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Hamburg, Germany, 9–14 September 2010

REPORT OF THE 2010 SESSION OF THE JOINT EIFAC/ICES WORKING GROUP ON EELS

HAMBURG, GERMANY, 9–14 SEPTEMBER 2010

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This publication is the report of the 2010 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 Hamburg, Germany, from 9 to 14 September 2010.

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Abstract

Indications are that the eel stock is at a historical minimum, continues to decline and is outