to monitor and to collect information on (1) **pollution and disease** to be able to designate areas producing high quality spawners (e.g. with **low contaminant and parasite burdens** in order to maximize protection for these areas; and (2) the **chemical status** of eel under the implementation of the WFD.

An increasing level of evidence on the detrimental impact of contamination and diseases on the eel has been made available.

ICES 2007 reported on the advances made in the collection of data on contaminants, parasites and fat levels in eel, and reported that many Member States started the monitoring of eel quality. In 2007, the WGEEL initiated the set-up and development of a European Eel Quality Database (EEQD), allowing the compilation of a comprehensive overview on the contaminant load in eel over its distribution area. Results from the EEQD demonstrated that considerable variation in contaminant load exists within river basin districts, according to local anthropogenic pollution, linked with land use. There is evidence that, on a pan-European scale, large differences in eel quality occurs between catchments. Furthermore, 'black spots' with low quality eels were detected. Lipid content, which is believed to be an important index of fitness, was highly variable between sites. New evidence (Geeraerts, *et al.*, 2007) was presented on the negative impact of certain contaminants on the fitness of eel.

The recommendations of the Working Group 2007 (ICES 2007) proposed that:

1) MS should further develop and maintain the European Eel Quality Database.

2) MS should initiate harmonized monitoring strategies to develop a European Eel Quality Monitoring Network, to collect the relevant data to be fed into the EEQD. National eel management plans, should take account of these data for evaluation of the quality of spawners.

3) Under the implementation of the WFD eel specific extensions should be included, using the eel as an indicator of river connectivity and ecological and chemical status, and making cost-effective use of collected data, also for the benefit of the EU Eel Regulation and recovery of the eel stock.

During the WGEEL 2008 session, new scientific evidence of eel quality as an important factor in the decline of the species has been presented and discussed. The WGEEL 2008 also updated the EEQD. In the light of the introduction of the EU Regulation in 2007, the WGEEL proposed recommendations and discussed urgent research needs/demonstrated gaps in eel quality knowledge.

6.2 Contaminants

6.2.1 Introduction

Due to specific ecological and physiological traits, eels are particularly sensitive to bioaccumulation of lipophilic contaminants. From recent scientific evidence (Belpaire, 2008) there is reason for serious concern as the level of measured concentrations of some contaminants has been demonstrated to have adverse effects on the reproduction success of the silver eel.

Current gonadal levels of dioxin-like contaminants, including PCBs, in eels from most European locations impair normal embryonic development and that PCBs and other contaminants may have contributed to the decline of eel recruitment observed since 1980 (van den Thillart *et al.*, 2005; Palstra *et al.*, 2006), a conclusion consistent with the fact that the emission of PCBs in the environment (van Leeuwen and Hermens, 1995) preceded the decline of European eel.

An extensive dataset of contaminants has been analysed by statistical modelling, to demonstrate relationships between fitness (lipid content and eel condition) and various environmental variables and PCBs (especially the higher chlorinated ones) and DDTs were revealed to have a negative impact on the lipid content of the eel. (Geeraerts *et al.*, 2007).

Extensive information has already been provided in the WGEEL 2006, and 2007 reports (ICES 2006; 2007). Recently, Belpaire, 2008 compiled an overview of research on contaminants in Flanders (Belgium). The status and trends of eel quality factors and the potential role of contamination in the collapse of the stock are presented and discussed here.

6.2.2 The eel and the Water Framework Directive

The EU Water Framework Directive requires monitoring of a selection of priority substances in the aquatic phase, including lipophilic substances. However, there are strong arguments for measuring the latter in biota (Belpaire and Goemans, 2007a, b). Yellow eel is a good candidate because it is widespread, sedentary and accumulates many lipophilic substances in its muscle tissue. Several authors have described the indicative value of measured concentrations, yet few studies have investigated the extent to which the spectrum of contaminants present characterizes the local environmental pollution pressure. To evaluate the value of the pollution profile of an eel as a fingerprint of the chemical status of the local environment, two datasets were selected from the Flemish Eel Pollutant Network database. One set from a small catchment area to investigate site-specific profiles, and one from seven large Flemish rivers to investigate river-specific profiles. The pollution profiles of persistent organic pollutants in individual eels along a river (even at distances <5 km) proved to be significantly different (Figure 6.1). Analysis of pooled contaminant data from multiple sites and sampling years within rivers allows characterization of river-specific chemical pressures. The results highlight the usefulness of eel as a bio-indicator for monitoring pollution with lipophilic chemicals like polychlorinated biphenyls and organochlorine pesticides in rivers (Belpaire *et al.*, 2008). It was concluded that, as such, eel may be used effectively within the monitoring programme for a selection of priority substances referred to in the Water Framework Directive (Table 6.1). Some countries reported planning reporting eel quality data within the WFD chemical status report.

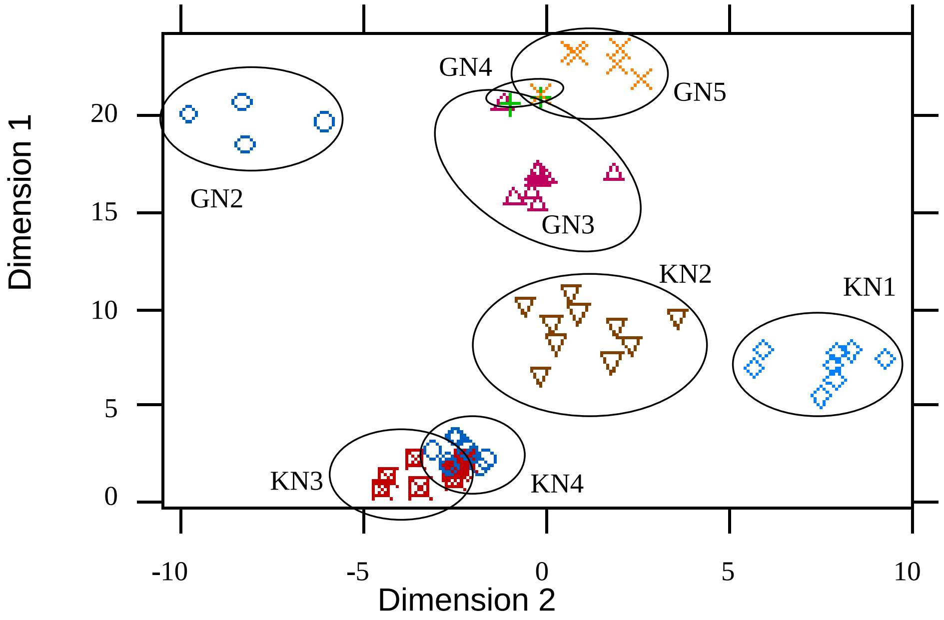


Figure 6.1: Canonical discriminant analysis of eels collected at eight sites in the Grote Nete and Kleine Nete on the basis of their PCB and OCP concentrations (N= 61). Distance between locations varied between 4 and 20 km.

Table 6.1: WFD substances mentioned under CEC (2007), and available data from measurements of Flemish eels. All data are expressed in ng g^{-1} wet weight. DL, detection limit (from Belpaire and Goemans, 2007).

SUBSTANCE	NOTE	RANGE MIN – MAX (MEAN)	%<DL	NO. OF SITES	YEARS	SOURCE
Benzene	a	1.2–18.9 (5.7)	0	20	1996–1998	j
Brominated diphenylethers	a	6.9–5 284.4 (369.1)c	0	18	2001	l
Cadmium and its compounds	a	D.L.-151.4 (11.7)d	19	357	1994–2005	k
1,2-Dichloroethane	a	D.L.-4.9 (1,2)	55	20	1996–1998	j
Hexachlorobenzene	a	D.L.-61.6 (5.7)	<1	357	1994–2005	k
Hexachlorobutadiene	a	D.L.-12.2 (1.8)	50	20	1996–1998	j
Alfa-Hexachlorocyclohexane	a	D.L.-13.7 (0.8)e	13	357	1994–2005	k
(gamma-isomer, Lindane)	a	0.1–2 076.4 (46.9)	0	357	1994–2005	k
Lead and its compounds	a	D.L.-1 744.2 (56.6)f	3	357	1994–2005	k
Mercury and its compounds	a	10–535.4 (113.5)g	0	355	1994–2005	k
Naphthalene	a	1.5–63 (5.8)	20	20	1996–1998	j
Nickel and its compounds	a	D.L.-2 944.7 (186.2)h	16	297	1994–2005	k
(1,2,4-Trichlorobenzene)	a	D.L.-30.9 (6.0)	15	20	1996–1998	j
Trichloromethane (chloroform)	a	D.L.-96.0 (13.4)	25	20	1996–1998	j
DDT total	b	6.6–1 102.7 (90.2)i	0	357	1994–2005	k
p,p′-DDT	b	D.L.-62.6 (2.9)	38	357	1994–2005	k
Aldrin	b	D.L.-11.4 (1.3)	33	96	1994–2005	k

SUBSTANCE	NOTE	RANGE MIN – MAX (MEAN)	%<DL	NO. OF SITES	YEARS	SOURCE
Dieldrin	b	D.L.-237.6 (19.1)	15	357	1994–2005	k
Endrin	b	D.L.-29.1 (1.1)	80	346	1994–2005	k
Tetrachloroethylene	b	D.L.-88.9 (13.4)	50	20	1996–1998	j
Trichloroethylene	b	D.L.-30.3 (2.0)	95	20	1996–1998	j

[a] **Priority substances.**

[b] **Other pollutants, which fall under the scope of Directive 86/280/EEC and which are included in List I of the Annex to Directive 76/464/EEC, are not in the priority substances list. Environmental quality standards for these substances are included in the Commission's proposal to maintain the regulation of the substances at Community level.**

[c] **The data present the Sum of 10 BDEs.**

[d] **Cd.**

[e] **alpha-hexachlorocyclohexane.**

[f] **Pb.**

[g] **Hg.**

[h] **Ni.**

[i] **Sum of p,p′-DDD, p,p′-DDT, and p,p′-DDE.**

[j] **Data from Roose *et al.* (2003).**

[k] **INBO Eel Pollutant Monitoring Database.**

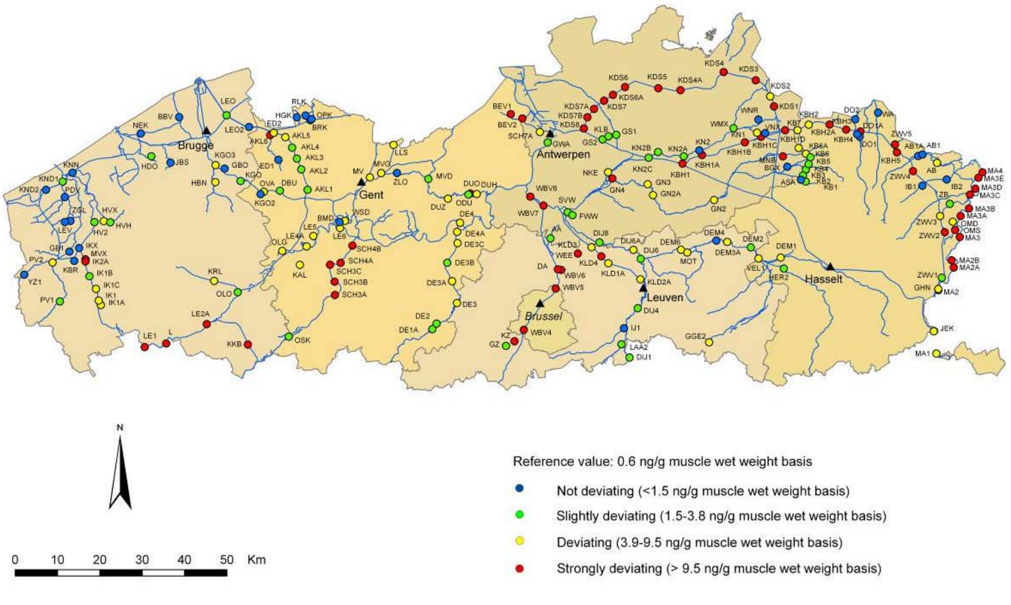
[l] **Data from de Boer *et al.* (2002) and Belpaire *et al.*, 2003.**

6.2.3 Eel pollution monitoring networks-status and trends

Most of the countries submitted data on contaminants to the EEQD (see Annex 5 for Country reviews). In many sampling sites, concentration of contaminants fell and this probably reflects decreasing contaminant exposure. However, the monitoring does not evaluate the presence of new contaminants not to mention the increasing number of non-native species. Nevertheless there are widespread industrialized regions where contaminant loads still exceed reference levels.

Some countries are operating Eel Pollution Monitoring Networks on a national scale. The networks allow the follow-up of contamination in eels and allow detailed analyses of the status and trends for a specific contaminant, or a group of contaminants. They also allow detailed analysis of status and trends of contamination on a certain spatial scale (site, river, catchment, town, province, region). In some countries (e.g. Belgium) these trends can be viewed in reports via predefined queries on a national database available on the Internet, and maps are available for contamination in eel for PCBs, pesticides and heavy metals (e.g. Goemans *et al.*, 2008). As an example the distribution of PCB 156 in eel from Flanders (Belgium) is represented in Figure 6.2. This allows the indication of good and bad quality eel areas.

Eels from different river basins differ in contamination. Belpaire *et al.*, 2008 presented PCB and OCP contamination profiles for some basins in Belgium. Eels from the river Yser are characterized by high OCPs, especially dieldrin and lindane (γ-HCH), and low PCB levels. In the River Maas, PCB concentrations are high, and are dominated by the higher chlorinated (and higher toxic) PCBs.



Goemans *et al.*, 2008: The Eel Pollutant Monitoring Network: results for 2002-2005. Carthography.

Figure 6.2: Distribution of PCB 156 in yellow eel in Flanders (2002–2005); means on muscle wet weight basis, classified following the deviation from the reference value (Goemans *et al.*, 2008).

High concentrations of some substances in eel tissue confirmed the previously known high pollution load of some specific areas, but in many cases however, eel analyses revealed unknown environmental problems. In a few cases analysis of eels from a specific location has demonstrated unsuspected high pollution levels of several contaminants. But several contaminants (e.g. BTEX (benzene, toluene, ethylbenzene and the xylenes) compounds, PCBs and some very persistent OCPs like DDTs) are widespread in certain countries. (Roose *et al.*, 2003)

Results of measurements of dioxins on eight locations in Belgium (Flanders) indicate some reason for concern. Dioxin concentrations in eel vary considerably between sampling sites, suggesting that eel may be good indicators of local pollution levels. The European Commission has set maximum levels of 4 pg TEQ g^{-1} fresh weight for the sum of dioxins (WHO-PCDD/F TEQ) and 12 pg TEQ g^{-1} fresh weight for the total-TEQ i.e. the sum of dioxins and dioxin-like PCBs (WHO-PCDD/F-PCB TEQ) in muscle meat of eel and products thereof (Directive 2002/69/EC). Half of the sampling sites in Belgium demonstrate DL-PCB levels exceeding the European consumption level (with a factor three on average). The levels of PCDD/FS and DL-PCBS measured in some sites gave rise to serious concern about the reproduction potential of the eels from these sites. Human consumption of eels, especially in these highly contaminated sites, seems unwise (Geeraerts *et al.*, in press).

Trend analysis in a Belgian study (Maes *et al.*, 2008) over the period 1994–2005 indicated that there were significant decreases in the average wet weight concentration of all PCB congeners, nearly all pesticides and four metals. The observed decline of PCBs in eel tissue was in agreement with other studies reporting on time-series of contaminants in fish. PCBs were banned from the EU in 1985 and since then, several time-series have indicated decreasing levels of contamination. Also concentrations of most pesticides decreased significantly over time. This was especially evident for α-HCH and lindane, demonstrating that the ban of lindane in 2002 has positive effects on the accumulation in biota. Similar reductions were modelled for HCB, dieldrin and endrin; however these compounds were banned many years ago. Unexpectedly, concentrations of *p,p′*-DDT increased while at the same time, *p,p′*-DDD and *p,p′*-DDE demonstrated significant decreases.

The ratio of DDE over DDT was >1 in all eels analysed, normally suggesting that DDT had not been recently reapplied. At some locations in Flanders, however, the ratio of DDE over DDT rapidly decreased by an order of magnitude of three over a few years. Such a steep decrease, even if the ratio was higher than one, probably indicates recent application of DDT and demonstrates that not all stock was depleted. This urged regional policy-makers to make a serious attempt in order to collect the remaining stock of banned pesticides.

Some heavy metal concentrations decreased in the eel, in particular lead, arsenic, nickel and chromium were notably reduced. The concentration of lead in eel muscle tissue was consistently decreasing between 1994 and 2005, which possibly is related to the gradual changeover from leaded to unleaded fuels and a reduction of industrial emissions. For arsenic, nickel and chromium, the trend may be biased as data were available only since 2000. Cadmium and mercury, however, did not demonstrate decreasing trends and remain common environmental pollutants in the industrialized region of Flanders.

Following the very high levels of BFRs encountered in eels from Oudenaarde, new measurements were carried out in 2006 (Roosens *et al.*, 2008). A descending trend in the contamination with BFRs was observed from 2000 to 2006 on this site. For PBDEs, levels have decreased by a factor 35 (26 500 to 780 ng g^{-1} LW), whereas for hexabromocyclododecane (HBCD), the decrease was less conspicuous, (35 000 to 10 000 ng g^{-1} LW). Based on these results we can conclude that in 2006, fish seem to be less exposed to PBDEs than 6 years earlier. This is probably as a consequence of the restriction regarding the use of the penta-BDE technical mixture (since 2004), a better environmental management and a raising awareness concerning PBDEs. However, since there are no restrictions regarding its usage, HBCD can still be detected in large quantities, especially in aquatic environmental samples taken next to industrialized areas, where it is used in specific applications. The textile industry is likely the cause of elevated BFR levels in fish on this part of the river Scheldt, but further studies should be set up to determine the exact origin and how far this contaminated area extends over the whole river.

It was concluded that Eel Pollution Monitoring Networks, such as the ones operated in Belgium and The Netherlands, allow getting a comprehensive overview of contaminants indicating environmental pressure, and they are able to document the temporal evolution of some of these pressures. These national monitoring networks should be upscaled at the European level. The intensity of pollution, at least at some sites, may well indicate potential negative effect on the health of these contaminated eels. These data underline the large variation in quality status of the eel over its distribution range. It is believed that this variation in quality is indicative with a variation in reproduction potential (Belpaire *et al.*, in press).

6.2.4 Contamination in eel and its role in the decline of the stock

We summarize the main findings of work in this field (see also Belpaire, 2008) in the following section and draw some conclusions related to the potential role of contamination in the collapse of the stock.

As a consequence of the increased international concern about the decline of the stocks, also research actions have paid increasing attention to analyse contaminants in the eel and to investigate the effects of these substances in the eel. As a result a large and growing quantity of information became available, and as suggested ICES 2007 a review on the effects of contaminants is underway. Many studies have examined the impact of a wide variety of xenobiotics on various aspects of fish biochemistry, physiology and population structure. In some cases of acute pollution, direct effects are clearly visible as fish may be moribund or dying. But contaminant exposure can lead to a decrease in growth or a lowered or deficient immunological system, causing an increased sensitivity to infectious diseases and parasites. But in most cases, these effects have been induced by effects on molecular and subcellular level. The last 20 years, an increasing number of reports deal with studying causality between pressure of xenobiotics and response at the subcellular level. In the eel, the impacts of contaminants on metabolic functions and on behaviour of the eel are widely divergent and act through various mechanisms. Figure 6.3 shows a simplified conceptual model of the effects of pollution exposure on the population structure of the European eel (after Geeraerts *et al.*, in prep, adapted from Lawrence and Elliott, 2003).

A significant negative correlation between heavy metal pollution load and condition was observed, suggesting an impact of pollution on the health of subadult eels (Maes *et al.*, 2005. In general, a reduced genetic variability was observed in strongly polluted eels, as well as a negative correlation between levels of bioaccumulation and allozymatic multi-locus heterozygosity (Maes *et al.*, 2005).

Van Campenhout *et al.*, 2008 studied the effect of metal exposure on the accumulation and cytosolic speciation of metals in livers of European eel by measuring metallothioneins (MT) induction. This research was carried out in four sampling sites in Flanders revealing different degrees of heavy metal contamination (Cd, Cu, Ni, Pb and Zn). It was concluded that the metals, rather than other stress factors, are the major factor determining MT induction. The effects of perfluorooctane sulfonic acids (PFOS) in Flemish eels were studied by Hoff *et al.*, 2005, indicating that PFOS induces liver damage.

In France, migrating silver eels *A. anguilla* were collected in a river system where algal blooms occurred yearly. Fifty per cent of eel livers were contaminated by microcystin-LR (the most common and toxigenic compounds associated with cyanobacterial blooms). Contaminated silver eels had lower fish condition compared to non-contaminated eels. Consequences of this impact for the breeding potential of these migrating eels are discussed, in particular the importance of lipids and energy reserve allocation. The consequences of contamination by microcystins on the breeding potential of silver eels should be further investigated (Acou *et al.*, 2008).

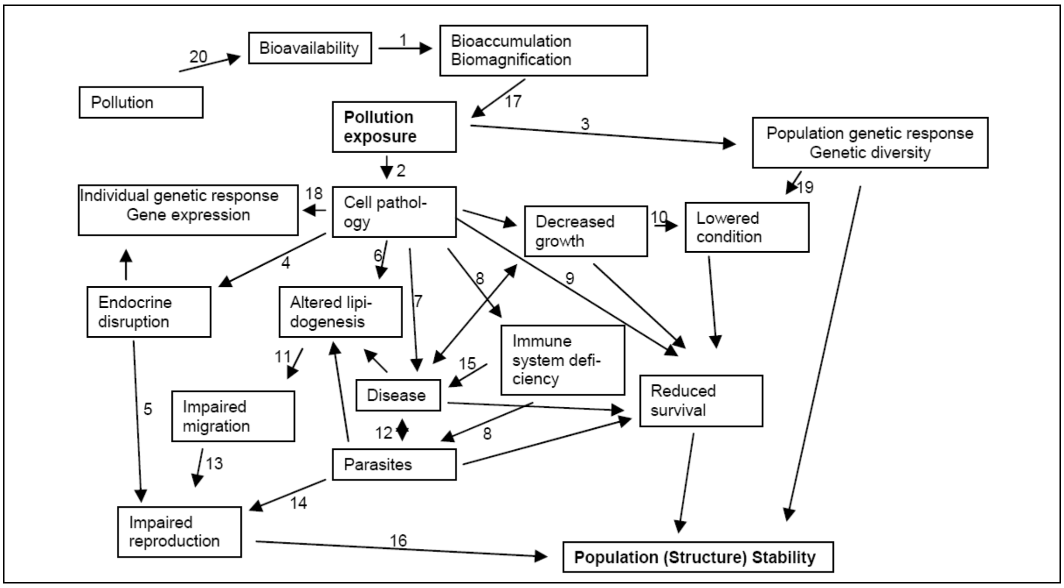


Figure 6.3: A simplified conceptual model of the effects of pollution exposure on the population structure of the European eel, *A. anguilla*. Adapted from Lawrence and Elliott, 2003. Numbers refer to references: (1) Vollestad, 1992; (2) Tuurula and Soivio, 1982; Svobodova *et al.*, 1994; Azzalis *et al.*, 1995; Stohs and Bagghi, 1995; Sancho *et al.*, 1997; Ibuki and Goto, 2002; Pacheco and Santos, 2002; (3) Nigro *et al.*, 2002; Jha, 2004; Maes *et al.*, 2005; Nogueira *et al.*, 2006; (4) McKinney and Waller, 1994; Versonnen *et al.*, 2004; (5) Jobling *et al.*, 2002; (6) Jimenez and Burtis, 1989; Sancho *et al.*, 1998; Fernandez-Vega *et al.*, 1999; Robinet and Feunteun, 2002; Hu *et al.*, 2003; Pierron *et al.*, 2007; (7) Roche *et al.*, 2002; (8) Sures and Knopf, 2004; Sures, 2006; (9) Sancho *et al.*, 1997; (10) Gony, 1987; (11) Ceron *et al.*, 2003; van den Thillart *et al.*, 2005; (12) Van Ginneken *et al.*, 2005; (13) Johnson *et al.*, 1998; Palstra *et al.*, 2007; (14) Sures, 2006; (15) Van Ginneken *et al.*, 2005; (16) Corsi *et al.*, 2003; (17) Van Campenhout *et al.*, 2008; (18) Ahmad *et al.*, 2006; Maria *et al.*, 2006; (19) Jha, 2004; Maes *et al.*, 2005; (20) Belpaire *et al.*, 2003 (after Geeraerts *et al.*, 2008, in prep).

Geeraerts *et al.*, 2007 analysed an extensive dataset of contaminants by statistical modelling and concluded that PCBs, especially the higher chlorinated ones, and DDTs, have a negative impact on lipid content of the eel. It was further demonstrated that fat stores and condition decreased significantly during the last 15 years in eels in Flanders and in The Netherlands (Belpaire *et al.*, 2008), jeopardizing a normal migration and successful reproduction. In Belgium and The Netherlands over the past 15 years, lipid contents dropped by about one-third (from ca. 20% to 13%) (Figure 6.4). Also the condition (Le Cren's relative condition factor) of the eels decreased. Lipid reserves are essential to cover energetic requirements for silver eel migration and reproduction. On the basis of the somatic energy reserves, reproductive potential of eels from various latitudes over Europe was estimated, assuming fat levels in yellow eel are indicative of those in silver eels. Only large individuals, females as well as males, with high lipid content seem to be able to contribute to the spawning stock (Belpaire *et al.*, 2008). Belpaire *et al.*, 2008 argue that the decrease in fat content in yellow eels may be a key element in the stock decline and raises serious concerns about the chances of the stock to recover (Figure 6.4).

It is therefore important to gain insight of the quality, lipid reserves and condition of the eels leaving continental waters and to include quality aspects in eel stock management. Both muscle lipid content and condition factor seem to be important integrative indicators in an overall estimate of the quality of the eels escaping to their spawning grounds.

Contaminant pressure is a plausible concern for the recovery of eel stocks and here we summarize arguments and hypotheses to underpin this:

1) Contamination has been demonstrated as the cause of population collapse of many other biota from the 1970s on (e.g. the collapse of several birds of prey in the 1960s as a consequence of DDT).

2) Many chemicals have been developed and put on the market, simultaneous with the intensification of agricultural and industrial activities during the 1970s. The timing of this increase in the production and release of chemicals may fit with the timing of the decrease in recruitment from 1980 on.

3) Eels bioaccumulate many chemicals to a high extent.

4) The more or less comparable decreases in recruitment in the Northern-hemisphere *Anguilla* species, like *A. rostrata* and *A. japonica*, during the last 30 years, might suggest that some new contaminants quickly spreading over the industrialized world, might have contributed to the decline.

5) Many reports have been dealing with direct adverse effects of contamination on individual, population and community level in fish. In eel, many detrimental effects of contaminants on the individual level have been demonstrated, including impact on cellular, tissue and organ level. Also genetic diversity seems to be lowered by pollution pressure.

6) Considering the high levels of contamination in eels from many areas, endocrine disruption in mature silver eels might be expected, jeopardizing normal reproduction. Dioxin-like contaminants have been reported to hamper normal larval development.

7) Lipid levels in eels have decreased considerably over the past 15 years. This decrease in lipid levels is mainly induced by contamination. Low lipid levels may have contributed to a reduction in migration and reproduction success.

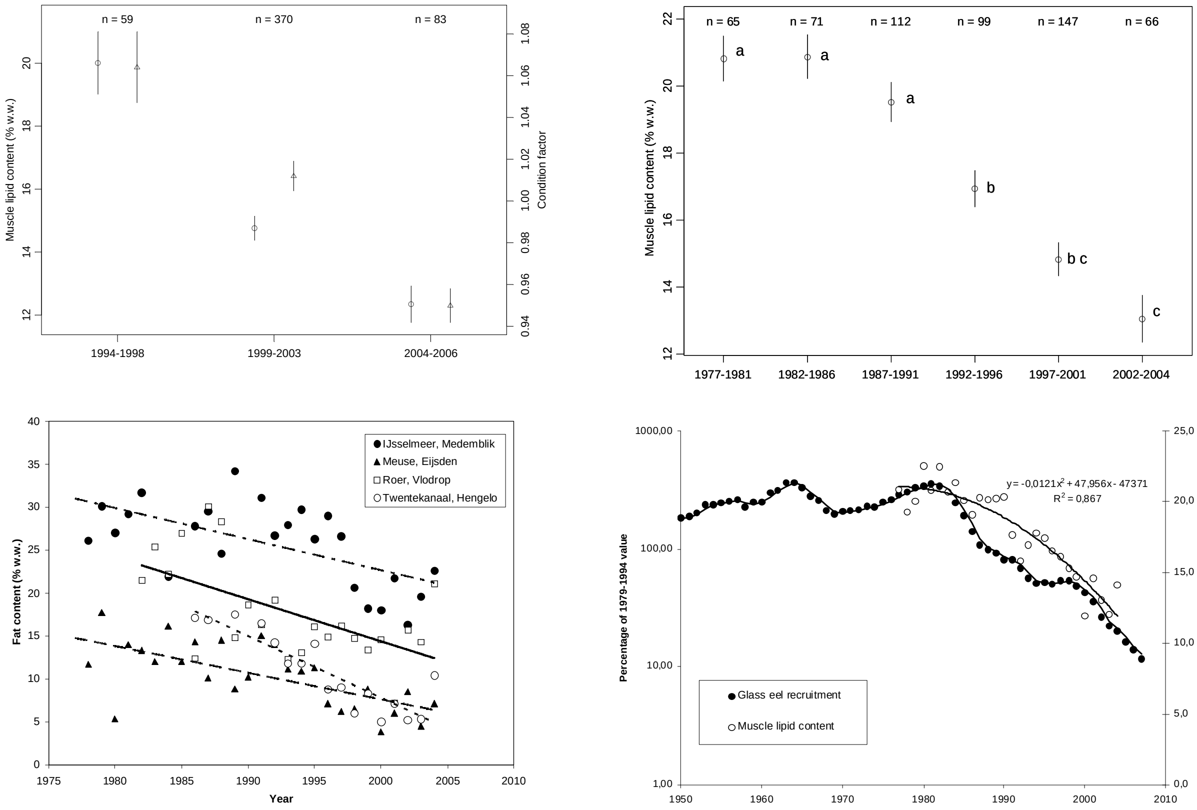


Figure 6.4: Temporal trend in fat contents (% of wet muscle weight) of yellow eels in Belgium (upper left panel) and The Netherlands (upper right panel) (means, bars indicating standard errors). The number of sites is indicated. Means of periods with the same letter are not significantly different from each other. For the Belgian eels also condition factor is presented. Lower left panel: Temporal trends in fat contents in yellow eels from four water bodies of different typology. Time trend of the fat content in muscle tissue (pooled samples) from yellow eels in a lake (IJsselmeer), a large river (Meuse), a small river (Roer) and a canal (Twentekanaal) in The Netherlands. Lower right panel: Time-series of glass eel recruitment in Europe (ICES 2007) and of muscle lipid contents in yellow eels from The Netherlands. Data of the time-series of glass eel recruitment are geometric means of monitoring data of recruiting biomasses in 21 European rivers, each series being scaled to its 1979–1994 average. Data of muscle lipid contents are means of pooled yellow eel samples from The Netherlands between 1977 and 2004 (Belpaire *et al.*, 2008).

Note: in the lower right panel: recruitment is on a log scale and muscle lipid is on a normal scale.

6.3 Parasites/pathogens

A. crassus can be considered widespread throughout Europe and there is a growing evidence that *A. crassus* is spreading further into new areas. New data in 2008 indicated the presence of the nematode in Canada (not included in the EEQD yet) for the first time. Further process research is required before the impact of contaminants and parasites can be included in the quantitative stock assessments.

6.4 Quality assessment of spawners using genomic tools

Eel decline might depend not only on the quantity of adult eels leaving the continent, but also upon their quality. Good quality spawners are those that succeed in crossing the Atlantic Ocean and reproduce. Parasites, such as the exotic swimbladder nematode *A. crassus* can impair eel viability by both increasing continental mortality and affecting the swimming ability of adult eels. Organic and inorganic pollutants may significantly reduce the quality and reproductive capacity of vertebrates. This is especially the case in fish, where pollutants may accumulate in the water and sediment and in the benthic biota (food). Additionally, infections and pollution have been revealed to impair strongly the survival and reproductive capacity of eels in experimental trials, resulting in an even stronger response to pollution and vice-versa (Palstra *et al.*, 2006; 2007). A thorough analysis of pollutants and pathogen stress levels and a better understanding of the biological response (besides measures of condition index) are missing. Pujolar *et al.*, 2005 and Maes *et al.*, 2005 assessed whether the genetic background of European eels could be linked to two fitness traits, early growth and pollutant bioaccumulation. Summarizing both studies here, there was strong evidence of a relation between genetic diversity and fitness measures (also called Heterozygosity-Fitness-Correlations or HFCs). It might be explained either by an effect of direct overdominance at functional markers. Recently, it became possible to reliably quantify the gene and protein expression levels during exposure to pollutants and parasites, allowing the early detection of decreased fitness and survival. Such knowledge would provide the chance for early warning systems, facilitating management actions before major mortality events in natural populations and provide a long-term assessment of success rates of conservation measures. Using sufficient background information on the identity and concentration of pollutant, this approach may yield better insights into the factors influencing the recently observed decrease in fat content, a potentially crucial measure for eel's ability to reach the Sargasso Sea. The ongoing analyses of northern (Belgium) and Southern (Italy) eel populations for their gene expression level and health status will allow adding a quality status tag on silver eels, while identifying good quality habitat for preservation.

6.5 The European Eel Quality Database

6.5.1 Introduction

In 2006 the EEL WG recommended that further sampling and ongoing monitoring into eel quality was urgently required. Member countries should set up a national programme on RBD scale to evaluate the quality of emigrating spawners. This should include at least body burden of PCBs, BFRs, infestation levels with *A. crassus*, and EVEX. It should be included in the national management plans while special emphasis should be given to standardization and harmonization of results (units and methods). To this effect the European Eel Quality Database was created in Belgium in 2007 and circulated among members of the EELWG requesting data on fat composition, contaminant analysis and infection parameters of *A. crassus.* During the intersession period and during the Working Group meeting 2008 eel quality data has been provided and included in the EEQD.

The database is coordinated by the Research Institute for Nature and Forest (Belgium) and includes data on eel quality elements, such as condition, contaminant concentrations and epidemiological parameters, in addition to the relevant descriptors of date and place of sampling and sample characteristics (eel life stage, number and morphometrics). The database was initially restricted to a limited number of quality elements (lipid content, ca. 30 chemicals and *A. crassus* infection parameters). During WGEEL 2007 some countries reported on some more elements, and the list of ICES7 (CB28, CB52, CB101, CB118, CB138, CB153 and CB180) congeners was extended with non-*ortho* and mono-*ortho* congeners, as they exhibit the highest dioxin-like toxicity and contribute most to the TEQ (toxic equivalency). Also one pesticide, several metals and some bacterial disease agents were added.

During the WGEEL, 2008 evidence has been presented that condition factors are important elements for estimating eel quality (Acou *et al.*, 2008; Belpaire *et al.*, 2008). It was recommended that condition should be included in the EEQD, this requires however a standardized methodology (Froese, 2006).

6.5.2 Analysis of the EEQD

During the Working Group session, new data were compiled and the EEQD now contains information from 14 countries reviewed in Table 6.2. Data from Norway, France and Estonia also are available and will be included in 2008. Data source is heterogeneous, data deriving most from national or local level surveys, but also from eco-toxicological studies. Belgium has presented the most exhaustive information, as a consequence of the availability of data from the Flemish eel pollution network, in place since 1994 (Belpaire and Goemans, 2007). Norway also provided a long time monitoring series in the Grenland fjords (S. Norway) following the discovery of PCDF/PCDDs in edible organisms after a 99% reduction in the load of waste components from the Hydro Porsgrunn magnesium factory (Knutzen *et al.*, 2001). However, the longest dataseries for bioaccumulation of contaminants is from the Netherlands, because in this country a monitoring network for PCBs, OCPS and mercury in eel is in place since the 1979s, linked to the safety for consumption norms. Germany and UK have provided data on concentration of pollutants and contaminants relative to some river basins, carried out within local monitoring programmes. Some countries (Italy, Portugal, Spain) did report data drawn from eco-toxicological studies carried out within specific researches. Some countries (e.g. France and the Netherlands) have published reports demonstrating that considerable information is available. At the present moment this information is not accessible for inclusion in the EEQD. On the whole, eel quality data were provided for approximately 600 different sites over Europe; at the present however, the database is overbalanced, most of the sites being situated in Belgium. Most information is available for heavy metals (771 records), PCBs (695 records) and organochlorine pesticides (OCPs) (656 records) while 566 observations on lipid content were also included. Apart from some observations on bacterial diseases available for three sites in Spain and one site in UK, disease agents included in the database are restricted to the swimbladder nematode *A. crassus*, with epidemiological data from 335 sites across Europe.

Given the importance of lipid levels as an energy resource utilized during the eels' migration and for the production of gametes, disturbing data are seen in Europe. Four out of twelve countries have a fat percentage above 20% (Figure 6.5, the minimal lipid storage needed for a successful reproduction (Boëtius and Boëtius, 1980; Van den Thillart *et al.*, 2004; 2005).

Research on the fat content in yellow eels has been done on two (independent) large datasets of lipid contents in yellow eels from Belgium and the Netherlands. A 7.7%

decrease in lipid content on wet weight basis over a 13 year period has been revealed in Belgium. Whereas in the Netherlands before 1990 the mean fat content was generally superior to 20%, a clear and significant decrease occurred after 1990. Notwithstanding the differences in both network concepts, and large variation in lipid contents of eels from various water bodies, similar trends were obvious in Belgium and the Netherlands: a drop in lipid contents over the past 15 years by about one-third (from ca. 20% to 13%) (Belpaire *et al.*, in press).

Table 6.2: Overview of the number of records of eel quality data compiled during the WGEEL 2008 and incorporated in the European Eel Quality Database.

COUNTRY	FAT	PCB	PESTICIDES	HEAVY METALS	A. CRASSUS	BFR	DIOXIN	PFOS
Belgium	409	408	373	373	140	24	8	
Denmark	7	6	6		3	4		12
Estonia								
Finland								
France		12		3				
Germany	14	12	23	23	26		2	
Ireland	13	9	7		6	7	7	
Italy	24	24	20	7	10			
Latvia								
Lithuania								
Northern Ireland	2				3			
Norway	8	8	8					
Poland	7	7	7	7	21		7	
Portugal	1	1		12	8			
Spain	18	60	73	52	52			
Sweden	25	10	1	179	51		7	
The Netherlands	37	99	99	76				
UK	1	39	39	39	16			
TOTAL	566	695	656	771	335	35	31	12

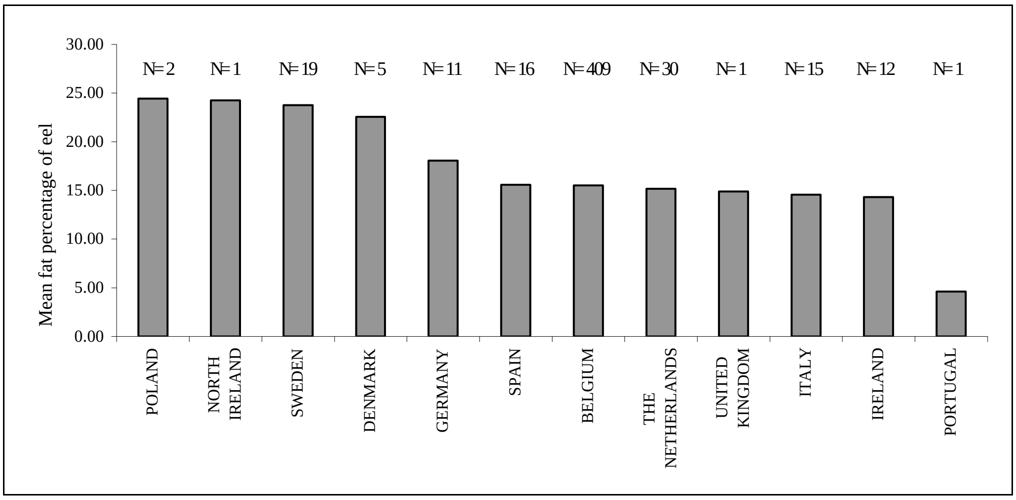


Figure 6.5: Variations in mean muscle lipid content (%) in yellow end silver eels in Europe. N indicates the number of sites on which the mean values are calculated.

6.5.3 Future development of the database

The development of a European Eel Quality Database in the WGEEL 2007 has been updated during the 2008 session and now forms the basis for compiling a comprehensive pan-European overview of eel quality data.

There is a wide range of information widely scattered over Europe by location and collecting agency. The collection and reporting of eel quality data are recommended within the international framework for the restoration of the species (Data Collection Regulation) as proposed by the Working Group on Eel (ICES, 2006) and the Scientific, Technical and Economic Committee for Fisheries of the EC (STECF, 2006). The collection of such data are now also included in the guidelines for the preparation of Eel Management Plans.

Some information is missing and the database has to be expanded and further updated in the future. For instance some countries (e.g. France and the Netherlands) have published reports that demonstrate considerable information is available but data were not presented for inclusion in the EEQD. It is also presumed that many unpublished results are available in some countries and should be utilized by inclusion in the database. Some were provided during the Working Group meeting, but could not be included in the database at the time.

Considering that eel quality could be a major element in the decline of the species, the database may become a useful tool for the (inter)national eel conservation measures. The database allows the identification and designation of good quality sites where special measures for maximum protection of stocks and emigrating spawners of good quality can be proposed (e.g. restriction of fisheries, priority places for restocking, priority for habitat restoration measures, etc). From preliminary analyses it was clear that many contaminants and lipid reserves varied a lot over the distribution area of the eel (ICES, 2007) and the presence of 'black spots' was identified. EEQD data on disease agents such as *A. crassus* demonstrated a widespread distribution over Europe. From an environmental point of view it is clear that the database will give information about specific environmental chemical pressures and will indicate pollution areas for specific contaminants. The database will allow an overview and in-depth analysis of eel quality on a Europe wide scale and follow-up of emerging problems of a chemical or epidemiological nature and could also be used as an early warning system for the spread of new eel diseases or contaminants. Yellow eels have been proposed as a sentinel organism for evaluating the chemical quality of priority hazardous substances in biota in accordance with the WFD. EEQD can integrate these data and make them available for eel stock management. The database will pinpoint sites where the quality of eels is below that deemed suitable for human consumption, so adequate fisheries management measures, like closing fisheries or preventing consumption of eels, can be taken in these areas.

6.6 Conclusions and recommendations for Chapter 6: Eel quality

6.6.1 Conclusions

Estimation of effective spawner biomass requires quantification of the adverse effects of contaminants, parasites, diseases, low fat levels, non-lethal turbine damage, along the lines previously proposed for *A. crassus*, as well as other mortality rates throughout the river basin. Present knowledge does not fully permit quantitative assessment of the effects of these factors on the overall stock.

The European Eel Quality Database (EEQD) has been updated with data on contaminants, parasites and fat levels in eel, allowing the compilation of a comprehensive overview of the contaminant load in eel over its distribution area. Results demonstrate highly variable data within river basin districts, according to local anthropogenic pollution, linked with land use. Persistently elevated contamination levels, above human consumption standards, are seen in many European countries. The most important reported impact is seen on the fat content of the yellow eels (i.e. in Belgium and the Netherlands) which has decreased over the last number years and which raises concern regarding the migratory and reproductory success of silver eels. There is growing evidence that *A. crassus* is spreading further into new areas and new data indicate the presence of the nematode in Canada (not included in the EEQD yet) for the first time.

Clear ecotoxicological effects of contaminants have been demonstrated. The most important impact is seen on the fat content of the eels which is decreasing over the last number of years and which may jeopardize migration and reproduction success.

The value of monitoring contaminants in eel for environmental issues has been demonstrated. But the eel as a bio-indicator is not recorded in the Water Framework Directive and the number of contaminants recorded is insufficient for safeguarding sufficient eel health.

6.6.2 Recommendations

The Working Group recommends the continuation on a local scale of the long-term monitoring of quality (contaminants, parasites and disease) in eel with an emphasis on standardizing the methodological approach, analysis of new compounds, an appropriate communication system and robust data management. The European Eel Quality Database should be developed and maintained. Member States should initiate harmonized monitoring strategies aimed toward the development of a European Eel Quality Monitoring Network, to collect the relevant data to be fed into the EEQD.

The Working Group recommends investigations into eel quality of the eels leaving continental waters so as to include quality aspects in eel stock management and evaluation of effective spawning escapement.

Carry out a Europe wide study to comprehend relationships between contamination and eel stock decline. An important focus should be to study the effects of contaminants on lipid metabolism and condition.

The Working Group repeats its recommendation that contaminant monitoring in eel should be included as a tool for measuring the chemical status of our water bodies as defined in the Water Framework Directive.

7 Oceans, climate and recruitment

7.1 Introduction

Term of Reference c. tasked the Working Group to, "review hypotheses and information on the possible relationships between the European (and American) eel stock(s), recruitment patterns and climatic and oceanic factors".

European *A. anguilla* and north American *A. rostrata* eel spawn in the Sargasso Sea. This part of the life cycle has not been witnessed or quantified and therefore the full stock–recruitment relationship circle cannot be closed at present. Oceanic factors, biological and physical, may influence the recruitment of eel through impacting on both the migrating silver eels and on the subsequent return of juvenile recruits. Overlaid on this, recruitment of European eel has decreased by approximately 95% since 1982 (Dekker, 2003) and is below 5% since 2000 (ICES, 2007).

In addressing this ToR, the WG in its pre-meeting undertook a literature review and invited submissions to this review. The WG would like to acknowledge inputs from Beaulaton, Bonhommeau, Cairns, Dekker, Friedland, Kettle, Knights, and Miller.

7.2 Review of ocean change/controlling mechanisms

Long-term climate variation in the North Atlantic has been revealed to correlate with observed trends in aquatic and terrestrial ecosystems throughout Europe (Ottersen *et al.*, 2001). SST (sea surface temperature) differences may be the main drivers of the North Atlantic Oscillation (NAO) and associated continental climate change. Cycles of change could result from slow transfers of warmer/colder water by the major thermohaline and wind-driven gyre currents (Hurrell, 1995). Changes in the NAO winter index (NAOI) since the 1820s appear to follow cycles with periods varying in the range 7 to 13 years. In addition to the NAO there are other natural longer period climate cycles i.e. the approximately 60 year Atlantic Multidecadal Oscillation (AMO, Sutton and Hodson, 2005) (Figure 7.1). Superposed on the natural climate oscillation is the steady anthropogenic increase of global temperature.

The widely used NAO index quantifies alterations in atmospheric pressure between the subtropical Atlantic (Azores) and the Arctic (Iceland). An increased Azores High indicates more and stronger winter storms crossing the Atlantic in a more northerly track, and shifts the Gulf Stream to a more northerly position. A number of alternative indices have been defined, varying in the months included, the analysis procedure and the exact locations measured (Dekker, 2004a). The NAO winter index is always used, because it provides the most pronounced signal. The North Atlantic SST demonstrates a long-time downward trend expressing the combined effects of NAO and AMO from the early 1940s until the early 1970s followed by a gradual increase until the mid 2000s, amplified by the anthropogenic warming. The most recent data indicate the beginning of a cooling period. The unusual warming of the North Atlantic is also indicated by the relationships to the Sargasso Sea Surface Temperature (SS-SST) (Figure 7.2). Other parameters have also been analysed by various authors and their putative effects are described in Table 7.1.

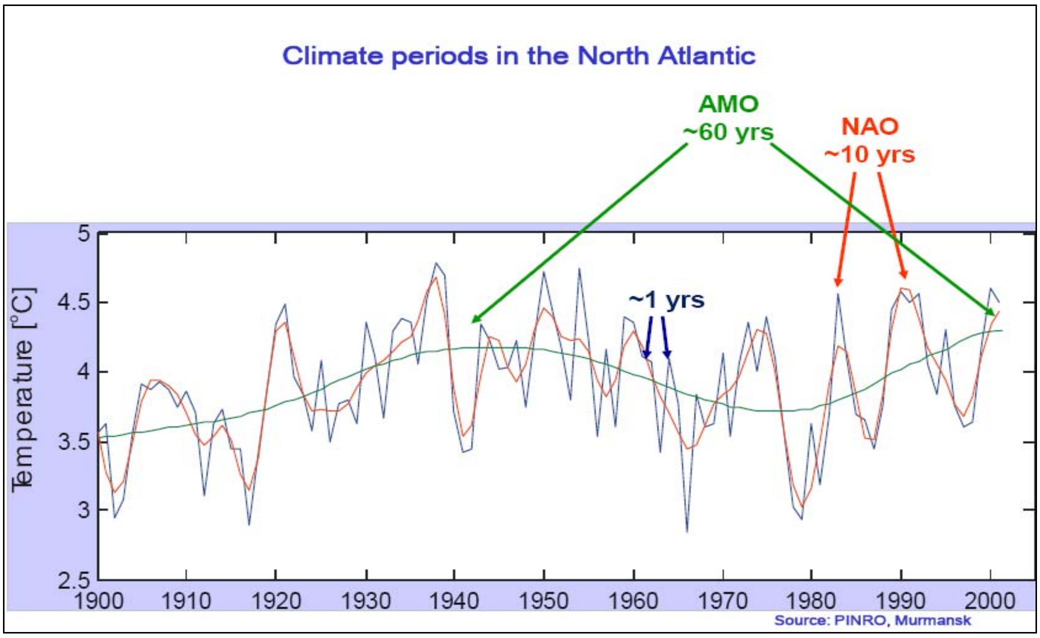


Figure 7.1: The effect of the natural climate oscillations over the North Atlantic area on the mean yearly sea temperature of the Kola section in the Barents Sea illustrating the interaction between decadal and multidecadal time-scales. From Svein Sundby presented at *Fisheries Management and Climate Change in the Northeast Atlantic Ocean and the Baltic Sea,* Bergen 17–18 April 2008.

7.3 Review of recruitment patterns in eels

Leptocephali larvae of European eel are transported along the Gulf Stream and North-Atlantic Drift for a journey taking somewhere between an estimated 8–9 months (Lecomte-Finiger, 1992) and 2–3 years (Tesch, 2003; Kettle and Haines, 2006; Bonhommeau *et al.*, 2008) to arrive back to the eastern Atlantic coast where they metamorphose to glass eels, ascend rivers and grow as yellow eels until reaching partial maturity (Tesch, 2003). American eel leptocephali must also reach the Florida Current or Gulf Stream, although they later have to leave that current system to recruit to the coast of North America. Leptocephali grow larger and have a longer larval duration than most fish species, taking up to a year or longer before they recruit to fresh-water habitats as glass eels or elvers. This long larval duration is thought to make leptocephali particularly susceptible to changes in ocean currents and food availability (Friedland *et al.*, 2007).

A fundamental question in resolving the role of ocean circulation in life cycle of the European eel is the duration of the larval migration. Schmidt, 1923 made a careful analysis of the age cohort size structure for leptocephali captures across the Atlantic Ocean and concluded that the passive transatlantic migration lasts two years with the metamorphosed glass eels entering fresh and brackish waters in spring at the end of their third year. Direct Lagrangian simulations (Harden Jones, 1968) indicated that the migration should take 2.5–3 years. A more recent Lagrangian study (Kettle and Haines, 2006) suggested that the duration of the larval eel migration was probably about two years. On the other hand, glass eel otolith ring counts have indicated an oceanic migration time of less than a year (Lecomte-Finiger, 1992), but there is debate about whether the growth rings are deposited daily. Knights, 2003 and Friedland *et al.*, 2007 suggest that there may only be a one year time delay oceanic perturbations represented by the NAO and the DenOever glass eel index, implying a one year migration period. The most recent study by Bonhommeau *et al.*, 2008 has indicated that there is a 2–3 year time-lag between perturbations of ocean temperature and primary productivity in the Sargasso Sea and glass eel recruitment indices in Atlantic France, and there is a convergence of opinion that the duration of the larval migration may be approximately two years.

Table 7.1. Oceanic parameters that have been analysed by various authors and their putative effects on eels.

OCEANIC FACTOR	MECHANISM OF INFLUENCE	AUTHOR
North Atlantic oscillation NAO	NAO quantifies the alteration in atmospheric temperatures between the Azores and Iceland. It indicates a more northerly position of the Gulf Stream. Impacts larval migration	Dekker, 2004
Sargasso Sea Sea Surface Temperatures (SS-SST), average 0-100 m deep	The marine production increases with sea surface temperature in the cooler waters from the North Atlantic but decrease in warmer waters. This effect is as a consequence of a reduced vertical mixing and lower marine production thus impacting larval feeding	Bonhommeau *et al.*, 2008
Sargasso Sea Winds	Surface current, caused by the combined effect of wind and Coriolis forces, have diminished, reducing the westward transport towards the Florida current into the Gulf Stream–could affect transport of leptocephali	Friedland *et al.*, 2007
Mean Temperature of the northern hemisphere (NHT)	Would reflect climate change and its impact on primary production in the ocean and larval feeding.	Knights and Bonhommeau, unpublished
Gulf Stream Index (GSI)	Latitude of the Gulf Stream, from monthly charts of the north wall	Bonhommeau, 2008
Transport index (TI)	Strength of the Gulf Stream and North Atlantic current system (baroclinic gyre circulation in the North Atlantic) Calculated from potential energy anomalies (PEA) between Bermuda and Labrador basin – could affect transport of leptocephali	Bonhommeau, 2008
PP (Bermuda biological station, North of spawning area)	Primary production. Considered as a good proxy for leptocephali food.	Bonhommeau, 2008
Sea surface temperatures anomalies (SSTA)	Food availability for leptocephali would be expected to be reduced during warm high SSTA periods as a consequence of reduced spring mixing, nutrient recirculation and productivity	Knights, 2003
Surface expression of the 22.5°C isotherm	The 22.5 °C isotherm is a useful indicator of the northern limit of spawning by both species of eels in the Atlantic. Therefore, changes in the latitude or intensity of these fronts may affect both the spawning location and the subsequent transport of the leptocephali to continental habitats.	Friedland *et al.*, 2007

A very short time-lag compared to the drift estimates seems unlikely considering the swimming ability of the leptocephalus larvae (Bonhommeau, 2008). To gain one year in the transatlantic migration the larvae has to sustain a continuous, directed swimming velocity of 15 to 20 cm/sec, or 3–5 body-lengths/sec. A typical anguilliform swimming speed is of the order 0.5 body-lengths/sec (Ellerby *et al.*, 2001).

Meta-analyses of many local dataseries have revealed common trends in the population. The breakpoint in the recruitment series in south and middle Europe from 1980 points to a shared process causing the decline thereafter. Recruitment series of young yellow eel in northern Europe deviates from this, with an earlier decline starting during the 1950s. This could be interpreted as a different climatic effect on the north- and south- going branches of the North Atlantic drift, which splits into the North East Atlantic and the Canary currents to the southwest of Ireland.

7.4 Review of hypotheses of causal linkages between oceanic factors and recruitment patterns

The mechanism or mechanisms behind the observed correlation between glass eel recruitment and climate oscillations are unknown. The migratory phase of adults and larvae, as well as the egg and larvae production might have been influenced by climate variation. Currently it is difficult to separate out the impact of ocean and climate on spawner migrations and on subsequent migrations of larvae and recruiting glass eels.

It has long been recognized that there may be a direct link between larval migration success and the density, or thermohaline circulation, of the ocean. The NAO might impact the larval migration by changing the ocean currents or by influencing ocean productivity and food availability for the migrating larvae (Knights, 2003). The long-term variations in glass eel recruitment indices may be modulated by characteristic time-scale of the NAO index, which varies in periodicity between 7 and 13 years. This had important implications in explaining the long-term decline in glass eel recruitment across Europe since the late 1970s as it has been recognized that the NAO index had been in a prolonged positive phase over this period (ICES, 2001; Friedland, 2007).

Focussing on the long term DenOever glass eel index, Friedland *et al.*, 2007 established the existence of significant correlations with environmental parameters in the North Atlantic during the spawning period between February and May: the surface expression of the 22.5°C isotherm, the eastward windspeeds, and the NAO. Explanations for the observed relationships focused on the possible influence of wind-induced geostrophic transport in advecting larvae into the Gulf Stream and on the impact of interannual variability of the mixed layer depth on nutrient supply and ocean productivity in providing food to the developing larvae.

A close negative relationship has been found over the last four decades between long-term fluctuations in recruitment and in sea temperature (Table 7.2). By contrast, variations in integrative indices measuring ocean circulation, i.e. latitude and strength of the Gulf Stream, did not seem to explain variations in glass eel recruitment (Bonhommeau *et al.*, 2008).

The impact of food availability in the Sargasso Sea on the success of the larval eel migration was suggested and rejected by Desaunay and Guerault, 1997. Using information about the length of the oceanic migration from otoliths the conclusion was that the number and physical condition of glass eels arriving on the coast of France was linked to chlorophyll concentration and food availability in the Sargasso Sea at the time of spawning. The largest glass eels near the spring arrival peak in coastal France were assumed to have started in the Sargasso Sea during the spring chlorophyll bloom of the previous year.

Bonhommeau *et al.*, 2008 used a short time-series to demonstrate a correlation between recruitment and primary production in the Sargasso Sea demonstrating a strong bottom–up control of leptocephali survival and growth. On a longer timescale, SST is used as a proxy for primary production and related to recruitment indices. Sea warming in the eel spawning area since the early 1980s may have modified marine production and eventually affected the survival rate of European eels at early life stages (see Figure 7.2). Direct measurements of primary productivity in the northern Sargasso Sea were also found to be correlated with a three-year lag to the Loire River recruitment time-series in France, but not those at the other locations (Bonhommeau *et al.*, 2008). Changes in ocean productivity may also be associated with changes in the length and condition of glass eels recruiting to Europe (Desaunay and Guerault, 1997; Dekker 1998; 2004b).

Kettle *et al.*, 2008 have demonstrated that the NAO repeat cycle is present both in the glass eel catches and the FAO eel landing statistics. This means that there may be a resonant amplification between silver eel escapement and glass-eel recruitment. All stages of the life cycle appear to respond to interannual climate variability associated with the NAO, but it is not clear if the larval migration success is impacted directly by meteorological conditions over the Sargasso Sea or if it is modulated by the number of silver eels that are triggered to spawn by NAO-associated rainfall patterns in Europe.

Table 7.2: Correlations between various glass eel recruitment series and oceanic parameters.

RECRUITMENT SERIES	OCEANIC PARAMETER	CORRELATION	TIME LAG (YEARS)	AUTHOR
		Transport related parameter		
Series from Loire, L'Ems & Den Oever, 1950–2001	NAO (winter index)	-0.13	0 (max 1 and 6 years)	Dekker, 2004
DenOever 1938–2005	NAO (winter index)	-0.35	0 (max 0 and 8)	Friedland *et al.*, 2007
10 series	NAO (winter index)	GAM model significant effect but no linear trend		Beaulaton, 2008
26 series	NAO (winter index)	Anticorrelated-significant	1 to 4	Kettle *et al.*, 2008
Drakkar model, particles that succeeding in reaching the 20 W	NAO (winter index) GSI PEA	0.5 0.73 0.57	0	Bonhommeau, 2008
Mercator model, particles succeeding in reaching the 20 W	NAO (winter index) GSI TI	0.78 0.80 0.47	0	Bonhommeau, 2008
Drakkar model, minimum migration duration	NAO (winter index) GSI TI	-0.57 -0.75 -0.48	0	Bonhommeau, 2008
21 series 1935–2007	NAO	-0.28 -0.31 -0.35	2 3 7	Knights and Bonhommeau, unpublished
7 series	TI	NS	3	Bonhommeau *et al.*, 2008

RECRUITMENT SERIES	OCEANIC PARAMETER	CORRELATION	TIME LAG (YEARS)	AUTHOR
7 series	GSI	NS	3	Bonhommeau *et al.*, 2008
DenOever 1947–2004	Latitude of the surface expression of the 22.5°C isotherm in the Sargasso Sea	-0.15 to -0.39 according to month and longitude	1	Friedland *et al*., 2007
DenOever 1949–2003	Winds	-0.09 to -0.48	1 year	Friedland et al., 2007
		Production related parameters		
1955–2007	SS-SST	NS	1–6 years	Knights and Bonhommeau, unpublished
1935–2007	NHT	NS	2–3 years	Knights and Bonhommeau, unpublished
Loire series from trader 1994–2004	PP	0.74	2.5 years	Bonhommeau *et al.*, 2008
Ems DenOever, Loire Nalon 1960–2005	SS-SST	-0.88	2.5-year	Bonhommeau, 2008
DenOever (3 year average) 1952–1995	SST anomaly at 100–250 m	-0.47 -0.30	0 year 1 year	Knight, 2003
DenOever (1960–1996)	Size of glass eels	0.7	0 year	(Dekker, 1998)

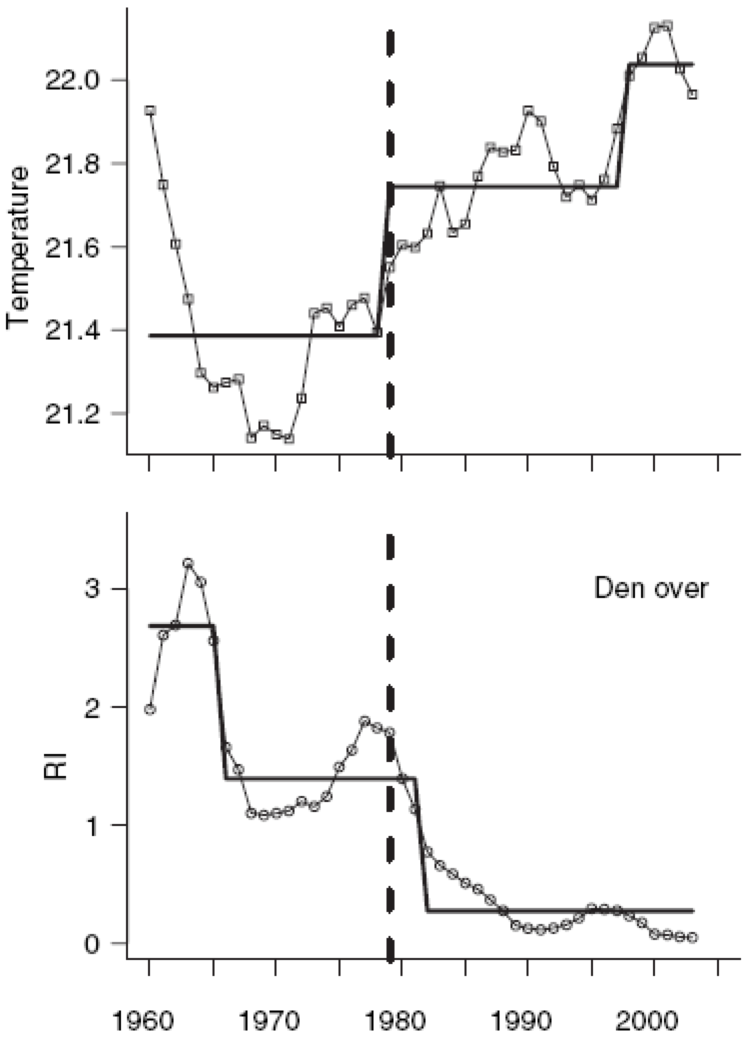


Figure 7.2: Time series of DenOever recruitment index (5-yr moving average; solid line with circles) and temperature (°C; 5-yr moving average; solid line with squares) in the Sargasso Sea from 1960 to 2003. Bold lines indicate regime shift detection (Rodionov and Overland, 2005) and vertical dashed line indicates the regime shift in temperature in 1979. (Reproduced from Bonhommeau *et al.*, 2008).

7.5 Ocean factors as reason (or contributory factor) for recruitment decline (1980s onwards)

The historic record shows strong evidence that the abundance and size of glass eels recruiting to the continent have the same periodicity as natural climate oscillations (Figure 7.3). Evidently NAO, and other climate cycles, are primarily meteorological indices that, at most, can be proxies to those ecological and hydrographic changes in the North Atlantic that could be the primary causes for variations of eel recruitment. Several parameters are possible candidates for the cause of the decline e.g. sea surface temperature anomalies and changes in productivity linked to temperature.

A shift in sea temperature in 1979 marked the beginning of changes in the Sargasso Sea environment and was followed by the large shift in eel recruitment detected in 1982 in most of the European rivers that have been analysed (Bonhommeau *et al.*, 2008). Correlation analysis of the glass eel catches revealed that almost all the monitoring indices across Europe vary in phase, providing support that they are modulated by a large-scale meteorological disturbance (i.e. as previously suggested by Knights 2003; Friedland *et al.*, 2007). However, measuring ascending young eels (young of the year, and older), the drop in recruitment in northern European rivers was observed considerably earlier. This leaves the possibility open that conditions closer to the European shelf may be important or that the decline in southern Europe started earlier also (see l'Adour and Gironde series, Chapter 2).

Temperature may be one of the main governing factors influencing eel larvae survival by decreasing food availability in the Sargasso Sea (Bonhommeau *et al.*, 2008). The size of glass eels is positively correlated with abundance and with the NAO-cycle. This also points to a role of ocean primary production on the feeding of glass eel and possible starvation of leptocephali. (Dekker, in prep, Figure 7.3).

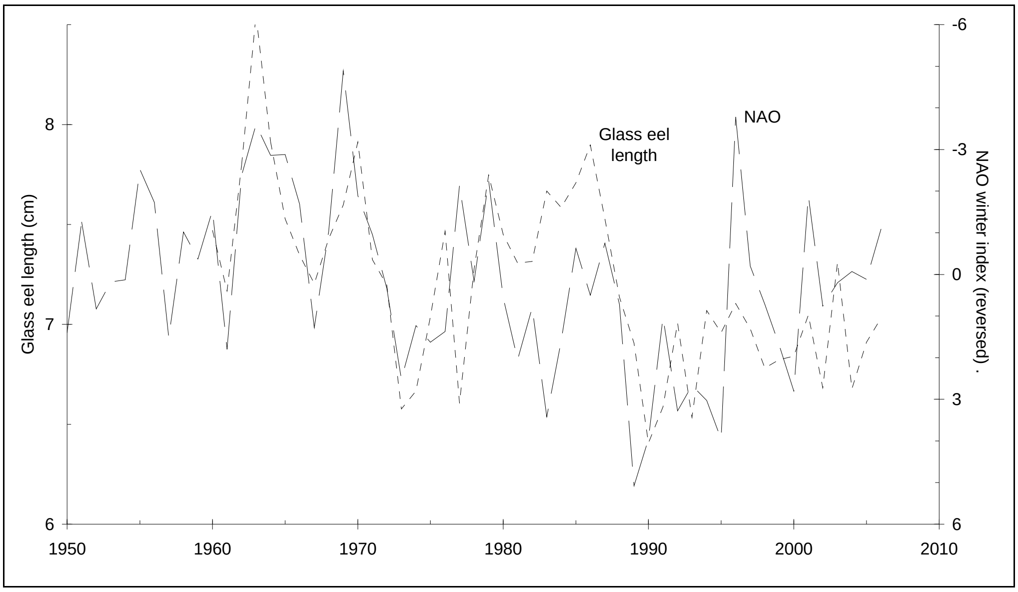


Figure 7.3: Trends in glass-eel length entering Lake IJsselmeer (short dash), and the NAO winter index (long dash). (Data from Dekker, 1998 and Hurrell, 1995). (From Dekker, in prep).

Changes in ocean currents, particularly in the Sargasso area, may have also affected glass eel recruitment. This assertion is supported by the correlation between recruitment series and NAO. It is also supported by results from modelling demonstrating the positive effect of transport indices on both success and time of migration. However, when looking at indices related to the strength of the Gulf Stream (TI and GSI), no significant correlation was found (Bonhommeau, 2008).

The steep decline in recruitment between 1980 and 1983 and the continued low and still declining recruitment since then cannot be easily explained by oceanic factors alone. The demonstration of a possible stock recruitment relationship (Dekker, 2003; 2004b; updated by WGEEL 2007) demonstrates strong evidence of a depensatory mechanism in the relationship. In this S/R relationship, landings have been used as a proxy for continental stock and it is assumed that continental stock varies in parallel with SSB. It is possible that this relationship between stock and SSB is not constant and that SSB has declined faster than the stock, possibly as a consequence of a breakdown in the migratory phase, the spawning process and/or the quality of the spawners, leading to a smaller number of recruits per spawner than observed prior to the 1980s. Isolation or fragmentation of spawning effort as a consequence of low SSB may have exacerbated this. The steep stock related decline in recruitment could be overlaid on the oceanic influences and might have drowned out the ocean signals in latter years.

A different view to this is proposed by Knights and Bonhommeau, unpublished. They found that combined and geographical-area stock trends are more meaningful than landings data for use in formulating stock–recruitment hypotheses and modelling and in developing management targets. Their results predict that glass eel recruitment would to be able to recover in less than 10 years from very low levels if ocean-climate conditions become more favourable. This conflicts with the life cycle modelling study of Astrom and Dekker, 2007 which concluded that stock recoveries could take >80 years. Also, Dekker *et al.*, 2003 and Dekker, 2004b assumed the general decline in combined landings was a proxy for stocks and hence spawning stock and that depensation could have led to the falls in recruitment 20 years later. The study by Knights and Bonhommeau, unpubl. however, suggests that fluctuations in environmental factors, both oceanic and near-continent, are the main determinants of recruitment over shorter periods and that classical stock–recruitment models cannot be applied to the European eel. It also debated the assumption that large female eels produced in the Baltic make a major contribution to overall production of the European eel (e.g. Tesch, 2003), as North Atlantic/North Sea glass eel recruitment was relatively very high around 1980, despite the major declines in Baltic stocks beginning in the 1950–1960s. In conclusion, Knights and Bonhommeau, unpubl. suggest that combined European landings data cannot be used as a simple direct proxy for stocks, certainly in different regions in NW Europe. The lack of any clear recovery in recruitment during the low NAO periods in the late 1990s led Dekker, 2004a to question the role of the NAO in affecting glass eel recruitment. However, the continual warming of the N Atlantic signalled by the rising SS-SST and NHT has probably overridden the effects of the NAO (Knights and Bonhommeau, unpubl.).

7.6 Conclusions and recommendations for Chapter 7: Oceans, climate and recruitment

7.6.1 Conclusions

- Sufficiently long time-series of glass eel recruitment, covering several periods of the natural climatic oscillation over the North Atlantic, reflect the same periodicity.
- The causal link between climate and recruitment strength, is unknown.
- It is unknown where and when during the oceanic life of the eel larvae the climate effect operates. It may be in the Sargasso Sea or closer to the European coastal area.
- The recent, prolonged strong decline in eel recruitment is out of phase with the dominating climate cycle, the North Atlantic Oscillation, although continual warming has probably overridden the effects of the NAO.

As long as the causal factors of oceanic influence are unknown, it is not safe to assume that the decline is explained by climate alone, especially while we know that the anthropogenic influences during the continental life stage of the eel are large and better understood. The fact that oceanic climate may contribute to recruitment variation is not grounds for abstaining from all possible measures to increase silver eel escapement to boost spawning-stock biomass. At some level the stock/recruitment relation will always be important-there is no recruitment without eggs. Ocean environmental factors can never justify a lack of conservation measures.

The options and expectations for management outcomes can be summarized in Table 7.3 that can be used in a risk analysis:

Table 7.3: Options and expectations for management outcomes.

	HYPOTHESIS ABOUT CAUSE OF DECLINE		
	Pure stock/recruitment	**Ocean environment**	
ACTION TAKEN		**Improving**	**Deteriorating**
Reduce anthropogenic mortality	Recovery if measures are sufficient	Recovery faster than expected	No recovery or slower than expected
No action	No recovery	Possible recovery	Faster continued decline

7.6.2 Recommendations

To address the difficulties comparing ocean environmental cycles with biological cycles of eel it is necessary to improve our knowledge of the oceanic phases of the eel life cycle. This will allow us to better understand which oceanic factors are behind the climate effects. This in turn will allow for a more sophisticated analysis than mere correlations and the weighting of the role of climate effects on reproductive success, compared to continental factors. Some key questions are:

- The question of the interaction between leptocephali mortality and dispersion.
- The role of leptocephali in the ecosystem, including feeding and predation.

WGEEL proposes that an ICES Study Group is established to coordinate and plan research on the oceanic effects on leptocephali and metamorphosis to glass eel.

8 Research needs

8.1 Introduction

The Working Group on Eel identified a considerable need for new research on eel population dynamics and its influencing factors. Due to the current implementation of the EU eel recovery plan (EU Regulation 1100/2007), the primary focus of discussions on research requirements at WGEEL 2008 was on supporting the assessment of the stock and its recovery as sought by the implementation of this regulation. WGEEL 2008 did not, however, lose sight of the continuing lack of knowledge of the fundamental biology (i.e. carrying capacity and density-dependence) and of the European eel's ocean phase (including spawner quality and migrations). It is recognized that methods for evaluation of the outcome of management measures are not yet fully available either at the population (international target), or local (sub target) level.

8.2 Priority research needs

WGEEL believes that the best approach is a series of integrated and internationally coordinated projects and is set out in Figure 8.1. A programme of research is needed to address gaps in knowledge, gather data to evaluate the status of the stock, and further develop stock assessment methods to determine compliance with targets and the effectiveness of management actions at the international and local level.

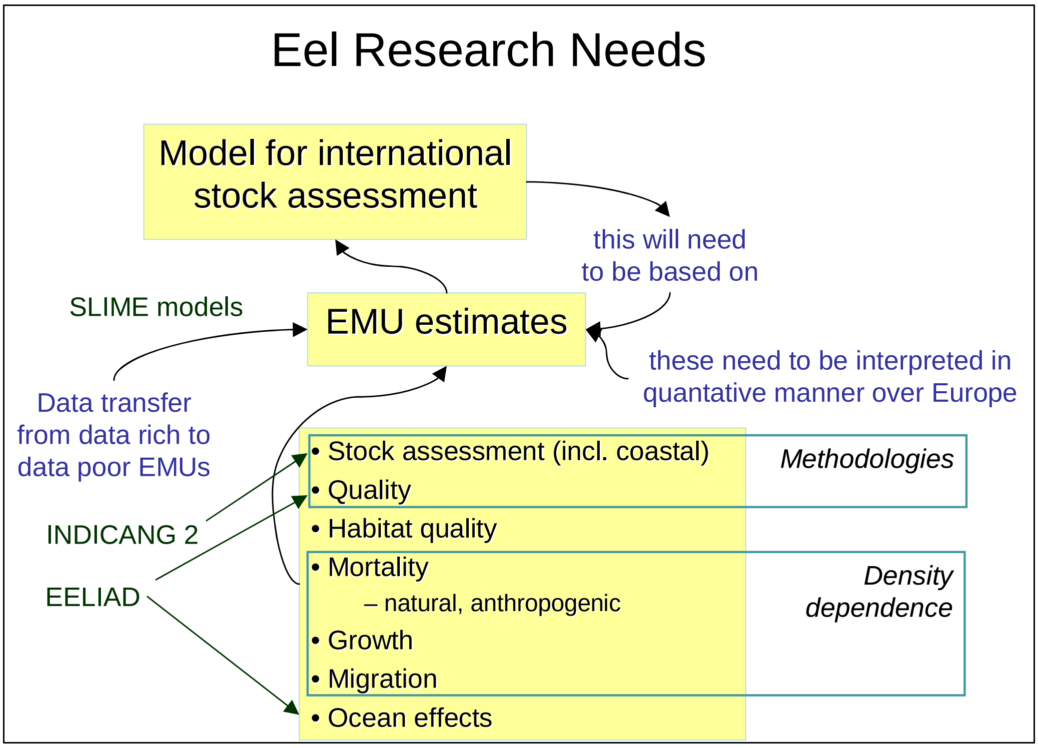


Figure 8.1: Flow diagram showing linkages between research needs.

The priorities for integrated research are as follows:

- International Stock Assessment and trend monitoring
- Local stock assessment and post-evaluation of management actions
- Process based research on biological parameters required for estimating escapement.

8.2.1 International stock assessment and trend monitoring

Improved annual trends on recruitment, stock and yield

Emigrating silver eel biomass, numbers and sex ratio

The aggregation of river basin specific data and assessments, into stock-wide assessments in support of stock to recruitment (S-R) and recruitment to spawner stock biomass (R-SSB) assessment and modelling (e.g.VPA).

The further development of models to assess compliance with the recovery target and evaluate management actions

The international assessment of recruitment and stock trends to assess the response of the stock to management actions under the Regulation, noting the WGEEL recommendation on accessibility to national eel management plans and supporting eel data.

8.2.2 Local stock assessment and post-evaluation of management actions

The development of local stock assessment procedures and estimates of silver eel escapement

The further development of models and methodologies to assess compliance at the local scale with the recovery target and evaluate management actions

The development and testing of methods to characterize and quantify eel stocks in deeper areas of rivers, lakes, estuaries and coastal waters

The testing of relationships between habitat characteristics, eel quality and eel production as indicators of the relative production potential for different habitats

To develop methods for quantitative assessment of the availability of local surplus for stocking, and for the contribution of stocking to escapement

Implementation of EMPs requires the development of methodologies to obtain estimates of escapement. These can be direct (*e.g.* mark-recapture or acoustic counting) or indirect methods (*e.g.* yellow eel proxies to determine silver eel production and eel habitat modelling production). Validation of indirect methodologies is required.

8.2.3 Process based research on biological parameters required for estimating escapement

Quantify the possible density-dependence effects in various processes including mortality, growth, movement, maturation and sex differentiation.

Quantify the impacts of pathogens, parasites, diseases, and low chemical quality on effective silver eel escapement and spawning success. This should include the relationship between eel quality and body fat content.

Quantify any impact of aquaculture, transport and stocking of eel in terms of reduced spawner production

Research is required on the relative importance of the habitat types used by eels and what demographic characteristics they exhibit in these habitats, such between fresh (rivers and lakes) and saline (brackish/salt) waters.

Recent research has suggested that processes in the oceanic phase (including spawner quality) may be important in determining recruitment levels. Improved knowledge of the oceanic phases of the eel is needed to further the initial search for correlations between eel recruitment and oceanic processes.

8.3 Other research needs

WGEEL 2008 focused heavily on the requirements of the EU Regulation and the need for international and national stock assessment. Additional research will be required in order to fill many gaps in the biology and management of eel.

Research on optimum collection and transport methods for glass eel to reduce mortality for stocking

Timing and frequency of stocking

Related eel health issues

Post-evaluation methods for the net benefit of stocking for conservation

Investigations examining the competitiveness, survival and reproductive capacity of stocked glass eels, compared with their naturally recruited counterparts by marking the stocked individuals and comparing their recapture at sexual maturity

Quantify the relation between fat content and eel quality, the effects of specific contaminants and parasites on fat metabolism and a possible relationship between eel fat content and environmental variables such as changing temperature, changing trophic status, and food availability

Predator prey relationships (e.g. cormorants).

8.4 Proposals for study groups

WGEEL proposes that an ICES Study Group is established to coordinate and plan research on the oceanic effects on leptocephali and metamorphosis to glass eel.

WGEEL notes and approves the proposal for an eel age calibration workshop.

WGEEL notes and approves the proposal to the DFC (2008) for a study group on anguillid eels in saline (brackish/salt) waters.

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Annex 2 – Agenda

Agenda for Joint EIFAC/ICES WGEEL 2008, Leuven

Wednesday 3rd September

9.00	Get organized
9.30–10.00	Welcome RP
	Welcome Dr Jurgen Tack, INBO
	Local Welcome and Information: Filip Volckaert/Greg Maes
10.00–10.30	Intro to Working Group, ToR, etc. RP
10.30	Coffee
10.45–11.15	EEQD and eel Quality, introduced by Belpaire
11.15–11.45	Aquaculture and Restocking, introduced by Wickstrom and Evans
11.45–12.15	Methodologies-concepts, time frames, introduced by Astrom
12.15–13.30	Lunch
13.30–14.00	Methodologies-biomass, escapement and targets, intro by Aprahamian
14.00–14.30	Data Group, introduced by Dekker/Beaulaton
14.30–15.30	Ocean and Climate, introduced by O'Toole and Westerberg
15.30	Coffee
16.00–16.30	Genetics and the EU Regulation, introduced by Maes
16.30–17.00	Genetics, introduced by Zane
17.00–17.15	Update from Norway on marine data on eel, introduced by Knutsen
17.15–17.30	Update from N. America/Canada, introduced by Verrault
until 18.00	Breakout to get organized, subgroups, rapporteurs, approaches, etc.

Thursday-Sub Groups breakout

16.00–18.00	Plenary

Friday-Sub Groups breakout

16.00–18.00	Plenary

Saturday morning-Sub Groups breakout

9.00–10.00	Plenary (optional depending on progress on Friday pm)
14.00–15:00	Present conclusions and recommendations draft 1.
15.30–18.00	Producing draft report [DEADLINE 18:00]

Sunday-Sub Group leaders and Chair to do initial draft of technical advice

Print hard copies of report

Monday

9.00–13:00 Circulate draft advice and hard copy report for comment

14.00–18:00 Discuss and agree Report, and Recommendations

Tuesday

9.00–13:00 Discuss Report, and Recommendations and agree technical advice

Conclude at 14.00 The afternoon is available to tie up loose ends.

Annex 3 – Recruitment, landings and stocking dataseries

Table 1 Part 1 Recruitment dataseries of glass eel: Sweden, Northern Ireland (N.Irl) and Ireland.

COUNTRY	SE	SE	SE	SE	N.IRL	IE	IE
Year	IYFS/IBTS (old data)	IYFS/IBTS (new data)	Ringhals	Viskan	Bann	Erne	Shannon
Unit	Index	Index	Kg	Kg	Kg	t	t
1923							
1924							
1925							
1926							
1927							
1928							
1929							
1930							
1931							
1932							
1933							
1934							
1935							
1936					7333		
1937					9000		
1938					8000		
1939					6333		
1940					9000		
1941					10 000		
1942					7000		
1943					6000		
1944					5333		
1945					5667		
1946					7000		
1947							
1948							
1949							
1950							
1951							
1952							
1953							
1954							
1955							
1956							
1957							
1958							
1959						0.24	
1960					7409	1.23	
1961					4939	0.63	
1962					6740	2.47	

COUNTRY	SE	SE	SE	SE	N.IRL	IE	IE
1963					9077	0.43	
1964					3137	0.21	
1965					3801	0.90	
1966					6183	1.40	
1967					1899	0.30	
1968					2525	1.50	
1969					422	0.60	
1970					3992	0.60	
1971				12,00	4157	0.50	
1972				88,00	2905		
1973				177,00	2524		
1974				13,00	5859	0.80	
1975	45.00			99,00	4637	0.40	
1976	655.00			501,00	2920	0.40	
1977	405.00			850,00	6443	0.10	1.00
1978	126.00			532,60	5034	0.30	1.30
1979	122.00			505,20	2089	0.50	6.70
1980	6.00			72,50	2486	1.40	4.50
1981	134.00		849.00	513,10	3023	2.90	2.10
1982	90.00		710.72	472,00	3854	4.50	3.10
1983	355.00		553.48	308,40	242	0.70	0.60
1984	26.00		175.39	20,70	1534	1.10	0.50
1985	54.00		304.64	211,50	557	0.50	1.09
1986	72.00		45.09	150,90	1848	0.90	0.95
1987	24.00		51.78	140,90	1683	2.40	1.61
1988	19.00		168.60	91,90	2647	3.00	0.15
1989	34.00		183.95	32,70	1568	1.80	0.03
1990			186.03	42,10	2293	2.40	0.47
1991		0.001	138.14	0,40	677	0.50	0.09
1992		0.003	282.97	70,30	978	1.40	0.03
1993		0.007	373.94	43,40	1525	1.80	0.02
1994		0.012	636.41	76,10	1249	4.50	0.29
1995		0.009	276.66	5,50	1403	2.40	0.40
1996		0.001	43.80	10,00	2668	1.00	0.33
1997		0.001	116.89	7,60	2533	1.09	2.12
1998		0.002	164.40	5,00	1283	0.74	0.28
1999		0.003	147.19	1,80	1345	1.06	0.02
2000		0.011	399.67	14,10	563	0.91	0.04
2001		0.001	31.89	1,80	315	0.70	0.00
2002		0.003	170.95	26,20	1092	0.11	0.18
2003		0.002	92.00	45,10	1210	0.69	0.38
2004		0.000	30.65	5,00	342	0.29	0.06
2005		0.002	110.44	25,80	852	0.84	0.04
2006		0.001	41.95	2,70	456	0.12	0.04
2007		0.000	102.40	2,10	445	0.19	0.05
2008		0.000	34.00	3,40	25	0.03	0.00

Table 1 Part 2 Recruitment dataseries of glass eels: UK, Denmark, Germany and Netherlands.

***HMRC = nett export data from Her Majesty’s Revenue and Customs (see UK Country report)**

COUNTRY	UK	DK	DE	NL	NL	NL	NL	NL
Year	Severn (HMRC)*	Vidaa	Ems	Lauwersoog	DenOever	IJmuiden	Katwijk	Stellendam
Unit	t	Kg	Kg	Index	Index	Index	Index	Index
1923								
1924								
1925								
1926								
1927								
1928								
1929								
1930								
1931								
1932								
1933								
1934								
1935								
1936								
1937								
1938					20.75			
1939					46.68			
1940					17.46			
1941					14.90			
1942					23.61			
1943					15.77			
1944					45.88			
1945								
1946			600		7.56			
1947			1438		7.37			
1948			1640		6.41			
1949			1182		6.34			
1950			875		8.23			
1951			719		16.60			
1952			1516		106.71			
1953			3275		18.17			
1954			5369		27.03			
1955			4795		37.37			
1956			4194		9.76			
1957			1829		21.82			
1958			2263		71.79			
1959			4654		39.37			
1960			6215		29.74			
1961			2995		51.34			
1962			4430		120.66			
1963			5746		172.22			
1964			5054		53.57			

Country	UK	DK	DE	NL	NL	NL	NL	NL
1965			1363		110.71			
1966			1840		26.64			
1967			1071		40.88			
1968			2760		27.91			
1969			1687		23.96	47.30		
1970			683		54.59	31.50		
1971		787.00	1684		24.12			15
1972		780.00	3894		43.24			4
1973		641.00	289		31.05	32.80		13
1974		464.00	4129		35.93	119.30		23
1975		888.00	1031		46.60	66.80		14
1976		828.00	4205	14.40	38.21	73.10		11
1977		91.00	2172	28.40	80.27	159.20	130.25	42
1978		335.00	2024	83.90	54.29	131.70	30.23	42
1979	40.10	220.00	2774	66.20	75.47	176.00	3.23	27
1980	32.80	220.00	3195	80.30	37.82	101.50	171.60	45
1981		226.00	962	55.10	32.09	113.90	31.65	47
1982	30.40	490.00	674	17.40	20.24	20.80	4.13	11
1983	6.20	662.00	92	15.10	13.58	15.60	2.10	14
1984	29.00	123.00	352	7.10	18.07	11.40	23.62	4
1985	18.60	13.00	260	25.20	18.28	1.00	6.67	9
1986	15.50	123.00	89	1.30	19.25	4.70		6
1987	17.70	341.00	8	52.00	7.46	7.70	14.00	10
1988	23.10	141.00	67	0.50	5.72	3.50		8
1989	13.50	9.00	13	12.10	3.95	1.60	3.67	4
1990	16.00	5.00	99	5.00	4.71	4.70		11
1991	7.80		52	6.30	1.44	2.00	5.10	2
1992	17.70		6	7.30	3.79	2.50	8.20	10
1993	20.90		20	20.80	3.80	1.60	13.50	5
1994	22.30		52	22.50	5.98	3.60	15.10	3
1995			40	11.60	8.37	13.10	27.10	3
1996	23.90		20	34.40	9.49	4.00	25.40	0
1997	16.20		5	20.90	15.24	1.30	10.90	3
1998	20.10		4	9.90	2.73	1.20	38.80	1
1999	18.00		3	15.10	4.23	1.60	101.30	1
2000	7.60		4	6.60	2.06	1.50	8.80	6
2001	5.40		1	1.70	0.68	0.40	8.10	1
2002	5.10			3.40	1.36	0.05	9.80	4
2003	10.00			1.20	1.84	0.00	11.80	0
2004	14.40			1.70	1.87	0.11	4.50	0.3
2005	8.80			0.90	1.02	0.00	4.40	0.2
2006	8.20			1.39	0.43	0.07	1.33	0
2007				1.13	1.35	0.09	24.77	0
2008				2.54	0.36	0.06	4.31	0

Table 1 Part 3 Recruitment dataseries of glass eels: Belgium and France.

COUNTRY	BE	FR	FR	FR	FR	FR	FR	FR
Year	Ijzer	Vilaine	Loire	Sèvres Niortaise (cpue)	Gironde (cpue)	Gironde	Adour	Adour (cpue)
Unit	Kg	Kg	Kg	cpue	cpue	t	t	cpue
1923						46.0		
1924			65.0					
1925			70.0					
1926			90.0			18.7		
1927			65.0			34.1		
1928			102.0			22.4		
1929						22.5		
1930			1.0			28.2		
1931						26.9		
1932						31.1		
1933						13.5		
1934			90.0			13.4		
1935			150.0			19.7		
1936			30.0					
1937			7.0					
1938			15.0					
1939			17.0					
1940			27.0					
1941			21.0					
1942								
1943								
1944			10.0					
1945			66.0					
1946			43.0					
1947			178.0					
1948			197.0					
1949			193.0					
1950			86.0					
1951			166.0					
1952			121.0					
1953			91.0					
1954			86.0					
1955			181.0					
1956			187.0					
1957			168.0					
1958			230.0					
1959			174.0					
1960			411.0					
1961			334.0			32.2		
1962			185.0	30.00		217.8		
1963			116.0	72.00		363.0		

COUNTRY	BE	FR	FR	FR	FR	FR	FR	FR
1964	3.70		142.0					
1965	115.00		134.0	17.00		352.5		
1966	385.00		253.0	13.00		27.6		
1967	575.00		258.0	8.00		162.8		
1968	553.50		712.0	15.00		284.2		
1969	445.00		225.0	14.00		36.6		
1970	795.00		453.0	15.00		203.8		
1971	399.00	44	330.0	12.00		47.1		
1972	556.50	38	311.0	11.00		69.0		
1973	354.00	78	292.0	8.50		20.0		
1974	946.00	107	557.0	9.00		54.6		
1975	274.00	44	497.0	8.50		44.1		
1976	496.00	106	770.0	17.00		120.9		
1977	472.00	52	677.0	15.00		121.6		
1978	370.00	106	526.0	18.00		64.7		
1979	530.00	209	642.0	17.50	19.7	73.2		
1980	252.00	95	526.0	12.00	25.9	124.7		
1981	90.00	57	303.0	9.00	20.0	84.9		
1982	129.00	98	274.0	8.50	15.0	61.0		
1983	25.00	69	260.0	6.00	13.6	66.7		
1984	6.00	36	183.0		19.2	45.0		
1985	15.00	41	154.0		9.6	27.0		2.40
1986	27.50	52.6	123.0		10.6	35.3	8.00	1.5
1987	36.50	41.2	145.0		14.0	44.6	9.50	3.3
1988	48.20	46.6	177.0		10.9	27.9	12.00	3.7
1989	9.10	36.7	87.0		7.2	45.9	9.00	4.1
1990	218.20	35.9	96.0		5.6	29.3	3.20	1.2
1991	13.00	15.35	36.0		7.7	38.4	1.50	0.7
1992	18.90	29.57	39.0		3.7	22.5	8.00	2.9
1993	11.80	31	91.0		8.2	42.4	5.50	2.4
1994	17.50	24	103.0		8.7	45.5	3.00	1.4
1995	1.50	29.7	133.0		8.2	43.5	7.50	2.6
1996	4.50	23.286	81.0		4.8	27.9	4.10	1.53
1997	9.80	22.85	71.0		6.5	49.3	4.60	1.6
1998	2.25	18.9	66.0		4.3	18.4	1.50	1.07
1999		16	87.0		7.5	43.1	4.30	1.82
2000	17.85	14.45	80.0		6.6	28.5	10.00	4.43
2001	0.70	8.46	33.0		1.9	8.2	2.00	0.49
2002	1.40	15.9	42.0		4.9	35.1	1.80	0.89
2003	0.54	9.37	53.0		2.7	9.6	0.60	0.31
2004	0.38	7.49	27.0		2.5	14.4	1.80	0.6
2005	0.79	7.36	17.0			17.2	3.20	1.13
2006	0.07	6.6	15.0			9.3	1.70	0.72
2007	2.21	7.7	21.0			8.0	1.40	0.66
2008	0.96	5.1						0.76

Table 1 Part 4 Recruitment dataseries of glass eel: Spain, Portugal and Italy.

COUNTRY	ES	ES	ES	ES/PT	IT	ALL COUNTRIES
Year	Nalon	Albufera	Minho	Minho	Tiber	Geo mean
Unit	Kg	Kg	Kg	Kg	t	
1923						44.74
1924						58.58
1925						69.37
1926						77.02
1927						89.04
1928						64.77
1929						55.96
1930						39.00
1931						13.00
1932						33.24
1933						106.35
1934						154.02
1935						171.46
1936		35 000				186.74
1937		48 000				237.53
1938		45 000				277.85
1939		30 000				224.47
1940		40 000				240.02
1941						237.68
1942						193.96
1943						165.03
1944						175.47
1945						161.63
1946						158.41
1947						181.24
1948						186.83
1949						201.97
1950						217.48
1951						212.26
1952	14 529					226.69
1953	8318					271.49
1954	13 576					277.86
1955	16 649					261.82
1956	14 351					294.95
1957	12 911					291.36
1958	13 071					298.88
1959	17 975	10 000				315.73
1960	13 060	17 000				375.14
1961	17 177	11 000				400.34
1962	11 507	16 000				359.92
1963	16 139	11 000				346.25
1964	20 364	4000				342.57
1965	11 974	6000				302.23
1966	12 977	5000				295.73
1967	20 556	4000				324.68

Table 1 Part 4 cont. Recruitment dataseries of glass eel: Spain, Portugal and Italy.

COUNTRY	ES	ES	ES	ES/PT	IT	ALL COUNTRIES
Year	Nalon	Albufera	Minho	Minho	Tiber	Geo mean
Unit	Kg	Kg	Kg	Kg	t	
1968	15 628	4000				321.77
1969	18 753	5000				291.24
1970	17 032	1000				284.07
1971	11 219	1000				253.16
1972	11 056	1000				256.52
1973	24 481	2000				250.27
1974	32 611	1000	1600	1650		285.49
1975	55 514	6000	5600	10 600	11.00	308.72
1976	37 661	5000	12 500	20 000	6.70	333.15
1977	59 918		21 600	36 600	5.90	359.93
1978	37 468		17 300	24 300	3.60	380.91
1979	42 110		15 400	28 400	8.40	371.26
1980	34 645		13 000	16 000	8.20	331.89
1981	26 295	1309	18 000	50 000	4.00	268.50
1982	21 837	640	9700	16 400	4.00	207.08
1983	22 541	2387	14 000	30 000	4.00	152.15
1984	12 839	2980	15 300	30 100	1.80	114.54
1985	13 544	402	6000	13 000	2.50	99.85
1986	23 536	2845	6539	16 039	0.20	92.32
1987	15 211	4255	5600	8200	7.40	79.45
1988	13 574	2513	7359	10 359	10.50	77.32
1989	9216	1321	3962	8462	5.50	63.56
1990	7117	1079	5743	8243	4.40	53.62
1991	10 259	831	2835	7335	0.80	48.83
1992	9673	299	4893	8493	0.60	52.91
1993	9900	302	2068	4968	0.50	50.79
1994	12 500	199	4701	10 001	0.50	54.08
1995	5900	271	6523	15 223	0.30	53.06
1996	3656	366	4283	8683	0.10	47.36
1997	3273		2878	7378	0.10	39.70
1998	3815	616	3812	7412	0.13	35.35
1999	1330	323	3812	6812	0.06	26.73
2000	1285	678	1519	2719	0.07	22.88
2001	1569	466	1427	2527	0.04	20.60
2002	1231	357	1755	3198	0.02	16.54
2003	506	233	1562	2376	0.02	14.20
2004	914	209	1331	2505	0.03	12.67
2005	836		320	3056	0.03	11.26
2006	615		1140	2045	0.00	7.91
2007	871	165		750		7.41
2008						5.78

Table 2 Part 1 Recruitment dataseries of yellow eel: Norway and Sweden.

Country	NO	SE	SE	SE	SE	SE	SE	SE
Site	Imsa	Dalälven	Motala Ström	Mörrumsån	Kävlingeån	Rönne Å	Lagan	Göta Älv
Unit	Numbers	Kg	Kg	Kg	Kg	Kg	Kg	Kg
1900								530
1901								5100
1902								340
1903								858
1904								552
1905								8700
1906								2000
1907								275
1908								
1909								
1910								
1911								5728
1912								6529
1913								20
1914								2828
1915								
1916								
1917						45		
1918						5		
1919								1465
1920								800
1921								1555
1922								455
1923								1732
1924								4551
1925							331	5463
1926						49	358	3893
1927						445	581	4796
1928						0	212	47
1929						0	5	756
1930						147	268	5753
1931							316	2103
1932							408	7238
1933							304	6333
1934							236	6338
1935							54	1336
1936							25	2537
1937							1	8711
1938							107	3879
1939							36	4775
1940							684	1894
1941							321	2846
1942			14				454	427
1943			283				1248	1848
1944			773				1090	2342
1945			406				1143	2636
1946			280			30	767	2452
1947			273			6	441	675
1948			120			6	495	1702
1949			43			39	604	1711
1950			305			94	420	2947
1951		210	2713			1	281.8	1744
1952		324	1543.5			9.1	379.1	3662
1953		241.5	2698			70	802.4	5071

Country	NO	SE	SE	SE	SE	SE	SE	SE
1954		508.5	1030			2.7	511.3	1031
1955		550	1871			42.6	506.9	2732
1956		215	429			14.1	501.6	1622
1957		161.5	826			46.8	336.1	1915
1958		336.7	172			73.2	497.2	1675
1959		612.6	1837			80	910.5	1745
1960		289	799	29		93	552.4	1605
1961		303	706	665.5		143.7	314.8	269
1962		289	870	534.8		113	261.9	873
1963		445.4	581	241.2		32.5	298.1	1469
1964		158	181.6	177.8		34.7	27.5	622
1965		276.4	500	292.3		87.1	28	746
1966		157.5	1423	196.3		48.5	216.5	1232
1967		331.8	283	353.6		6.6	24.4	493
1968		265.5	184	334.8		398	74.4	849
1969		333.7	135	276.8		85.7	117.1	1595
1970		149.8	2	80.4		29.8	24.7	1046
1971		242	1	141.1		53.3	45.3	842
1972		87.6	51	139.9		249	106.2	810
1973		159.7	46	375		282.3	107.1	1179
1974		49.5	58.5	65.4		120.7	33.6	631
1975	42 945	148.7	224	93.3		206.7	78.4	1230
1976	48 615	44	24	147.2		17.1	20.2	798
1977	28 518	176.4	353	89.6		32.1	26.4	256
1978	12 181	35.1	266	168.4		10.8	75.8	873
1979	2457	34.3	112	61.4		56.1	165.9	190
1980	34 776	71.2	7	36.5		165.7	226	906
1981	15 477	6.8	31	72.8		49.2	78	40
1982	45 750	0.5	22	129		40	90.8	882
1983	14 500	112.1	12	204.6		37.6	87.8	113
1984	6640	33.9	48	189.9		0.5	68	325
1985	3412	69.7	15.2	138.1			234.1	77
1986	5145	28.4	26	220.3		8.6	2.5	143
1987	3434	73.5	201	54.5		84.8	69.8	168
1988	17 500	69	169.5	241		4.9	191.7	475
1989	10 000		35.2	30			44	598
1990	32 500		21	72.5		32	21.6	149
1991	6250		2	151			161.3	264
1992	4450	9.6	108	14	12.5		42.2	404
1993	8625	6.6	89	45.7	25.8		8.7	64
1994	525	71.9	650	283	4		30.7	377
1995	1950	7.6	32	72.4	2.9		11.6	
1996	1000	17.5	14	51.9	13.5		2.8	277
1997	5500	7.5	8.1	148	19.4	10.4	31.7	180
1998	1750	14.7	5.5	12.9	15.3	24	62.6	
1999	3750	15.5	85	84.2	22.2	4.2	49.5	
2000	1625	12.4	270.1	1	5		13	
2001	1875	8.2	177.5	19.3	34.5	1.8	26.8	
2002	1375	58.6	338.8	37.4	19.3	27	102	693
2003	3775	126.1	19	11	9.7	9.1	31.7	266
2004	375	26.4	42	1.5	248.3	2	29	125
2005	1550	30.9	24.8	2.5	3.4	0.1	20.5	105
2006	350	35.1	25.9	2.5	94.4	0.1	38.1	0.04
2007	100	18.4	30	112.6	76	4.45	77	>0
2008		30.5					25	>0

Table 2 Part 2 Recruitment dataseries of yellow eel: Ireland, Denmark and Belgium.

COUNTRY	IE	DK	DK	BE	ALL COUNTRIES
Site	Shannon (Parteen)	Tange	Harte	Meuse (Lixhe dam)	GeO mean
Unit	Kg	Kg	Kg	Kg	
1900					431.01
1901					417.75
1902					375.37
1903					656.92
1904					544.76
1905					522.12
1906					565.16
1907					747.03
1908					328.77
1909					556.39
1910					2711.05
1911					402.41
1912					534.63
1913					534.63
1914					318.05
1915					129.79
1916					169.26
1917					135.94
1918					172.77
1919					227.85
1920					229.01
1921					476.60
1922					597.87
1923					758.60
1924					739.67
1925					1118.82
1926					1229.23
1927					1042.09
1928					958.06
1929					1007.62
1930					984.53
1931					1034.89
1932					1039.92
1933					791.69
1934					624.67
1935					325.48
1936					279.10
1937					224.80
1938					300.35
1939					392.97
1940					490.04
1941					558.65
1942					748.44
1943					793.63
1944					743.91

Table 2 Part 2 cont. Recruitment dataseries of yellow eel: Ireland, Denmark and Belgium.

COUNTRY	IE	DK	DK	BE	ALL COUNTRIES
Site	Shannon (Parteen)	Tange	Harte	Meuse (Lixhe dam)	GeO mean
Unit	Kg	Kg	Kg	Kg	
1945					801.02
1946					606.09
1947					449.17
1948					399.33
1949					366.84
1950					454.81
1951					637.36
1952					679.34
1953					743.05
1954					783.63
1955					769.58
1956					656.79
1957					810.48
1958					692.09
1959					721.90
1960					730.62
1961					710.24
1962					492.69
1963					460.66
1964					443.88
1965					354.52
1966					333.47
1967			500		369.91
1968			200		285.38
1969			175		205.28
1970			235		213.55
1971			59		201.87
1972					170.90
1973			117		220.02
1974			212		229.87
1975			325		217.71
1976			91		196.31
1977			386		189.19
1978			334		164.10
1979			291		152.73
1980		93	522		133.34
1981		187	279		122.33
1982		257	239		108.26
1983		146	164		100.89
1984		84	172		100.00

COUNTRY	IE	DK	DK	BE	ALL COUNTRIES
1985	984	315	446		103.08
1986	1555	676	260		111.98
1987	984	145	105		120.01
1988	1265	252	253		115.23
1989	581	354	145		112.06
1990	970	367	101		97.76
1991	372	434	44		76.79
1992	464	53	40	5613	74.26
1993	602	93	26		62.15
1994	125	312	35		51.00
1995	799	83	23	4240	50.31
1996	95	56	6		46.37
1997	906	390	9	2706	44.80
1998	255	29	18	3061	42.81
1999	701	346	15	4664	43.72
2000	389	87.9	18.9	3365	48.39
2001	3	239	11.4	2915	52.90
2002	677	278.2	17	1790	45.00
2003	873	260.2	9.6	1842	40.37
2004	320	246.1	8.7	423	33.64
2005	612	87.7	7.4	758	24.01
2006	467	122.5	6.8	559	14.48
2007	757	62	7	6619	11.84
2008	1236				10.06

Table 3 Landings of European eel in Europe (tons). Data obtained from Country Reports 2008.

	BE	DK	EE	FI	FR	DE	IE	IT	LV	LT	NL	NO	PL	PT	ES	SE	UK
1945											2668	102				1664	
1946									1		3492	167				1512	
1947									10	8	4502	268				1910	
1948									10	14	4799	293				1862	
1949									11	21	3873	214				1899	
1950									14	29	4152	282			90	2188	
1951									13	32	3661	312			102	1929	
1952									14	39	3978	178			80	1598	
1953									30	80	3157	371			98	2378	
1954									24	147	2085	327			103	2106	
1955									47	163	1651	451			106	2651	
1956									26	131	1817	293			80	1533	
1957									25	168	2509	430			115	2225	
1958									27	149	2674	437			100	1751	
1959						84			30	155	3413	409			98	2789	
1960						51			44	165	2999	430			95	1646	
1961						48			50	139	2452	449			91	2066	
1962						67			46	155	1443	356			95	1908	

	BE	**DK**	**EE**	**FI**	**FR**	**DE**	**IE**	**IT**	**LV**	**LT**	**NL**	**NO**	**PL**	**PT**	**ES**	**SE**	**UK**
1963						55			64	260	1618	503			92	2071	
1964						56			43	225	2068	440			76	2288	
1965						56			41	125	2268	523			79	1802	566
1966						68			43	238	2339	510			80	1969	617
1967						92			46	153	2524	491			66	1617	570
1968						103			34	165	2209	569			57	1808	586
1969						302		2469	43	134	2389	522			0	1675	607
1970						238		2300	29	118	1111	422			43	1309	754
1971						255		2113	29	124	853	415			44	1391	844
1972						239		1997	25	126	857	422			44	1204	634
1973						257		589	27	120	823	409	705		33	1212	725
1974						224		2122	20	86	840	368	747	0	25	1034	767
1975						226		2886	19	114	1000	407	869	5	17	1399	764
1976				28		205		2596	24	88	1172	386	804	8	14	935	627
1977				63		214		2390	16	68	783	352	911	15	0	989	692
1978				77		163		2172	18	70	719	347	929	7	0	1076	825
1979				77		158		2354	21	57	530	374	1025	13	0	956	1206
1980				79		140		2198	9	45	664	387	1233	3	11	1112	1110
1981				39		131		2270	10	27	722	369	970	32	19	887	1139
1982				38		166		2025	12	28	842	385	939	7	16	1161	1189
1983				38		155		2013	9	23	937	324	896	18	14	1173	1136
1984				28		114		2050	12	27	691	310	846	19	11	1073	1257
1985				28		477		2135	18	29	679	352	1048	10	14	1140	1035
1986				28	2462	405		2134	19	32	721	272	947	13	12	943	926
1987				19	2720	359		2265	25	20	538	282	914	6	15	897	1006
1988					2816	364		2027	15	23	425	513	943	6	10	1162	1110
1989					2266	379		1243	13	21	526	313	813	8	0	952	1172
1990					2170	374		1088	13	19	472	336	768	5	4	942	1014
1991					1925	335		1097	14	16	573	323	670	7	0	1084	1058
1992					1585	322		1084	17	12	548	372	638	7	5	1180	915
1993			59		1736	250		782	19	10	293	340	568	9	5	1210	857
1994			47		1694	246		771	19	12	330	472	635	7	4	1553	1077
1995			45		1832	242		1047	38	9	354	454	638	10	4	1205	1312
	BE	DK	EE	FI	FR	DE	IE	IT	LV	LT	NL	NO	PL	PT	ES	SE	UK
1996			55		1562	220		953	24	9	300	353	632	6	6	1134	1246
1997		797	59		1537	263		727	25	11	285	467	533	5	23	1382	1190
1998		597	44		1345	28		668	30	17	323	331	551	5	43	645	943
1999		717	65		1253	38		634	26	18	332	447	592	4	45	734	963
2000		628	67		1200	36		539	17	11	363	281	438	2	90	561	702
2001		707	65		1103	141	98	438	15	12	371	304	434	1	106	543	742
2002		609	50			130	123	105	19	13	353	311	371	2	80	633	650
2003		649	49			125	111	105	11	12	279	240	359	2	70	565	574
2004		546	39			117	136	382	11	16	245	237	330	2	71	551	634
2005		534	36			108	101	75	11	22	230	249	251	4	74	628	545
2006		595	33			87	133	56	8			293	217	2	39	670	408

	BE	DK	EE	FI	FR	DE	IE	IT	LV	LT	NL	NO	PL	PT	ES	SE	UK
2007	43	537	31			317	114		10		130	194	193	2		568	427

Table 4 Landings of European eel in Europe (tons). Source: FAO.

	BE	DK	EE	FI	FR	DE	IE	IT	LV	LT	NL	NO	PL	PT	ES	SE	UK
1950		4500			500	400	100	895			4200	300	700		100	2200	100
1951		4400			500	400	100	849			3700	300	700		100	1900	100
1952		3900			700	400	100	873			4000	200	900		200	1600	100
1953		4300			600	500	100	846			3100	400	900		200	2400	400
1954		3800			500	300	100	830			2100	300	800		200	2100	500
1955		4800			500	500	100	814			1700	500	1000		700	2600	700
1956		3700			500	400	100	1796			1800	300	900		800	1500	600
1957		3600			500	400	100	1776			2500	400	800		501	2200	600
1958		3300			600	400	100	1754			2800	400	1200		500	1800	600
1959		4000			900	500	100	2614			3400	400	700		600	2800	700
1960		4700			1300	400	100	2276			3000	400	1000		400	1600	800
1961		3900			1300	500	100	2134			2500	500	900		400	2100	800
1962		3900			1300	400	100	2589			1600	400	1000		801	1900	700
1963		4000			1400	2100	100	2939			1900	500	1000		1300	1900	700
1964		3300			1400	1900	100	2884			2500	400	1100		1800	2368	600
1965		3200			1700	1500	200	2524			2600	500	900		1400	1868	800
1966		3700			1300	1700	100	2357			2800	500	1000		1400	2070	1000
1967		3500			2000	1900	100	2286			3100	500	1100		1500	1667	600
1968		4300			2700	1800	100	2306			2700	600	1100		1400	1872	600
1969		3700			1900	1600	100	2418			2800	500	1100		1500	1773	600
1970		3400			3091	1600	200	3292			1500	400	1000		1100	1270	800
1971		3200			4521	1300	200	3408			1200	400	900		1100	1469	800
1972		3300			2600	1300	200	2893			1100	400	900		1500	1274	700
1973		3554			3937	1282	91	2910			1105	409	825	47	700	1213	800
1974		2870			2493	1285	67	2697			1029	368	891	42	1300	1030	817
1975		3293			1590	1398	79	2973			1213	407	917	44	570	1492	833
1976		2926		28	2959	1322	150	2677			1353	386	674	38	675	1023	694
1977		2381		63	1538	1317	108	2462			961	352	996	52	666	1084	742
1978		2379		77	2455	1162	76	2237			891	347	941	44	655	1162	877
1979		1860		77	3144	1164	110	2422			729	374	1007	25	460	1038	879
1980		2254		64	1921	1051	75	2264			877	387	910	32	344	1205	1053
1981		2229		31	1425	1033	94	2340			898	369	752	33	250	976	858
1982		2538		30	1469	1027	144	2087			1153	385	895	14	269	1250	1032
1983		2120		30	1856	1029	117	2076			1288	324	1103	11	188	1302	1113
1984		1855		24	2306	911	88	2361			723	310	1698	20	170	1161	957
1985		1601		23	2228	866	87	1907			688	352	1337	16	215	1211	781
	BE	DK	EE	FI	FR	DE	IE	IT	LV	LT	NL	NO	PL	PT	ES	SE	UK
1986		1643		25	2687	887	87	1928			685	272	1134	42	226	922	997
1987		1273		1	1978	731	230	2076			359	282	962		297	703	939

	BE	DK	EE	FI	FR	DE	IE	IT	LV	LT	NL	NO	PL	PT	ES	SE	UK
1988	<0.5	1784	11	1	2109	746	215	2165	3	94	433	513	1087		224	965	715
1989	30	1696	32	1	1672	678	400	1301	8	81	332	313	1109		119	952	1075
1990	30	1674	74		1674	978	256	1199		120	209	336	913	28	104	941	1039
1991	125	1464	3		1450	1010	245	1106		16	160	323	1097	44	85	1085	822
1992	125	1448	9		1164	1026	234	1662	19	12	89	372	1095	52	97	1180	782
1993	125	1081	59		864	1027	260	1307	18	10	419	340	1116		77	1144	752
1994	125	1200	54		607	585	300	986	39	12	358	472	1090		80	1298	873
1995	125	904	38		320	584	400	886	28	10	433	454	627		68	1100	808
1996	125	735	54	22	403	696	400	883	26	12	336	353	639		68	1042	895
1997	125	796	56	22	1782	746	400	1010	29	11	316	497	489		72	1073	807
1998	125	600	44	22	449	717	400	682	27	17	344	363	454		23	645	741
1999	100	711	60		289	746	250	645	17	18	372	475	474	30	39	736	697
2000	100	620	67		399	686	250	549	15	11	351	281	429	29	70	561	796
2001	100	658	67		415	638	110	446	19	12	374	304	425	37	62	580	595
2002		569	55		402	636	104	402	11	13	373	311	361	36	93	634	571
2003		620	64		412	251	81	458	11	13	366	240	321	13	40	565	588
2004		534	47		321	243	119	387	12	16	331	237	270	11	57	568	504
2005		531	69		186	285	87	115	17	22	317	249	220	9	55	668	493

Stocking

- Lithuania: the first stocking was in 1928–1939, when 3.2 million elvers were released in the lakes. Since the 1960s, about 50 million elvers or young yellow eels have been stocked.
- Estonia: stocking on a national level.
- France: no stocking on a national level.
- Italy: historic stocking in considerable amounts in lagoons and lakes, but no national recording.
- Germany: No national database for eel stocking, but data available for some river basins. Situation will improve next year, when all data become available in the EMP's. Stocking data for the Elbe RBD-system 1950–1980 are restricted to about 30% of the total basin area.
- Lithuania: stocking of glass eel on a national level.
- Spain: no stocking on a national level.
- Poland: stocking in the Vistula and Szczecin Lagoons on a national level.
- Portugal: no stocking on a national level.
- Ireland: no stocking on a national level. Upstream transport of glass eel (elver) and young yellow (bootlace) eel on the Shannon and Erne-see Country Report.

Table 5 Stocking of glass eel. Numbers of glass eels (in millions) stocked in (eastern) Germany (DE)*, Lithuania (LT), the Netherlands (NL), Sweden (SE), Poland (PL), Northern Ireland (N.Irl), Belgium (BE), Estonia (EE), Finland (FI) and Latvia (LV).

*** Values for Germany are for East Germany until 1990 and for East Germany and data from some western German states in the River Elbe RBD since 1991.**

	D E	NL	SE	PL	N.Irl.	BE	EE	FI	LT	LV
1927										0.3
1928									0.1	0.0
1929									0.2	0.0
1930										0.0
1931									0.2	0.4
1932									0.2	0.0
1933									0.2	0.3
1934									0.3	0.0
1935									0.6	0.2
1936									0.3	0.0
1937									0.3	0.3
1938									0.4	0.0
1939									0.1	0.2
1940										0.0
1941										0.0
1942										0.0
1943										0.0
1944										0.0
1945										0.0
1946		7.3								0.0
1947		7.6								0.0
1948		1.9								0.0
1949		10.5								0.0
1950	0.0	5.1								0.0
1951	0.0	10.2								0.0
1952	0.0	16.9		17.6						0.0
1953	2.2	21.9		25.5						0.0
1954	0.0	10.5		26.6						0.0
1955	10.2	16.5		30.8						0.0
1956	4.8	23.1		21.0			0.2		0.3	0.0
1957	1.1	19.0		24.7						0.0
1958	5.7	16.9		35.0						0.0
1959	10.7	20.1		52.5						0.0
1960	13.7	21.1		64.4			0.6		2.3	3.2
1961	7.6	21.0		65.1			0.0			0.0
1962	14.1	19.8		61.6			0.9		2.0	1.9
1963	20.4	23.2		41.7			0.0		1.0	1.5
1964	11.7	20.0		39.2			0.2		2.4	0.9
1965	27.8	22.5		39.8			0.7		2.1	0.4
1966	21.9	8.9		69.0			0.0	1.1	0.7	0.0
1967	22.8	6.9		74.2			0.0	3.9	0.5	1.0
1968	25.2	17.0		16.6			1.4	2.8	3.0	3.7
1969	19.2	2.7		2.0			0.0		0.0	0.0
1970	27.5	19.0		23.5			1.0		2.8	1.8
1971	24.3	17.0		17.4			0.0		1.6	0.0

	DE	NL	SE	PL	N.Irl.	BE	EE	FI	LT	LV
1972	31.5	16.1		21.5			0.1		0.3	1.6
1973	19.1	13.6		61.9			0.0		1.4	0.0
1974	23.7	24.4		71			1.8		1.8	0.0
1975	18.6	14.4		70			0.0		2.2	0.0
1976	31.5	18.0		68			2.6		1.0	0.6
1977	38.4	25.8		77			2.1		1.4	0.5
1978	39.0	27.7		73			2.7	3.7	2.7	0.0
1979	39.0	30.6		74.3			0.0		0.75	0.0
1980	39.7	24.8		52.9			1.3		1.8	0.0
1981	26.1	22.3		60.5			2.7		3.0	1.8
1982	30.6	17.2		64			3.0		4.6	0.0
1983	25.2	14.1		25.1			2.5		3.7	1.5
1984	31.5	16.6		49.2	4		1.8		0.0	0.0
1985	6.0	11.8		36.3	11		2.4		1.6	1.5
1986	23.8	10.5		54.4	17.8		2.5		2.6	0.0
1987	26.3	7.9		56.8	13.7		2.5			0.3
1988	26.6	8.4		15.9	6.3		0.0			2.2
1989	14.3	6.8		5.9	0.0		0.0	0.0		0.0
1990	16.7	6.1	0.7	8.6	0.0		0.0	0.1		0.0
1991	3.2	1.9	0.3	1.7	0.0		2.0	0.1		0.0
1992	6.5	3.5	0.3	13.8	2.4		2.5	0.1		0.0
1993	8.6	3.8	0.6	10.6	0.0	0.8	0.0	0.1		0.0
1994	9.5	6.2	1.7	12.2	2.3	0.5	1.9	0.1	0.1	0.0
1995	6.6	4.8	1.5	23.7	2.1	0.5	0.0	0.2	1.0	0.6
1996	0.8	1.8	2.4	2.8	0.1	0.5	1.4	0.1	0.4	0.0
1997	1.0	2.3	2.5	5.1	0.2	0.4	0.9	0.1		0.0
1998	0.4	2.5	2.1	2.5	0.1	0.0	0.5	0.1	0.1	0.0
1999	0.6	2.9	2.3	4.0	3.6	0.8	2.3	0.06		0.3
2000	0.3	2.8	1.4	3.1	0.5	0.0	1.1	0.06		0.0
2001	0.3	0.9	0.8	0.7	0.0	0.2		0.05		0.0
2002	0.3	1.6	1.7	0.0	3.0	0.0		0.06		0.23
2003	0.1	1.6	0.8	0.5	3.9	0.3		0.0	0.4	0.0
2004	0.2	0.3	1.3	2.3	1.2	0.0		0.06		0.0
2005	0.6	0.1	1.0	0.0	2.4	0.0		0.06		0.12
2006	0.0	0.6	1.1	0.0	1.0	0.3		0.05		0.006
2007	0.0	0.2	1.0	0.0	3.6	0.0		0.1		0.018
2008	0.0	0.0		0.0	1.3	0.3		0.1		0.0

Table 6 Stocking of young yellow (bootlace) eel. Numbers of young yellow eels (in millions) stocked in (eastern) Germany (DE)*, Lithuania (LT), ´The Netherlands (NL), Sweden (SE), Denmark (DK), Belgium (BE), Estonia (EE), Finland (FI) and Latvia (LV).

*** Values for Germany are for East Germany until 1990 and for East Germany and data from some western German states in the River Elbe RBD since 1991.**

	DE	NL	SE	DK	BE	EE	FI	LT	LV	PL
1946									0.0	
1947		1.6							0.0	
1948		2.0							0.0	
1949		1.4							0.0	
1950	0.9	1.6							0.0	
1951	0.9	1.3							0.0	
1952	0.6	1.2							0.0	
1953	1.5	0.8							0.0	
1954	1.1	0.7							0.0	
1955	1.2	0.9							0.0	
1956	1.3	0.7							0.0	
1957	1.3	0.8							0.0	
1958	1.9	0.8							0.0	
1959	1.9	0.7							0.0	
1960	0.8	0.4							0.0	
1961	1.8	0.6					0.1		1.0	
1962	0.8	0.4					0.1		0.7	
1963	0.7	0.1					0.0		0.4	
1964	0.8	0.3					0.1		0.4	
1965	1.0	0.5					0.1		0.3	
1966	1.3	1.1					0.1		0.0	
1967	0.9	1.2					0.0		0.8	
1968	1.4	1.0					0.0		0.0	
1969	1.4	0.0					0.0		0.0	
1970	0.7	0.2					0.0		0.4	
1971	0.6	0.3							0.0	
1972	1.9	0.4							0.0	
1973	2.7	0.5							0.0	0.2
1974	2.4	0.5							0.0	
1975	2.9	0.5					0.0		0.0	
1976	2.4	0.5					0.0		0.3	
1977	2.7	0.6					0.0		0.0	0.1
1978	3.3	0.8					0.0		0.0	
1979	1.5	0.8					0.1		0.0	
1980	1.0	1.0							0.0	
1981	2.7	0.7							0.0	
1982	2.3	0.7							0.3	0.1
1983	2.3	0.7							0.4	2.3
1984	1.7	0.7							0.0	0.3
1985	1.1	0.8							0.0	0.5
1986	0.4	0.7							0.0	0.2
1987	0.3	0.4		1.6					0.0	
1988	0.2	0.3		0.8		0.2			0.8	0.1
1989	0.2	0.1		0.4					0.0	0.7
1990	0.4	0.0	0.8	3.5					0.0	1.0

	D E	NL	SE	DK	BE	EE	FI	LT	LV	PL
1991	0.5	0.0	0.9	3.1					0.0	0.1
1992	0.4	0.0	1.1	3.9					0.0	0.1
1993	0.7	0.2	1.0	4.0	0.2				0.0	
1994	0.8	0.0	1.0	7.4	0.1			0.1	0.0	0.1
1995	0.8	0.0	0.9	8.4	0.1	0.2			0.0	
1996	1.1	0.2	1.1	4.6	0.1				0.0	0.5
1997	2.2	0.4	1.1	2.5	0.1				0.0	1.1
1998	1.7	0.6	0.9	3.0	0.1			0.1	0.0	0.6
1999	2.4	1.2	1.0	4.1	0.04			0.1	0.0	0.5
2000	3.3	1.0	0.7	3.8	0.003				0.0	0.8
2001	2.4	0.1	0.4	1.7	0.004	0.4			0.0	0.6
2002	2.4	0.1	0.3	2.4	0.008	0.4			0.2	0.6
2003	2.6	0.1	0.3	2.2	0.005	0.5				0.5
2004	2.2	0.1	0.2	0.8	0.009	0.4		0.1		0.5
2005	2.1		0.1	0.3	0.008	0.4				0.7
2006	5.5		0.0	1.6		0.4				1.1
2007	4.7		0.0	0.8		0.3				0.9
2008		0.2		0.8		0.2				1.0

Annex 4 – The use of genetics in the management of European eel

A working paper presented to the WGEEL by: Gregory Maes, Lorenzo Zane and Filip Volckaert.

Note: This working paper was used by the WGEEL to inform its discussions within the various subgroups and reviewed text is included in the relevant chapters. The whole document is annexed here for reference, but may not reflect the views of the Working Group.

Introduction

The life history of the catadromous European eel (*Anguilla anguilla* L.) depends on oceanic conditions; maturation, migration, spawning, larval transport and recruitment dynamics are completed in the open ocean (Knights, 2003; Tesch, 2003; Van Ginneken and Maes, 2005; Kettle and Haines, 2006). Despite the biological importance of the marine phase (Knights, 2003) to date most research has focused on the fresh-water phase of the life history. European eels have several life-history characteristics that make them particularly vulnerable to overexploitation: they are long-lived, are large, mature late, produce all their offspring at once, are subject to heavy mortality, and migrate long distances, right across the Atlantic. There is significant international trade demand for the species, both for live glass eels (from Europe to Asia) and the highly valued meat of adults. Given that poaching and the illegal trade are of major concern, as indicated by several reports, a better regulation of international trade is necessary. In addition, the decline may be exacerbated by other anthropogenic factors such as fresh-water and coastal habitat loss, pollution, parasitism, climate change, change in ocean currents, and blocking of inland migration routes (Dekker, 2003; Knights, 2003). A synergy between all these factors seems the most likely cause of the declines (Wirth and Bernatchez, 2003). All these factors have contributed to some extent that the European eel is beyond safe biological limits (Dekker, 2003), and recruitment is at a historical minimum (1% of the 1960 recruitment level). Many questions on the basic biology eel remain unanswered. For example, genetic data may help **assess species integrity within the North Atlantic**, evaluate the **number of genetic stocks** of the European eel, **clarify the spatio-temporal stability of genetic structure**, **estimate the population sizes**, define the **influences of oceanic conditions on genetic variability**, and **evaluate the effect of population decline on genetic variability, the origin of biological material (tracing)** and the overall fitness of eels.

The European Commission recently produced a community action plan for the recovery of the European eel stock , which aims to strengthen the return rate of adult eels to the Sargasso Sea and includes the development of eel management plans (EMP) (CEC, 2007). Further, the European eel has been added recently to Appendix II of CITES, implying drastic restrictions on trading. A number of restorative eel management responses are envisaged including; 1) assessing and reducing the impact of the fishery, 2) monitoring recruitment, 3) preserving migration routes (removing migration barriers), 3) the translocation of glass eel within the natural range of the species using glass eels from sources where there is still a demonstrable surplus and the assessment of the impact of the restocking practice (preserving potential local populations, disturbing homing behaviour, competition between local and introduced organisms), 4) the stocking of eels sourced from aquaculture production (justified on the basis that these are developed entirely on the basis of wild recruits), 5) assessing anthropogenic influences (pollution, parasites), and estimating the spawning population size (CEC, 2005; ICES, 2006).

When considering the use of genetics to complement these measures, immediately the need arises to assess the spatio-temporal population genetic structure at **spawning grounds** (in the Sargasso Sea), to **analyse the census population size (*Nc*) and to determine the relationship between historical and current effective population sizes (*Ne*)**, to **analyse genetic markers located in functional regions to unveil possible adaptive variation** under natural and anthropogenic conditions, and to gain understanding of molecular mechanisms involved in important traits for **aquaculture** and **artificial reproduction**. Knowledge of population structuring will provide insights on the appropriateness of trans-locating eels between river basins and between regions such as between the Mediterranean and the Atlantic or even the North Sea and the Baltic. To transfer eels between genetically different populations maybe counter productive to the long-term health of the resource. To protect the species, it is **important to maintain intraspecific genetic diversity**, to **develop sound restocking programmes for broodstock (wild spawning stock) enhancement** (avoiding the risk to introduce genetic depauperate individuals), and to **help realize profitable artificial breeding**. The present text synthesizes the most recent genetic knowledge of the European eel and provides an overview of possible better use of genetics in future management decisions on this declining species.

Genetic structure of the European eel populations

The European eel has been studied for more than 100 years, and hypotheses concerning its population structure have been tested using novel techniques each time they appeared. The most recent genetic information has answered several evolutionary challenges along the life cycle of the European eel (Figure 1). Many factors of its catadromous life strategy increase the chance of panmixia, such as the variable age-at-maturity, the highly mixed spawning cohorts, the protracted spawning migration, the sex-biased latitudinal distribution, and the unpredictability of oceanic conditions.

Historically, early population genetic studies, based on differences in transferrins and liver esterases, resulted in claims that European eel populations differed between continental European locations (Drilhon *et al.*, 1966, 1967; Pantelouris *et al.*, 1970), suggesting a southeastern Mediterranean reproductive area. Later allozymatic studies failed to detect obvious spatial genetic differentiation (de Ligny and Pantelouris, 1973; Comparini *et al.*, 1977; Comparini and Rodinò, 1980; Yahyaoui *et al.*, 1983). Mitochondrial DNA initially provided only limited insight into the geographical partitioning of genetic variability in the European eel, suggesting a single common gene pool (Lintas *et al.*, 1998). This commonly accepted view of a panmictic genetic population structure, based on oceanographic (Sinclair, 1988; Tesch, 2003) and genetic features, was, however, recently challenged by three independent studies (Daemen *et al.*, 2001; Wirth and Bernatchez, 2001; Maes and Volckaert, 2002). Wirth and Bernatchez, 2001 and Maes and Volckaert, 2002 detected a relationship between genetic and geographic distance (the so-called Isolation-By-Distance, IBD), suggesting a subtle spatio-temporal separation of spawning populations, with some degree of gene flow. Hydrodynamics, causing differential distribution of eel larvae, have also been suggested to explain partly the observed clinal genetic variation (Kettle and Haines, 2006). However, the unstable genetic architecture of European eel populations over time may be linked to oceanic factors (Dannewitz *et al.*, 2005). Neutral genetic markers are generally able to discriminate between populations with a gene flow of less than 1%. Hence, a lack of structure does not mean that there is no structure, but prompt for the use of more discriminatory markers to detect potential structuring.

Most recently, Maes and Volckaert, 2007 wrote a comprehensive review on the population genetics of the European eel, which should be consulted for a more detailed synthesis of the most recent research. In this review, the suggestion that the eel be managed as a catadromous species (including the crucial marine phase) is a significant insight on how the eel should be viewed in terms of its likely population organization, at least from the genetic perspective. The eel in fact, because of its assumed reproductive biology i.e. a prolonged spawning period, variance in age-at-maturity, high variability in parental contribution and reproductive success, might be expected to exhibit a high level of genetic variability, high exchange between populations (gene flow) resulting in low genetic differentiation (low genetic signal/noise ratio) and a high genetic population size, all of which are characteristics observed in other typically marine pelagic species with high migration potential such as cod, *Gadus morhua* (Nielsen *et al.*, 2006) and herring, *Clupea harengus* (Bekkevold *et al.*, 2005). Also, as has been observed by Rousset, 1997, widely distributed species are rarely fully panmictic (mating randomly), but are commonly divided into subgroups in a pattern that can be described by one of the classical population models, such as the island model, stepping-stone model or Isolation-by-Distance (IBD) model. In populations composed of a mixture of individuals reproducing at different times within a reproductive season, temporal differentiation can supplement possible geographical partitioning. Under these conditions, gene flow is expected to be limited between early and late reproducers, possibly creating a pattern of Isolation-by-Time (IBT) (Hendry and Day, 2005; Maes *et al.*, 2006). Additionally, temporal heterogeneity in the genetic composition of recruits is likely to result from a large variance in parental reproductive success driven by the unpredictability of the marine environment (Waples, 1998, Pujolar *et al.*, 2006). Under the hypothesis of "sweepstakes reproductive success" (Hedgecock, 1994), chance events determine which adults are successful in each spawning event, attributing the variation in reproductive success of adults to spatio-temporal variation in oceanographic conditions, occurring within and among seasons. Many marine species split their reproductive effort among several events during a protractive spawning season, to maximize their reproductive success (Hutchings and Myers, 1993; Maes *et al.*, 2006).

Ocean currents and diffusive processes, resulting in a differential distribution of eel larvae, have recently been suggested to explain this observed genetic structure (Kettle and Haines, 2006). Maes *et al.*, 2006 detected a significant correlation between genetic distance and temporal distance among recruitment waves indicative of Isolation by Time. Yet, despite these glimpses of putative structuring, Dannewitz *et al.*, 2005 still concluded from their detailed investigations that European eels from the coasts of Europe and Africa most probably belong to a single spatially homogeneous population. However the existence of discrete and stable spawning aggregations is not completely unrealistic. In explaining the high incidence of American and European eel (*Anguilla rostrata* and *Anguilla anguilla*) hybrids in Icelandic rivers, Albert *et al.*, 2006 suggest that intermediate larval development times for the hybrids are plausible with the effect that ocean currents will deliver the hybrids to rivers positioned in the middle of the natural range. Larval development times would have to be adaptive (transporting American eels into American rivers and European eels into European and African rivers) and therefore has to have some heritable basis. That American and European eels are described as two distinct species in itself suggests that possibility of structuring and maintenance of structuring over time, as it has been suggested that the spawning grounds of both species overlap in space and time (McCleave, 1987). It is also plausible that larvae and glass eel imprint during ocean transport and that this allows homing of adult eel to natal spawning areas (Maes, 2005).

Identifying and sampling discrete reproductive aggregations in the spawning areas will most effectively resolve the genetic structure of the European eel. This is a challenge because European eels spawn in an area that is not well defined and very remote. Since Schmidt, 1923 identified concentrations of eel leptocephali in the Sargasso

Sea in the 1920s there has been little progress in locating eel spawning areas. However it is likely that recent advances in physical oceanography (Kettle and Haines, 2006) offer a reasonable opportunity of overcoming this deficit in the near future. In addition, tagging and tracking of fish has progressed such that monitoring from feeding to spawning ground is feasible. An international project (http://www.Galathea3.dk, Spring 2007) lead by Danish scientists has recovered geolocational pop up tags in the Sargasso Sea from adult eels previously tagged leaving European rivers. Adult eels were tracked swimming to the spawning grounds for the first time.

There is now sufficient evidence available to suggest that small but significant levels of genetic structuring exist in European eel and that this diversity should be protected:

- Geographical clinal variation at enzymatic and neutral genetic markers between recruiting glass eels and adults.
- Large (yearly) and small (seasonal) scale temporal genetic differences between spawning cohorts and recruiting glass eels.
- Homing behaviour between North-Atlantic eel species and even hybrid individuals endemic to Icelandic waters. This points to the possibility of intraspecific homing behaviour based on adaptive traits, instead of neutral variation (see further).
- Correlation between genetic variability and fitness traits in natural populations, prompting for maintenance of genetic diversity for long-term survival of the entire species.

Within a precautionary principle framework, eel fisheries management should be aware of the genetic structure suggested by recent studies and that management strategies designed for recovering stocks should incorporate this possibility. Besides the existence of these small-scale level of genetic differentiation, many new initiatives are ongoing to determine the long-term genetic (effective) population size of eel, the presence of functional/adaptive genetic diversity which is more relevant to changing life-history traits, the assessment of oceanic influences on larval survival and the monitoring of individual responses to pollutants and parasites at the gene expression level (see further).

Genetic research perspectives and management of the European eel

Earlier conclusions drawn from molecular studies are not only important for inferring the panmictic status of the eel, but also to preserve the genetic resources in European eels and to define additional research priorities. For each priority, one can define a specific management objective and the time frame during which changes or reversal may be achieved (Table 1). It is obvious, for instance, that genetic diversity may be lost rapidly (i.e. genetic erosion), and that it recovers very slowly within populations (ICES, 2005). To assist with a sound management of European eel, future genetic research may therefore focus on the conservation issues listed above. We propose **four major lines of research**: assessment of the **spawning population structure and effective population size**, inclusion of **adaptive genetic variation** in management plans, **monitoring stress responses of eels** under heavy anthropogenic pressure (pollution, physical barriers and parasites) and **improving artificial reproduction** through aquaculture genomics.

Spawning population structure and size

The genetic structure of natural marine populations is best understood by identifying, sampling and analysing discrete reproductive aggregations (Waples, 1998). Our knowledge of the spawning biology and migration routes of North Atlantic eels remains poor. Identifying the precise location of the spawning grounds, nurseries and retention zones, along with a greater knowledge of the ecosystem where spawning takes place would help management decisions considerably. To date no observations have been made of adult eels in the Sargasso Sea, and their eggs have yet to be identified there (Tesch, 2003). In the Pacific Ocean, based on the distribution of newly hatched larvae, the spawning grounds of the Japanese eel have been reconfirmed by genetic identification techniques (Tsukamoto, 2006). The continental populations constitute mixed feeding aggregations, complicating interpretation of patterns of genetic structure (Dannewitz *et al.*, 2005; Maes *et al.*, 2006b; Pujolar *et al.*, 2006). Sampling putative populations on the continental shelf remains challenging, because of the confounding effect of overlapping generations in adults and the site-dependent age structure. The most effective solution is to sample spawning eels and newly hatched larvae across the Sargasso Sea, and to analyse them with a representative set of genetic markers. This would allow a reassessment of the spatial and temporal segregation found so far and a rough calculation of the size of the spawning stock (*Ne*), which still poses problems in marine fish. The development of precise, performing genetic markers (such as SNPs) for application on highly degraded or old DNA, would also provide new opportunities to compare present genetic patterns with the patterns found some 100 years ago, based on the available larval samples of Schmidt, 1923. Importantly, as a consequence of the long **restocking practices** since the 1950s, one can expect to see a homogenization of populations as a consequence of such large-scale translocations. To fully assess the effect of such translocations on the species level, it would be of interest to study the population structure before such major translocations. This can be done by studying historical material from different European sources from the mid-century and comparing this pattern with the present one at neutral and adaptive genetic markers (see later). Potential translocations of exotic species in Europe (such as American eel or other less exploited eel species) for restocking is also an important issue, requiring up to date molecular identification methods (Maes *et al.*, 2006a). This problem is already of great importance in Asia (Okamura *et al.*, 2002; 2004). This would enable **reliable tracing** of the location and species of origin of glass eels to be stocked.

Additionally, analysis of successive recruitment waves of European eels at sites with year-round recruitment would permit better understanding of the fine-scale genetic composition of glass eels and possibly pinpoint discrete spawning groups. A sharp break or clinal pattern in relatedness and genetic differentiation may point to reproductively isolated aggregations (Maes *et al.*, 2006b). In turn, stochastic variance in genetic composition might point to genetic patchiness, most likely under the influence of annual and seasonal oceanic and climatological fluctuations (such as the North-Atlantic Oscillation; Knights, 2003; Friedland *et al.*, 2007). These are thought to influence the reproductive success of adults and the survival rate of larvae (Dekker, 2004; Pujolar *et al.*, 2006).

Accurately estimating the effective (genetic) population size (*N*e) is another aim to develop appropriate conservation strategies for eels. *N*e predicts the rate of loss of neutral genetic variation, the fixation rate of deleterious and favourable genetic variants, and the rate of increase of inbreeding experienced by a population (Frankham *et al.*, 2002). Importantly, the *N*e of a population is often several orders of magnitude smaller than the census size (*N*c) of the population, owing to unequal sex ratios, variance in reproductive success and assortative mating. In marine fish (including eels)

Ne/*Nc* ratios may be expected to be more extreme than in other vertebrates because of the high female fecundity that allows large census numbers to be obtained from minimal numbers of breeding animals. Indirect methods for estimating *N*e based on molecular marker data have been developed to facilitate the inference of population size, a very difficult task in marine fish with their lack of confined geographic boundaries. When considering census population data of European eels, which indicate that the species is in serious decline over most of its range, it is essential to maintain the spawning stock(s) at sufficiently large levels to ensure that effective population sizes (Ne) as well as absolute population sizes (Nc) are optimized above safe limits. European eels are long-lived animals with reproductive ages roughly ranging from 6 to 60 years (Tesch, 2003). To assess fully the temporal fluctuation in population size (Ne), a long-term analysis over several generations would be ideal. An analysis of time-series of historical material may increase the confidence in genetic estimates of population sizes. This should be done over a period as long as possible to avoid the shifting-baselines trap and the influence of overlapping generations (Jorde and Ryman, 1995; Pauly, 2007). Realistically, the past 100 years should suffice, because anthropogenic impact seems to have been greatest during that period (e.g. endocrine disruption of spawning, overfishing, river management). Such an analysis is now feasible thanks to the development of appropriate genetic techniques for ancient DNA (Nielsen *et al*., 1997). For example, reliable estimates of population size have been calculated for several fish species in a pre- and post-industrial fishery (Nielsen *et al*., 1997; Turner *et al*., 2002; Hauser *et al*., 2002). This knowledge is of great importance in managing genetic variation, which is known to correlate with fitness components in eel (Maes *et al*., 2005; Pujolar *et al*., 2005), and to define sound management strategies.

Finally, the accurate interpretation and extrapolation of genetic results in eels requires an assessment of demographic scenarios through the development of new population dynamics models. Such models have been the basis of fisheries research for a long time, but here we ask for a joint assessment of demographic, hydrodynamic and genetic parameters. Simulating a range of scenarios of reproductive success, migration, survival, dispersal, age structure, maturation, fisheries pressure, and anthropogenic stress, preferably in an ecosystem perspective, looks a promising field. Subsequent validation with empirical genetic and population dynamic data may confirm the key factors.

Adaptive genetic variation for fisheries management

Heavy fishing and other anthropogenic influences, such as pollution and barriers of migration, will not only impact the census size and the effective population size of eels. Large declines in mature adults and recruiting individuals may trigger phenotypic and adaptive genetic changes over generations of harvesting (Law, 2000). Such phenotypic changes may include shifts in age- and size-at-maturity, less reproductive success, greater mortality, changes in growth patterns of juveniles and adults, lower fecundity and fertility, and changes in the sex ratio. If changes are heritable, this may lead to almost irreversible genetic changes in life-history traits (Law, 2000). Recent recommendations from the EU (ICES, 2005) urge the assessment of fisheries and climatologically induced changes in declining marine stocks. A suitable strategy would be a joint analysis of phenotypic and genetic data from contemporary populations, compared with a reference situation (preferably before the population decrease). There is clearly the need for reliable investigations of possible adaptive responses in exploited marine organisms using archival material (Nielsen *et al*., 1997; Myers and Worm, 2003). Although some evidence exists for phenotypic changes in the European eel stock throughout the past 50 years (increasing adult size and decreasing glass eel size since the 1960s), the evolutionary interpretation of overfishing is complicated by there being too few age-specific data, such as on age-at-maturation and growth rate (Dekker, 2004). The long-term genetic consequences of heavy fishing at the adaptive molecular level, such as a decrease or shift in genetic variability at important functional genes related to maturity and growth, have not been assessed yet.

Further, the presence of only a small level of geographical genetic differentiation at neutral microsatellites may lead to seriously underestimating quantitative and adaptive differentiation between populations that might be present but not detectable with these molecular markers. Indeed, apart from analysing neutral genetic variation to assess the demographic independence and stability of fisheries stocks, knowledge of geographic and temporal scales of adaptive genetic variation is crucial to species conservation (Conover *et al.*, 2006). Local adaptation is one of the most significant components of intraspecific biodiversity, and the relevance of local adaptation to fisheries management can be divided into two main issues, each differing in temporal scale (ICES, 2006). First, local adaptations and population structure affect short-term demographics through effects on local recruitment patterns. Second, local adaptations and genetic heterogeneity affect long-term population dynamics, with respect to the connectivity among stocks/populations and their resilience and response to environmental change and harvesting. Local adaptation and the maintenance of biodiversity on the long term for sustainable fisheries management has yet to be implemented into management strategies (ICES, 2006). Unfortunately, the understanding of these phenomena is particularly difficult in marine organisms. The spatial and temporal scale of adaptive divergence has been assumed to be very large. However, evidence of geographically structured local adaptation in physiological, morphological and functional genetic traits has become apparent (Giger *et al.*, 2006; Nielsen *et al.*, 2006). The proportion of quantitative trait variation at the among-population level (Q_{ST}) has repeatedly been demonstrated to be much higher than for neutral markers (F_{ST}) (Cousyn *et al.*, 2001; Conover *et al.*, 2006). As both metrics of genetic variation are poorly correlated, knowledge of neutral variation does not provide much information about adaptive variation (McKay and Latta, 2002; see Conover *et al.*, 2006, for a review). Given the important link between population genetics and dynamics, and the strong potential for selection in species with large population sizes, the application of both selected and neutral markers is obviously needed to resolve the stock structure of marine fish effectively.

Genetic stress responses to pollution and parasitic load

Organic and inorganic pollutants can significantly reduce the quality and reproductive capacity of vertebrates. This is especially the case in fish, where pollutants can accumulate in the aquatic and sedimentary environment and in the benthic biota (food). A benthic feeder can at the same time be seen as a good candidate to monitor environmental quality of aquatic habitats, but at the same time suffers most from the ability to bioaccumulate strongly all kinds of lipophilic substances, leading to the possible destabilization or even extinction of the species. Additionally, parasitic infection and pollution have been revealed to impair strongly the survival and reproductive capacity of eels in experimental, resulting in an even stronger response to pollution and vice-versa (Palstra *et al.*, 2006; 2007). However, although recent results have displayed a strong correlation between pollutants and decrease body fat concentration (crucial to spawning migration and egg production), the influence of stressors need a more in depth analysis at the population or stock level, to allow a reproductive success assessment and sound management options (Belpaire, 2008). A thorough analysis of pollutants and parasite stress level and better understanding of the organismal response is crucially needed. This will enable parallel analysis of responses (or not) and find out the synergetic fitness influences of pollution and parasite load.

Indeed, genetic diversity is the product of thousands of years of evolution, yet irreversible losses may occur rapidly (Kenchington *et al.*, 2003). It is essential to long-term survival, to adapt to climate change and anthropogenic pressure leading to the loss of populations, with the likely subsequent loss of adaptive variation. For fisheries management, the extent of genetic variability within populations is crucial in assessing the quality of stocks, the potential productivity or growth of a population, and the sustainability of fisheries. Pujolar *et al.*, 2005 and Maes *et al.*, 2005 assessed whether the genetic background of European eels could be linked to two fitness traits, early growth and pollutant bioaccumulation. Summarizing both studies here, there was strong evidence of Heterozygosity-Fitness-Correlations (HFC), likely explained either by an effect of direct overdominance at functional markers. The positive consequence of the catadromous life history of eels is that locally polluted rivers will only have a low impact on the entire population, because of the lack of spatial genetic structure at a local level. Nevertheless, selection during each generation will erode local genetic variability differentially, slowly reducing overall genetic variability. Differential selective pressures might induce variation between spawning cohorts in time and space, possibly increasing the temporal differentiation pattern described by Maes *et al.*, 2006b and Pujolar *et al.*, 2006.

Recently, it became possible to reliably quantify the gene and protein expression levels during exposure to pollutants and parasites, allowing the early detection of decreased fitness and survival. Such knowledge would provide the chance for early management actions before major mortality events in natural populations and provide a long-term assessment of success rates of conservation measures. Using sufficient background information on the identity and concentration of pollutant, this approach can yield better insights into the factors influence the recently observed decrease in fat content, a crucial measure for eels' fitness to reach the Sargasso Sea.

Artificial reproduction and aquaculture genomics

Current fishing pressure on European eels could be decreased considerably if artificial reproduction were possible (but see Palstra *et al.*, 2005 and references therein). Despite numerous attempts over the past 30 years, it remains impossible to produce economically profitable quantities of eels in aquaculture. Until now, naturally recruiting glass eels are caught and grown in tanks for later consumption. Additionally, eel aquaculture individuals are often used for restocking purposes, with the aim of rescuing depleted rivers and lakes. However, the fitness consequences of this practice remains to be thoroughly studied, as the fast growers and most fit individuals are first sold for food consumption and the remaining (most likely less fit) individuals are sold for restocking. No study has ever monitored life-long fitness of such individuals, an important point considering the link between genetic variability and fitness in eel and other organisms such as salmonids (Pujolar *et al.*, 2005; McGinnity *et al.*, 2003).

Recently, methodologies developed to produce eel larvae of *A. japonica* have been tested in Europe on *A. anguilla* resulting in fertilized eggs, embryonic development, and occasional hatching (Palstra *et al.*, 2005; Kagawa *et al.*, 2005). Success, however, remains low, calling for further study of the husbandry of eels, and of reproductive and general eel biology. Original insights on physiology and endocrinology may be expected from advanced genomic tools. For instance, Miyahara *et al.*, 2000 produced 196 Expressed Sequence Tags (ESTs) from a spleen library of Japanese eels, and Kalujnaia *et al.*, 2007 was able to identify, through subtractive hybridization and microarrays, a large number of genes down- and unregulated during osmoregulation in gill, kidney, and intestinal tissue. As new genetic tools become available in related *anguillids* (e.g. Japanese eel; Nomura *et al.*, 2006) and related genome information rich species, promising insights in functional and comparative genomics are expected in the near future. EST sequencing and linkage maps may be other feasible genomic approaches, representing the first steps toward identifying important genes and Quantitative Trait Loci (QTL), the basis for Marker Assisted Selection. Although larvae of Japanese eel have only been bred with great effort, Nomura *et al.*, 2006 have managed to prepare a low-density linkage map based on 43 microsatellite markers, and many more are being developed (K. Nomura, pers. comm.). Given the numerous genetic markers known to cross-amplify between *Anguilla* species (Maes *et al.*, 2006a), once progeny become available for European eels, reliable paternity screening, gene expression and microarray analyses and a linkage map become realistic goals. Quantitative traits such as growth rate, food conversion, postponed maturity, stress tolerance, and parasite resistance strongly correlate with the possibilities of artificial rearing. One long-term issue where QTL may be of great help is in the management of feed supply. Currently, wild-caught fishmeal is an important ingredient of dry feeding pellets, but it is expected to shift to a proportionally larger vegetarian diet.

Genetic implications and recommendations for the Eel Management Plan

The importance of maintaining genetic diversity can be divided into a **short-term impact (in the order of few generations),** by avoiding inbreeding and fitness decrease (population survival) and a **long-term impact (over decades or even centuries)**, by conferring the possibility to adapt to changing conditions (species survival). Genetic data may help to **assess species integrity within the North Atlantic**, evaluate the **genetic stock structure** of the European eel, **clarify the spatio-temporal stability of the genetic structure**, define the **influences of oceanic conditions on genetic variability**, **monitor** and **guide** the **stocking policy** in Europe, and **evaluate the effect of population decline and habitat degradation on genetic variability** and the overall fitness of eels. For the current ToRs genetic considerations can be focused on the issues of **restocking policies** and **eel quality assessment**.

Genetic consequences of stocking practices

Stocking of glass eels has been defined as a practice to increase the population abundance of European eel. Although an immediate effect on populations can been seen in an early phase, the long-term success of this practices has not been assessed yet, neither the genetic consequences. Stocking should be performed carefully and with knowledge of potential negative implications on eel populations. Importantly, **stocking should not been seen as the only solution for stock recovery**, as the fishing pressure may dramatically increase at source locations for glass eels and later spawning success of stocked individuals is not at all guaranteed. To supplement river populations impacted by migration barriers, hydropower, pollution, pathogens, a standard strategy to catch glass eels from the estuaries (or neighbouring sites) and transport them upstream to repopulate low-density habitats or surplus good habitat. Ideally, high quality habitats should be chosen and rivers with the least anthropogenic impacts selected. There should be a long-term plan to improve habitat in disturbed basins over the full river basin. In areas with no recruitment, the origin of glass eels should be the nearest from the target location. In areas with low recruitment, care must be taken to reduce competition and to stock smaller individuals. Areas with heterogeneous recruitment should focus on relocating recruits from neighbouring rivers and not from distant sites.

Below we list some important points to consider when planning restocking measures and provide some advice for sustainable stocking.

Deciding on mass stocking practices to supplement populations, can lead to the rapid **introduction of non-native genetic material**. Monitoring the correct species identity (tracing) is therefore crucial to preserve genetic integrity of the European eel. Examples of this phenomenon have already been observed, mainly in Germany (Trautner *et al.*, 2006), prompting for up to date molecular identification methods for species discrimination (Maes *et al.*, 2006a). The European eel has been listed under CITES, potentially leading to an increased import of other eel species. Such exotic eel introductions have been a major problem in Asia, where European eels were introduced to supplement Japanese eel stocks (Okamura *et al.*, 2002; 2004).

Aquaculture glass eels (grown from glass eels to 10 cm elvers) are often **used** for **stocking purposes**. Although at first sight no significant problem is expected from the genetic diversity point of view (glass eels are natural recruits), **fitness consequences could be higher than expected**. Indeed, keeping glass eels too long in such facilities will **adapt** them to **aquaculture conditions** (such as artificial food and temperature regimes), and will lower their competitiveness and fitness in the natural environment. Second, a common practice in aquaculture facilities is to **deliberately infect new glass eels with the highly virulent Herpes virus,** to decrease later mortality during grow-out. As such, after a large initial mortality, stocked eels are in many cases infected with Herpes (up to 50%) and can infect natural populations. Additionally, such practices create already a **high selective pressure on glass eels, reducing total genetic diversity and directionally selecting at the functional level for specific disease resistance genes (such as MHC)**. This has been demonstrated to have a very detrimental effect in salmonids when such individuals are released in the wild, as a consequence of a lower fitness for natural pathogens. Further, **large restocked individuals might cannibalise local recruits**, which are much younger. Stocking should be performed at well-chosen moments, namely at the end of the natural recruitment season. Additionally, attention should be paid that **stocked individuals** are not only composed of the **slow growers** of aquaculture, which have been demonstrated to exhibit a lower functional genetic diversity and could demonstrate lower survival rates under pollution stress (lower fitness). Additionally, using slow growing and small individuals for **stocking can significantly bias the sex-ratio** of stocked fish, inducing a non-natural distribution of sexes in stocked systems. We advise to **perform experiments** on competitiveness, survival and reproductive capacity of stocked glass eels, besides the marking of stocked individuals and their recapture at sexual maturity.

At the population level, **stocking practices can have major consequences on the intraspecific biodiversity**, as a consequence of the mixing of genetically differentiated populations. Although no stable geographical differentiation could be detected using past research efforts (Wirth and Bernatchez, 2001; Dannewitz *et al.*, 2005; Maes *et al.*, 2006), as a consequence of the long **restocking practices** since the 1950s, one can expect to contribute to a homogenization of populations as a consequence of massive translocations. Indeed, the presence of only a small level of geographical genetic differentiation at neutral genetic markers may lead to seriously underestimating quantitative and adaptive differentiation between populations. From recent studies on marine fish populations we know that adaptive differences might be present but not detectable with the current molecular markers. Indeed, apart from analysing neutral genetic variation to assess the demographic independence and stability of fisheries stocks, knowledge of geographic and temporal scales of adaptive genetic variation is crucial to species conservation (Conover *et al.*, 2006; Maes and Volckaert, 2007). For eel, no assessment has been made of the functional diversity yet, although work is in progress to contrast data on neutral and adaptive markers (Maes, Zane, pers. comm.), besides novel data on differing life-history traits (Feunteun, pers. comm.). **If distinct populations exist**, the introduction of genetically different glass eels can potentially break up any existing adaptation in local stocks and have major fitness consequences on life-history traits, such as migration duration and timing, temperature resistance and size at maturation sizes. The homogenization of these traits can lead to a decrease in diversity and the loss of important traits for survival. However, until results are available (within 1–2 years) we can only advise on the following stocking strategies, depending on the natural recruitment level.

Regions with no recruitment and very low escapement: Preserve natural recruits (if any) and escapees, while stocking glass eels in high quality habitats originating in the same main hydrographical region (Northern Europe, West Atlantic, Southern Europe, Mediterranean).

Regions with low recruitment: Preserve natural recruits and escapees, while preferably stocking glass eels from estuaries or neighbouring river basins in high quality upstream habitats.

Regions with high recruitment: care should be taken not to overfish glass eels for stocking purposes, as this will weaken the source region and deplete the rivers from escapees.

On the other hand, **if neither neutral nor adaptive differences can be detected** in the European eel, stocking practices may have a beneficial effect, as they would expand the feeding habitat size of eels, and help recover the total population. The question however remains, whether stocked individuals will find their way to the Sargasso Sea and ultimately contribute to the spawning stock. The most important issue is then to preserve the total genetic diversity to allow adaptation to a changing environment. Keeping the highest level of biodiversity in phenotypic (quantitative) and genetic traits is crucial to the survival of the entire species.

Lastly, the **ongoing investigation of the historical genetic** (neutral but especially adaptive) **structure and stability** before the start of large-scale stocking practices (1950s) and the monitoring of the evolutionary consequences from 50 years of re-stocking will enable to fully assess the effect of such translocations on the species level. This is being done by studying historical material (otoliths) from different European sources in the mid-twentieth century and by comparing this pattern with today's observations at neutral and adaptive genetic markers.

Quality assessment of spawners using genomic tools

Eel decline might depend not only on the quantity of adult eels leaving the continent but also, if not mainly, upon their quality. Good quality spawners are those that succeed in crossing the Atlantic Ocean and reproduce. Parasites, such as the exotic swimbladder nematode *Anguillicola crassus* can impair eel viability by both increasing continental mortality and affecting the swimming ability of adult eels. Organic and inorganic pollutants may significantly reduce the quality and reproductive capacity of vertebrates. This is especially the case in fish, where pollutants may accumulate in the water and sediment and in the benthic biota (food). Additionally, infections and pollution have been revealed to impair strongly the survival and reproductive capacity of eels in experimental trials, resulting in an even stronger response to pollution and vice-versa (Palstra *et al.*, 2006; 2007). A thorough analysis of pollutants and pathogen stress level and a better understanding of the organismal response (besides measures of condition index) are missing. Pujolar *et al.*, 2005 and Maes *et al.*, 2005 assessed whether the genetic background of European eels could be linked to two fitness traits, early growth and pollutant bioaccumulation. Summarizing both studies here, there was strong evidence of a relation between genetic diversity and fitness measures (also called Heterozygosity-Fitness-Correlations or HFCs). It might be explained either by an effect of direct overdominance at functional markers. Recently, it became possible to reliably quantify the gene and protein expression levels during exposure to pollutants and parasites, allowing the early detection of decreased fitness and survival. Such knowledge would provide the chance for early warning systems, facilitating management actions before major mortality events in natural populations and provide a long-term assessment of success rates of conservation measures. Using sufficient background information on the identity and concentration of pollutant, this approach may yield better insights into the factors influencing the recently observed decrease in fat content, a crucial measure for eels' fitness to reach the Sargasso Sea. The ongoing analyses of northern (Belgium) and Southern (Italy) eel populations for their gene expression level and health status will allow adding a quality status tag on silver eels, while identifying good quality habitat for preservation.

Recommendations

Using the current knowledge of the genetic structure, pollution and pathogens influence on eel and the potential risks of using aquaculture eels for restocking, we draft some conclusions, main recommendations for further research and management options, and potential advice to be issued by ICES. Besides developing the control of **artificial reproduction**, it is our opinion that an **integrated analysis of phenotypic, demographic and genetic data of contemporary and historical (otoliths) populations** would significantly increase our knowledge of human vs. natural impacts on eel stocks the last century (genetic baseline). Additional research focus on the **marine part of its life cycle**, including **hydrodynamics, ecotoxicology, archived material, and neutral vs. adaptive genetic variation**, are the next steps in developing a global management strategy. This should be integrated in a broader ecosystem perspective. The consequences of **earlier and future restocking** practices needs more attention to avoid weakening even more the species and disturbing the natural spawning cycle of this species. In light of emerging information suggesting putative stock structure of European eel it is recommended from the genetic viewpoint that glass eels, elvers and other life-history stages should not be trans-located between distant river basins for restocking purposes. However, given the need for rapid action and that stocking is one of the actions proposed by the EC, the precautionary approach should still apply in order to avoid imminent collapse of specific river stocks, where possible the translocation should be done within geographically proximate areas e.g. within the Mediterranean basin, the West Atlantic, the North Sea or the Baltic Sea. It is of crucial importance to assess the success of this practice and to overview actions to be taken along the complete life cycle of eels.

Finally, a thorough assessment of the success of such management options should be done in 2012, a time frame where new results on potential adaptive differences between eel stocks and loss of functional diversity the last 50 years will also be available.

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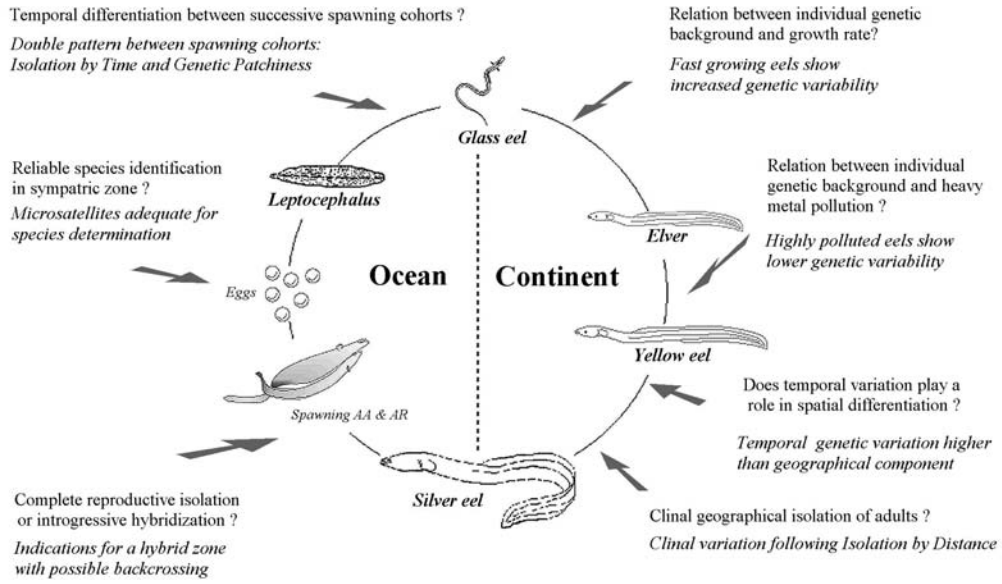

Temporal differentiation between successive spawning cohorts ?
Double pattern between spawning cohorts: Isolation by Time and Genetic Patchiness

Relation between individual genetic background and growth rate?
Fast growing eels show increased genetic variability

Reliable species identification in sympatric zone ?
Microsatellites adequate for species determination

Relation between individual genetic background and heavy metal pollution ?
Highly polluted eels show lower genetic variability

Does temporal variation play a role in spatial differentiation ?
Temporal genetic variation higher than geographical component

Complete reproductive isolation or introgressive hybridization ?
Indications for a hybrid zone with possible backcrossing

Clinal geographical isolation of adults ?
Clinal variation following Isolation by Distance

Figure 1. European eel: life cycle of the main recent evolutionary questions relevant to the management of eels (Maes and Volckaert, 2007).

Table 1. European eel management objectives related to the loss of genetic diversity (Maes and Volckaert, 2007).

CONSIDERATION	EXAMPLE MANAGEMENT OBJECTIVE	TIME-SCALE (GENERATIONS)
1. Genetic integrity at the species level	1.1. Avoid species translocations for restocking or aquaculture	1
	1.2. Trace species identity of endangered fish (products)	
2. Genetic diversity within and among populations	2.1. Maintain population size in river sheds	>100
	2.2. Decrease glass eel fishery and export	
	2.3. Increase silver eel escapement to contribute to spawning stock	
3. Population structure and relative abundance	3.1. Avoid large-scale translocations within Europe and between continents	>100
	3.2. Detect possible local adaptation between river basins	
	3.3. Maintain relative size of populations	
4. Effective population size and demographic stability	4.1. Maintain large number of individual populations	>10
	4.2. Minimize environmental degradation (pollution, habitat fragmentation)	>10
	4.3. Assess influence of parasites (e.g. Anguillicola) and pathogens (e.g. virus infection - EVEX) on reproductive potential	>10
5. Evolutionary potential	5.1. Minimize fisheries-induced selection	>10
	5.2. Avoid directional adaptation to anthropogenic and environmental changes	>10

Annex 5 – Country overview of contaminant and parasite/pathogens in eel

Contaminant analyses: Overview by country

Belgium

Extensive information has already been provided in the WG Eel 2006 and WG 2007 reports. During WGEEL 2008 a considerable amount of new information has been made available to the Working Group and to the EEQD (see the Belgian country report and Belpaire, 2008).

Canada

Concentrations of many contaminants in the North American environment were high in the 1960s and 1970s, then decreased as bans and restrictions took effect. The St. Lawrence River-Great Lakes system receives a wide variety of pollutants, some of which have lethal (Dutil *et al.*, 1987; Castonguay *et al.*, 1994a) or sublethal (Couillard *et al.*, 1997) effects on eels. Concentrations of most contaminants, including PCBs and mirex, in eels migrating through the St. Lawrence Estuary fell in the 1980s (Hodson *et al.*, 1994). This trend presumably reflects decreased contaminant exposure, but does not takes into account the presence of new contaminant (for example the brominated compounds) and the increasing number of non native species in the Great Lakes watershed that alter fish community composition and foodweb energy flow, leading to subsequent change to pathways and fate of contaminants.

Recently, a 3-year research project on the role of chemicals in the decline of the American eel was initiated to evaluate if eels accumulate sufficient chemical contaminants during their growth and maturation to cause embryo toxicity, and to estimate when contaminants might have affected eel. Under the leadership of Dr Peter V. Hodson (Queen's University), a team of university and government scientists, including colleagues in the US and Europe are collecting fresh and archived samples of eels from reference and contaminated ecosystems. The eels are analysed for concentrations of chemicals known to be embryo-toxic, such as chlorinated and brominated organic compounds, selenium, and alkyl tin. The toxicity of extracted chemicals will be assessed with a battery of tests using fish embryos and fish cells in culture.

Denmark

There are few surveys and mostly of older date. Recent data for PFAS and organotin-compounds in the aquatic environment extracted from report by Strand *et al.*, 2007 and unpublished data from Århus Amt, 2003. (see Appendix. A in the Danish country report).

Estonia

During last 20 years the feeding and the condition factor of eel in L. Võrtsjärv have been studied. The data will be provided to the EEQD.

France

Some data on PCBs and heavy metals in yellow and glass eel were made available from the Gironde and Adour basins, and will be included in the EEQD.

Germany

Concentrations of pollutants/contaminants in the musculature of eels from the river Elbe have been measured by the Elbe River Water Quality Board (ARGE ELBE) in 1999 and 2000 (e.g. ARGE ELBE 2000). Along the entire German length of the Elbe, contaminant levels were measured in excess of the maximum allowable levels. This was particularly evident for HCB (hexachlorobenzene) content. Occasionally, maximum levels were also exceeded for other contaminants, e.g. DDT. The most recent publication from the ARGE Elbe (ARGE ELBE 2008) provides data on concentrations of contaminants for eels from the river Elbe from a location close to the border to the Czech Republic in 2005 and 2006. Concentrations of mercury have remained rather constant (around 0.25 mg/kg wet weight), whereas the values for cadmium demonstrated a decreasing tendency (<0.008 mg/kg w. w.). Several PCB's had constant levels or a slightly decreasing tendency. Clearly decreasing values were observed for HCB (from 1.8 mg/kg Fat in 2001 to 0.56 mg/kg Fat in 2006). However, HCB-concentrations are still on a critical level.

The data are provided in detail for inclusion into the quality database. The reports from the Elbe River Water Quality Board are available at www.arge-elbe.de.

Concentrations of PCB's and dioxins were clearly below the maximum allowable levels in eels from the Baltic Sea (Bladt, 2007, cited in Karl, 2008). Mean values were 7.4 ng/kg w. w. for dioxin/dl-PCB.

Ireland

Some samples have been taken in 2005 and 2007 and these have been analysed for contaminants (PCBs, dioxins, BFRs) and presence of *Anguillicola* (included in the EEQD).

Italy

Only incidental samplings within specific research projects have been performed in the past and examined contaminants loads, eel condition and fat levels. Some recent data based on available information has been provided to the database. Some analyses for contaminants in relation to human or veterinary health have been monitored by official sanitary or veterinary services, but no information is ever made available, and it's most likely that only scattered sporadic samplings have taken place.

Latvia

No contaminant analysis is undertaken.

Lithuania

No contaminant analysis in eel is currently undertaken; however analyses are performed for other species. Lithuania will propose to analyse contaminants and fat levels in eels in future.

Netherlands

There is a long dataseries for bioaccumulation of contaminants in eels is available from the Netherlands, where a monitoring network for PCBs, OCPs and mercury in eel is in place since the 1970s.

This year, no new information about contaminants in the Netherlands was provided.

Norway

Data on PCBs and pesticides from 1996 and 2000 were provided during the WGEEL 2007 session for inclusion in the database.

An extensive set of data of contaminants in eels from 1970 onward from southern Norway is available at the NIVA institute. Data will be incorporated in the database as soon as possible.

Poland

In 2008 research on several factors influencing quality of eel was made in the Sea Fisheries Institute in Gdynia. Samples of eel were collected during autumn 2007 and spring 2008 in Vistula Lagoon and Szczecin Lagoon. Number and size of fish collected are in Table PL.H

In the laboratory chemical examinations were made on:

- fat contents,
- dioxins, furans and dl-PCB's
- heavy metals: Cd, Pb, As, Cr, Ni, Hg.

Results of heavy metals and PCDD/F and dl-PCB's were compared to maximum allowable values obligatory in UE and described in Regulation (EC) 18881/2006 and assessed to classes described by Belpaire and Goemans, 2007. The results were also compared to maximal values given in FAO Fisheries Circular No 825, 1989.

Resulting data of those all examinations were supplied to ICES WGEEL database.

Fat contents

Values of fat contents ranged from 15,1% to 31,4% with mean 15,1% ±5,46. There was observed slight tendency to increase fat contents with increase of eel length.

Heavy metals contents

It was found that presence of all heavy metals, of which contents in the food is limited in EU countries, was much lower in eel tissue comparing to allowed levels given in EU regulations.

The maximum contents of those metals in eel ranged from 2% (Cd) to 22,5% (Hg) of allowed values. In case of Ca, Pb and Cr all samples were classified as Class I, according to As as Class II, and according to Ni and Hg as Class I or II.

PCB's contents

It was found that according to majority of indicative congeners, all samples were of class I or class II. According to sum of six indicative PCB's six of seven samples were qualified as class I. Comparing results to very restrictive German regulations it was found that in none of samples allowed limits were not achieved.

Results of eel samples were also compared to samples from herring, sprat, flounder, cod and salmon. Sum of seven indicative PCB's expressed as μg/kg of tissue in case of eel was comparable to those of salmon and higher in case of rest of species.

Chloroorganic pesticides

In case of HCB four of seven samples were classified as class I and three others as class II. In case of ∑DDT four samples were classified as class I, two as class II and one as class IV. None of samples exceeded limits of ∑DDT 4 and HCB given in FAO Fisheries Circular No 825, 1989.

Dioxin-like-PCB's

In all samples the dominating congener among non-*orto* PCB's was congener penta-PCB 126, which demonstrated highest toxicity in that group, and dominating congener among mono-*orto* PCB's was congener 118.

Dioxin/furans (PCDD/Fs)

In most of samples concentration of PCDF was twofold higher than PCDD concentration, except sample no WTN1, where both concentrations were similar. In none of samples was found exceeding of limits PCDD/F nor sum of PCDD/F and dl-PCB's.

In all samples highest share of total toxicity constituted non-*orto* PCB's and that share was of 40–50% depending on sample.

Portugal

At national level several eco-toxicological studies using eels from different catchment areas have been published, e.g.: Aveiro lagoon (Ahmad *et al.*, 2006; Pacheco and Santos, 2001), Pateira de Fermentelos (Ahmad *et al.*, 2006; Maria *et al.*, 2006; Teles *et al.*, 2007) and Minho, Lima, Douro rivers (Gravato *et al.*, 2007). Information about trace metals in several fish species of the Ria de Aveiro, including eels is also provided by Cid *et al.* 2001.

Information about trace metals in several fish species of the Ria de Aveiro, included eels is given by Cid *et al.*, 2001 and PCB's in Minho River by Santillo *et al.*, 2005. Neto, 2008 analysed and compared Cd, Cu, Pb and Zn concentrations in muscle and liver of eels and sediment of the Tejo estuary.

Spain

Although there is not any specific survey to analyse the presence of contaminants on eel, eel is sometimes among the species included in the biomonitoring of water masses made by the public administrations. Additionally, in some studies that evaluate the contamination in the biota, the eel is among the studied species. In this way, information regarding PCBs, pesticides and heavy metals bioaccumulation in eels from rivers of the Basque Country (Sanchez *et al.*, 1998), from the river Ebro (Santillo *et al.*, 2006), river Miño (Santillo *et a.,*. 2006), river Jucar (Bordajandi *et al.*, 2003) and river Guadalquivir (Usero *et al.*, 2003) is available. Few studies represent a specific survey to analyse the presence of contaminants in eel, as heavy metals determination in eels from the Albufera lacuna (Alcaide and Esteve, 2007). These authors concluded that among the tested HM. bioaccumulation of Cd, Hg, Zn, and Cu in liver tissue is related to the age/length of individuals [W and B values; $p \leq 0.01$] and so recommendations are remarked on standardization on length and/on age of the eels used in such studies (Alcaide and Esteve, 2007). On the other hand, Ureña *et al.*, 2007 concluded for the same location of the latter study that the eels with similar length demonstrate different pattern of metal distribution among tissue depending on there are from the wild or farmed.

Sweden

The National Food Administration in Sweden has analysed both yellow and silver eels sampled in 2000 and 2001 from nine different sites in Sweden with respect to 17 dioxins and furans and 10 dioxin-like PCB congeners (www.slv.se). Pooled samples demonstrated that eels had less than 1 pg TEQ/g fresh weight of sum TCDD/F in muscle (TEQ = Toxic Equivalents, TCDD = $C_{12}H_4O_2Cl_4$). To this came about 3.8 pg PCB-TEQ/g fresh weight. Silver eels had higher levels than yellow ones. Compared to the other fish species analysed, eels have a higher ratio of PCB to dioxins. Due to the high costs for this type of analyses only few eels will be sampled regularly in future.

Recently yellow eels from the Sound (between Sweden and Denmark) outside a heavily loaded industrial area in Helsingborg were analysed for dioxins and dioxin-like PCBs. Pooled samples from 2005 contained 5.7 WHO-PCDD/F-TEQ pg/g and 11 WHO-PCB-TEQ pg/g, both based on fresh weights. In 2006 another five pooled samples from the same area were analysed. The dioxins varied between 0.9 and 4.7 with an average of 2,2 WHO-PCDD/F-TEQ pg/g. The PCBs varied between 3.9 and 12.7 with an average of 6,6 WHO-PCDD/F-PCB-TEQ. At some sites the level of dioxins in eel muscle exceeded by that the 4 p/g level of dioxins or the 12 pg/g level of summed up dioxins and dioxin-like PCBs, set as maximum allowed levels in eel by the Commission of the European Communities. In 2007 further samples were analysed from this area. Both yellow and silver eels were analysed in seven pooled samples. The dioxin levels varied between 0,6 and 2,7 pg/g and the summed up dioxins and dioxin-like PCBs between 2.3 and 8.3 pg/g, i.e. all below the maximum allowed levels. However, the sample sites were not exactly the same as in 2005 and 2006 (Source: SLV (The National Food Administration)).

Recent analyses of mercury (Hg) in eels from a number of lakes did demonstrate very low levels.

UK

Recent surveys investigating concentrations of most metals including mercury, arsenic, cadmium, chromium, copper, lead, nickel and zinc, Poly-chlorinated biphenyls (PCBs), Dichloro-diphenyl-trichloroethanes (DDTs), Hexa-chlorocyclo-hexanes (HCHs) and Aldrin and Endrin ('Drins) found they had decreased substantially in eels from Sussex rivers between 1994–1995 and 2005–2006 (Foster and Block, 2006). The EU regulation limit of 8 pg/g of dioxin-like PCBs in eels was significantly exceeded for the dioxin-like PCB-118 at 100% of sampled sites in 1994–1995 and 2005–2006. Current levels of dioxin-like contaminants in eels in Sussex rivers are higher than those necessary to impair survival of fertilized eel eggs (Palstra *et al.*, 2006). Whilst Northern Ireland has the largest eel fisheries in the UK no contaminant analysis of eels is undertaken. However, from 2006 samples of silver and yellow eels from Lough Neagh are now routinely monitored for lipid content.

England and Wales

Concentrations of most metals including mercury, arsenic, cadmium, chromium, copper, lead, nickel and zinc, Poly-chlorinated biphenyls (PCBs), Dichloro-diphenyl-trichloroethanes (DDTs), Hexa-chlorocyclo-hexanes (HCHs) and Aldrin and Endrin ('Drins) decreased substantially in eels from Sussex rivers between 1994–1995 and 2005–2006 (Foster and Block, 2006). In 2005–2006 more eels were in the low to moderate risk bands (to people) and fewer eels were in the high risk band for PCBs proposed by the Oslo and Paris Commissions. The EU regulation limit of 8 pg/g of dioxin-like PCBs in eels was significantly exceeded for the dioxin-like PCB-118 at 100% of sampled sites in 1994–1995 and 2005–2006. Current levels of dioxin-like contaminants in eels in Sussex rivers are higher than those necessary to impair survival of fertilized eel eggs (Palstra *et al.*, 2006).

Northern Ireland

No routine sampling undertaken but available by request.

Scotland

No assessments of contaminants in eels have been undertaken in Scotland.

Parasites/pathogens: overview by country

Belgium

Since WGEEL, 2006 no new information is available on *Anguillicola* in Belgium. *Anguillicola* infection rates were monitored in 1987, 1997 and 2000 in which year 139 of 140 sites had the infection. The high infection level in Flanders is thought to be the result of restocking with glass eel and yellow eel, both of which are susceptible to *A. crassus*. For distribution maps of the parasite, see Belpaire, 2006 or Audenaert *et al.*, 2003. Previous studies into endoparasitic helminth communities of eel have been undertaken (Schabuss *et al.*, 1997).

Canada

To avoid parasite transfers, screenings are routinely done for elvers caught in Nova Scotia and southern New Brunswick before their stocking in fresh-waters locations in the upper St-Lawrence River and estuary. Screenings for viruses (IHNV, ISAV, IPNV and EVH) and *Anguillicola crassus* in individuals prior to stocking were negative during these years. During summer 2006 and 2007, 914 yellow eels were collected from 17 sites in the Maritime provinces, Québec and Ontario and *Anguillicola crassus* was found for the first time in the country. This swimbladder parasite is now present in New Brunswick and Nova Scotia (Antigonish and Cape Breton) (Ken Oliveira, University of Massachusetts, pers. comm.).

Denmark

Anguillicola crassus was discovered in Danish wild eels in 1986. Since 1988 a monitoring programme on the abundance of the parasite in the eel population in different fresh and brackish water bodies has been continued annually.

Estonia

Since 1992 the intensity of *Anguillicola* infection in the eel population of L. Võrtsjärv has been studied. The data will be provided for inclusion in the EEQD.

France

No new information from France was made available.

Germany

Detailed information of *Anguillicola crassus* has been provided in WGEEL, 2007. Monitoring has been established at the rivers Elbe and Weser and Ems, which are all important rivers for eel. For this monitoring, commercial fisher collect eel swimbladders from commercial catches on a weekly basis. As a consequence, no data on length or weight of the fish are available.

Generally, the prevalence in eels from German waters appears to be between 80% and 90% (Knösche *et al.*, 2004; Lehmann *et al.*, 2005; Leuner, 2006; 2007; Lehmann *et al.*, 2007). Lehman *et al.*, 2007 also reported the presence of *Trypanosoma granulosum* in more than 90% of all investigated eels from the Rhine system.

The German country report presents more details with data of monitoring of infection of eels from the Rivers Weser, Elbe and Ems with *Anguillicola crassus.*

Ireland

Anguillicola crassus was first recorded in Irish eels in the Waterford area in 1997. They were subsequently recorded in the Erne (see below) and this invasion probably occurred between 1997 and 1998, as they were apparently absent in 1996 (Copely and McCarthy, 2005). *Anguillicola* has now also spread to the R. Shannon (McCarthy and Cullen, 2000). A summary of the known distribution of *Anguillicola* in Ireland was compiled in 2003 (McCarthy *et al.*, in press) and the database is currently being updated, following discovery of the species in small and reputedly unexploited western Irish catchments. Current information would indicate that *Anguillicola* is now present in approximately 50% of the wetted area in Ireland, see map and Figure I.1 in the Irish country report.

Investigations of parasites assemblages of eels in marine, mixohaline and fresh-water habitats in the Shannon and other Irish rivers are being undertaken by the National University of Ireland, Galway, as part of a research project funded by the Higher Education Authority (HEA PRTLI-3).

Annual surveys of yellow and silver eels in the Shannon fisheries, undertaken since 1992, demonstrate that *Anguillicola* was first detected in 1998 at Killaloe and that since then it has become well established in the lower catchment and that it has more recently spread to lakes further up in the river system.

Eight parasitic endohelminth worm species (2 Cestoda, 3 Nematoda and 3 Acanthocephala) were found in the intestines of 1089 brown eel examined from throughout the Erne system, 1998–2001. Of greatest concern was the discovery of the pathogenic blood-sucking nematode *Anguillicola crassus* in the swimbladder of brown and silver eel from the Erne.

Initially detected in the R. Barrow in 1997, the parasite has since spread to the lower reaches of the R. Shannon and was first recorded from brown eel in southern Lower Lough Erne in 1998 (Evans and Matthews, 1999). By 1999 the parasite was detected as far upstream as L. Garadice with 90% of brown eel from the Narrows, Lower L. Erne is infected.

Anguillicola has not been recorded to date in Burrishoole.

Preliminary analysis of information available on the presence of *Anguillicola* in different catchments would indicate that approximately 50% of the wetted area is now potentially infected by the parasite (Figure I.1).

Italy

Among the samplings and examinations performed within specific parasitology research projects, the presence of *Anguillicola crassus* has occasionally been examined but no eel specific monitoring is in place. The infection is widespread throughout Italy but temporal variations in infection parameters have been noted.

Latvia

There is no new information from Anguillicola in Lithuania.

Lithuania

There is no new information from Anguillicola in Lithuania.

Netherlands

No new information from *Anguillicola* in the Netherlands was provided.

Norway

Infection of eels from the river Imsa by *Anguillicola crassus* was first reported in July 2008. In total seven out of 22 silver eels contained the parasitic nematode *Anguillicola crassus* in their swimbladder, therefore a prevalence of 32%.

All eels were female and at the silver migrating stage. Infected eels tended to be bigger in length and weight, but their condition factor was not significantly different (Mann-Whitney test, P=0.934). Two eels contained mature worms filled with eggs, in their swimbladder. Small and medium sized worms were also found.

Poland

During recent fishery surveys in the Vistula Lagoon eels were analysed by SFI for stomach fullness, and presence of *Anguillicola crassus* in the swimbladder. In 2006, 190 eels were inspected and infection rate indicated almost 90% were infected.

The most recent data on occurrence of parasite *Anguillicola crassus* in eel of Polish waters was collected in 2007–2008, however, some earlier data are also presented.

Data were collected and calculated according to three categories:

- Prevalence-proportion between infested eel and number of eel in sample.
- Mean intensity of infection-mean number of parasites per one infected eel.
- Density-mean number of parasites per one eel in sample.

The range of prevalence varied from 0,0 in Szczecin Lagoon in 1971 to 100,0 in Lake Łebsko (2001, 2004).

Intensity of infection varied from 0,0 in Szczecin Lagoon in 1971 to 14,6 in Lake Łebsko (2007).

The density varied between 0,0 in Szczecin Lagoon (1971) to 9,4 in Lake Jamno (2007).

In 2007–2008 total of 168 samples of eel were collected from 15 places of rivers, lakes and lagoons in both RBD’s, namely Vistula and Odra. Those samples were examined on presence of viruses EVEX, AgHV-1, VHS, IHN, SVC and IPN. All examinations were made in the Department of Pathology and Immunology of Inland Fisheries Institute in Olsztyn.

Portugal

Anguillicola crassus is present in several regions but no standard monitoring programmes have been established to examine its distribution. Different works dedicated to eel parasites are available:

- Nematoda-Ria de Aveiro (Cruz *et al.*, 1992), Douro River catchment (Saraiva *et al.*, 2002; Saraiva *et al.*, 2002).
- Intestinal Helminth communities-Lima, Cavado, Ave and Douro catchment areas (Saraiva *et al.*, 2005).
- Protozoa-Âncora, Lima, Cávado, Douro and Tejo catchment areas (Carvalho-Varela, 1984; Cruz and Davies, 1998; Cruz and Eiras, 1997).

- Parasite fauna in general including *Anguillicola*-Minho River catchment (Antunes, 1999; Aguilar *et al.*, 2005; Hermida *et al.*, 2006), Tejo river estuary (Neto, 2008), several rivers (Saraiva and Molnar, 1990; Saraiva, 1994, 1995, 1996; Saraiva and Chubb, 1996; Saraiva and Eiras, 1996; Rodrigues and Saraiva, 1996; Cardoso and Saraiva, 1998).

Spain

Some studies have been carried out regarding the presence of *Anguillicola crassus* in rivers from Spain (See Table. ES.j. in the Spanish country report). These studies have demonstrated that the parasite is widespread in Spain. However, there are still some rivers **in Asturias** and **Galicia** that have not been colonized yet; therefore special measures should be taken to avoid the infection of these basins. It is difficult to follow the sequence of *A. crassus* introduction in Spain since the first data we have is from 2000 and probably the nematode arrived before that data. However, it looks like in the Mediterranean the presence of the parasite is lower than in the Atlantic (lower prevalence, intensity and abundance). In the **Basque Country**, comparing the results of Gallastegi *et al.*, 2002 in the Butron in year 2000, with those of Díaz *et al.*, 2007 in the Basque rivers in 2006, we can see that there is an increase in the prevalence of the parasite, but that the infection intensity has decreased.

Researchers of the University of Valencia have studied the incidence of infectious diseases in the Albufera´s eel population (Jucar basin, Valencia), through a 3-years period (from October 2003 to July 2005. They analysed 122 individuals of different growth stage (Durif *et al.*, 2005) and health condition and observed that eels suffer from acute diseases such as those produced by highly virulent bacteria belonging to *Edwardsiella tarda* and *Vibrio vulnificus* species (Alcaide *et al.*, 2006; Esteve *et al.*, 2007; Esteve and Alcaide, 2007). *Edwardsiella tarda* disease was present along the study period with a prevalence ranging from 5.6 to 27.8% in the nine surveys performed (Esteve and Alcaide, 2007). *Vibrio vulnificus* disease had a sporadic incidence during the study; it was detected in November 2003 with a very high prevalence of 77.2% (Esteve *et al.*, 2007). In addition, chronic and mixed infections caused by weakly virulent bacteria (*Aeromonas* sp. and *Pseudomonas* sp.) and fungi (*Saprolegnia* sp.) were observed along the study period with a prevalence ranging from 10.5 to 22.2% in the nine surveys performed (Esteve and Alcaide, 2007). In fact, authors remarked that pathogenic bacteria may play a leading role in the decline of Albufera´s eel population as the prevalence of each bacterial disease was at the same level than that observed for the swimbladder parasitic disease (Esteve and Alcaide, 2007).

Interestingly, the correlation between the sanitary status of an eel [Healthy; Acute bacterial disease; and Chronic disease] and its growth stage [Young Yellow; Sexually differentiated Yellow; and Mature Silver] was statistically significant: observed number of both “young yellow eels which present acute bacterial disease” and “silver eels which present chronic illness” notably exceed those expected [Pearson $X^2= 10.812$; $P(4 \text{ d.f.})= 0.029$] (Esteve and Alcaide, 2007). Thus, authors suggested that youngest eels could suffer high mortality rates in the natural habitat (Albufera lacuna), and that low quality of mature adults could reduce their survival along the downstream migration to the sea.

Sweden

The swimbladder parasite (*Anguillicola*) does occur in eels from most sites. All eels dissected at the Swedish Board of Fisheries are analysed macroscopically for the prevalence (at both Institutes involved) and intensity (at the Institute of Freshwater Research only) of *Anguillicola* in their swimbladders. The prevalence in coastal waters in 2002–2005 was close to 10% in the marine habitats of RBD 5 and about 60% in the central parts of RBD 4. The straight between Sweden and Denmark (Öresund, SD 23) took an intermediate position.

Prevalence of *Anguillicola crassus* is a mandatory variable in all coastal sampling of eel in Sweden, including the DCR sampling. The rate of infestation in the pooled data from 2002–2006 was less than 15% in the most marine areas, 47% in Öresund and close to 60 in the Baltic sites.

Between 2000 and 2008 the Institute of Freshwater Research analysed 3608 eels from 41 different fresh-water sites. Infested eels were found in all sites and the prevalence varied from 37% to 91%. Data have been presented for inclusion in the EEQD.

UK

England and Wales

Anguillicola crassus is now considered ubiquitous throughout the UK (Nigel Hewlett, Environment Agency National Fisheries Laboratory, pers. comm.). Foster and Block, 2006 reported infestation levels in eels (~300 mm total length) sampled across the Sussex area in 2005–2006 ranging from 60% to 88% (regional mean 72%). Similar levels of infestation were reported for eels in Kent rivers in 1996–1998 (Cave, 2000).

In October 2007, 50% and 83% of eels from the River Thames (respectively the estuary and the fresh-water part) were infected *A. crassus.*

On 30 elvers examined from UK glass eels (Gloucester, April 2008) low level granulomas were present in kidney region of one elver. In 30 elvers examined from River Severn at Maisemore (April 2008) occasional trichodinids were found on the gills.

A. crassus was found in small numbers in 23% of fish (n=30) from tidal River Thames (June 2008); also P. laevis found in small numbers in 7% of fish.

A. crassus was found in small numbers in 73% of fish (n=30) from Roman River (July 2008);

Eight eels were examined from Southern Leisure Lake (August 2007)-*A. crassus* was recorded in the swimbladder and kidney, *Myxobolus* sp. in fins and nematodes likely to be *Daniconema anguillae* in the muscle. Significant pathology was recorded in the gills of the fish examined, indicative of a water quality problem. Bacterial examination returned negative results. Virology testing was also negative for the presence of Infectious Pancreatic Necrosis (IPN) and Eel Rhabdovirus.

Northern Ireland

L. Erne

Anguillicola crassus was first recorded in the swimbladders of eels in Ireland during an extensive fykenet survey of the Erne system in July 1998. Of 328 yellow eels examined in 1998, 24 (7.3%) were infected, with a mean intensity of 4.3 worms per eel. Infected eels were only recorded in southern Lower Lough Erne and northern Upper Lough Erne. Examination of 432 yellow eels in 1999, demonstrated an increase in both mean intensity (6.7 worms per eel) and prevalence (9.9%) of *A. crassus*. The range of the parasite had also increased, with infected eels recorded from the lower reaches of the Erne, 30 km downstream of the original area of infection. Monthly samples of silver eels taken by commercial nets near the outlet of the Erne during October–December 1998 and 1999 confirmed active migrants contained the parasite.

Prevalence and mean intensity among silver eels rose from 4.5% and 2.5 worms per silver eel in 1998 to 15% and 8.6 worms per eel in 1999 (Evans *et al.*, 2001).

L. Neagh

A. crassus was found in Lough Neagh yellow and silver eels for the first time in 2003, and its spread has been monitored via the analysis of a total of 1100 yellow and 400 silver eels from 2003 to 2006. Samples were stored in 70% alcohol and in the lab; swimbladders were examined macroscopically for the presence of pre-adult and adult *A. crassus*, but not for larval *A. crassus*. Recorded prevalence and mean intensity in yellow eels rose from 24.4% and 2.2 in 2003 to 69% and 3.6, and to 100% and 7.7 in 2004 and 2005, respectively. However, the same infection parameters recorded for silver eel were significantly different, with almost 60% infected in 2003 rising to almost 90% in 2004. By 2005, 100% of yellow and silver eels were found to be infected with *A. crassus* (Evans and Rosell, 2006). In 2007 the prevalence of *A. crassus* in both yellow and silver eels had fallen to 70% and 76%, respectively.

Scotland

There is to date only a single reported instance of *Anguillicola crassus* in Scottish RBD (Lyndon and Pieters, 2005), for a fish farm near Bridge of Earn, on the Tay system. However, the absence of targeted effort on the identification of *A. crassus* in the Scottish RBD may have led to under-recording. The parasite is currently being sought in eel samples collected in the catchments of central Scotland, and there is an unconfirmed report of an infected eel from the Forth (Willie Yeomans, pers. comm.). However, the likelihood is that *A. crassus* is not sufficiently widespread as yet in Scotland, as a consequence of low levels of stock transfer, to have had possible impacts on eel populations.

Annex 6 – Draft WGEEL terms of reference 2009

2008/2/ACOM15 The **Joint EIFAC/ICES Working Group on Eels** [WGEEL] (Chair: Russell Poole, Ireland), will meet in ICES, 9–15 September 2009, to:

a) assess the trends in recruitment and stock, for international stock assessment, in light of the implementation of the Eel Management Plans;

b) Evaluate the EU eel management plan;

c) develop methods to post-evaluate effects of management plans at the stock-wide level;

d) develop methods for the assessment of the status of local eel populations, the impact of fisheries and other anthropogenic impacts, and of implemented management measures;

e) establish international databases on eel stock, fisheries and other anthropogenic impacts, as well as habitat and eel quality related data, and the review and development of recommendations on inclusion of data quality issues, including the impact of the implementation of the eel recovery plan on time-series data, on stock assessment methods;

f) review and develop approaches to quantifying the effects of eel quality on stock dynamics and integrating these in stock assessment methods;

g) respond to specific requests in support of the eel stock recovery Regulation, as necessary; and

h) report on improvements to the scientific basis for advice on the management of European and American eel

WGEEL will report by 22 September 2009 for the attention of ACOM and DFC.

Annex 7 – Technical minutes Eel Review Group 2008

- RGEEL
- By correspondence 29–30 October 2008
- Participants: André Forest (Chair), Russell Poole (WG Chair), Martin Castonguay (Canada), David Cairns (Canada), Dietrich Schnack (Germany), Maris Pliskhs (Latvia), Henrik Svedäng (Sweden).
- Working Group: WGEEL

General comments

This is a comprehensive, informative and well organized report. It is at the same time highly educational, as it includes a great amount of basic scientific background information for a good understanding of the specific problems related to the assessment of an eel stock. However, the report is clearly a result of an ongoing process that started years ago, and therefore does not present a comprehensive overview but should be read in conjunction with previous reports.

A great deal of emphasis is put on various risks of impaired reproduction and similar ecosystem based considerations but no data were presented on neither population dynamics nor the fisheries and a section dedicated to the fishery is not included. At least some studies aiming to describe fishing mortality and efforts have been performed over the years; these should be referred to.

The main message is that the eel stock is in a very poor state since many years, and this is consistent with the previous report. Obviously, securing fish with the highest fitness should be a top priority given the low recruitment, i.e. a ban on silver eel fishery is the quickest and safest measure to protect the European eel stock from a final and total collapse. The possibility that the effective spawning biomass is lowered due to parasite loads and contaminants, underscores the necessity of reducing the fishing pressure in both the short and long term perspectives as well as improving the habitat conditions.

The WG group has put a lot of effort to summarize available information on eel ecology (predation, mortalities), possible anthropogenic impacts, etc. There is listed a very wide range of possible measures that have to be taken into account, but a judgement of the potential efficiency or relative value of these measures is missing; so there is no basis for ranking the measures giving no guidance to the managers.

A certain number of questions were posed by the Review Group in 2007, but the majority remains unanswered.

Section 2 Trends in recruitment, stocking, yield and aquaculture

Landings

Existing data should be very or more(?) thoroughly analysed as it is probably the best indicatives on what is going on regarding the SSB (NB: increased catchability due to technological creeping).

Recruitment

Some observations concerning recruitment and stock size are overstated whereas others are neglected or considered to be of less importance without any obvious reason (for instance, commercial cpue series on glass eels fishery have been given greater weight than non-commercial series on yellow eel upstream migration).

Annex 3 includes the data basis for presenting trends in recruitment for different European rivers (Figures 2.1 and 2.2.), and defines also the different measures that have been used. It is however not clearly defined, how the "all countries" line has been obtained. It seems to be the geometric mean of the scaled data from the individual systems, but this should be mentioned in the heading of the table and the legend of the Figure.

The trend analysis on the commercial glass eel indices should have as a starting year when most if not all indices were running, i.e. about 1970. Otherwise, great weight is given to a few fishery-dependent catch records. It is also questionable why fisher-dependent data are given greater emphasis than upstream migration of yellow eels. The Göta älv index is a strong indication on a decline in recruitment already in the beginning of the 1950s, 30 yrs before such a decline was recognized in the commercial cpue time series. The Göta älv index and similar evidence from the Baltic region is now presented as a problem for this region and its data collection as two rather irrelevant hypotheses are put forward. The thing is that the recruitment decline in this region that began already in the 1950s, and the subsequent fall in the silver eel fishery in the Baltic Sea about a decade later fit strongly together. Moreover, the indices from the Mediterranean are similar to the Baltic development. This observation points at a declining recruitment (due to decline in SSB?) occurred much earlier than the 1980s, as it is reasonable that a fall is detected in the periphery of a species distribution rather at the core (i.e. the Celtic arc).

In Chapter 2.2.1 (and several other places where a corresponding summary is given) it is stated that "the decline is stronger in northernmost and southernmost area of the species distribution than in the central part". This cannot be seen from the data presented. The Baltic Sea and North Sea river systems are not more northern than the British Isles systems and the Mediterranean systems are hardly more southern than the Atlantic systems indicated in Figure 2.11. The decline is stronger in the more eastern areas or least in the more western areas, i.e. at the Atlantic cost.

In Figures 2.1 and 2.2 the scaling is done relative to the average over the period 1979–1994, whereas in all later figures the reference period is 1970–1979. Is there any reason to not use the same reference period for the scaling of the trend data?

Figure 2.5 compares eel landings from country reports with data from FAO. It would be helpful to receive some information on the time periods compared in each case and to include some comment on the possible reasons of major discrepancies in some cases.

In Figure 2.6 the legend for non-commercial catches does not show up.

In Chapter 2.2.2 (and corresponding summaries) it is argued that "we can thus build an index of recruitment of all Europe … calculated as the geometric mean of each of the monitoring indices" (based on different sampling methods). This argument is not convincing. It has been pointed out that the recruitment index is different among areas and also that sampling types are largely specific for the individual areas; thus each method is not representative for all Europe and any mean from all methods may not be expected to be representative for all Europe as well. Thus, it could be suggested presenting even in a summary the range of recruitment levels of 1–10% compared to the period 1970–1979, obtained for the different areas. It can also be stated that in all areas apart from the Atlantic coast the lever is below 5%.

Section 3 International stock assessment and data needs

In Chapter 3.3.3 it is argued that "the intervals in the reporting cycle under the EU Regulation are far too long to enable any rapid progress by WGEEL". It may sound like a contradiction to the statement given before that the restoration process for the eel stock will take decades. It may be important to state that to get an international assessment started and supported by adequate data, a yearly availability of data would be necessary, though on a long run assessment could perhaps be arranged on a multiannual scale.

Last sentence in second paragraph of Chapter 3.3.8 seems difficult to understand. Also the message of the last paragraph of Chapter 3.4 is not obvious.

Section 4 Assessing stocks and management actions

Table 4.1 is not readable.

Chapter 4.4: Achieving a reasonable estimate of the total spawning stock biomass appears to be a rather difficult and demanding task for the eel stock. It could be asked, if it has ever been thought of carrying out regular larval surveys in the Sargasso Sea to receive an index of effective spawning stock size? This would be rather demanding as well, but compared to the effort required for receiving an estimate of the total effective spawning stock size on the basis of silver eel escapement (if at all possible with sufficient reliability), the effort for a larval survey campaign e.g. every 3 years may not be too unrealistic. This would provide an index completely independent of all other methods and could allow at the same time to develop research programmes on the oceanic phase of the species.

Section 5 Stocking and aquaculture

Stocking

The effectiveness of using stocking of glass eels/ elver/ yellow eels as a way of handling the eel decline is debatable:

(a) Compiled data in the report quite effectively demonstrates the low rewards from already performed stockings, even on a regional scale. In spite of intense stockings in the 1960s in East Germany and Poland in the Baltic Sea region, the yield in the Danish and Swedish eel fisheries declined in the 1970s,

(b) The most important objection is the still unknown fate of translocated eels in terms of ability to return to their natal spawning area(s). There is some evidence that eel for instance removed from Western Europe to the Baltic Sea do not find their way back at spawning, whereas no data support the opposite.

(c) Unless the fishery on yellow and silver eel is completely stopped, there is an apparent risk of rather boostering the eel fishery, i.e. increasing the fishing pressure on those individuals that are naturally recruited. Accordingly, it should be stated crystal clear that stocking is NOT an option but a cul-de-sac unless it can be proved that the navigational skills of the stocked eels are as good, or at least almost as good, as the ability of the naturally recruited ones. It may be considered, however, that in cases where eels are so depleted that a river basin is at risk to fail completely in contributing to the spawning population, stocking might be used as a last resort, provided that a surplus of glass eels is locally available. In such cases, procedures to prevent the introduction and spreading of parasites and diseases according to the European fish disease prevention policies have to be applied.

In conclusion, the contribution of translocated eels to SSB is not known; this means that it might be nil, but it could as well have a positive effect. This chance, thought uncertain, should be utilized as a last resort in case it does not conflict with other demands and where an adequate river basin is otherwise depleted from eel.

Section 6 Eel quality

Section 7 Ocean climate and recruitment

Section 8 Research needs

There is listed of very wide range of additional research required in order to fill many gaps in the biology, stock assessment, post-evaluation of management actions, etc. However these proposals are not prioritised and as money will be a limiting factor for research in the future, a clear ranking of research needs as basis for management advice is imperative.

Annex 8 – Country Reports: Eel stock and fisheries reported by country – 2008

In preparation to the Working Group, participants of each country have prepared a Country Report, in which the most recent information on eel stock and fishery are presented. These Country Reports aim at presenting the best information, which does not necessarily coincide with the official status. This Annex reproduces the Country Reports in full detail.

Participants from the following countries provided an (updated) report to the 2008 meeting of the Working Group:

- Norway
- Sweden
- Finland
- Estonia
- Latvia
- Lithuania
- Poland
- Germany
- Denmark
- The Netherlands
- Belgium
- Ireland
- The United Kingdom of Great Britain and Northern Ireland
- France
- Spain
- Portugal
- Italy
- Canada

For practical reasons, this report presents the country reports in electronic format only (URL). Available at http://www.ices.dk/reports/ACOM/2008/WGEEL/Country_reports_2008.pdf In the printed version, these can be found on an enclosed CD-ROM.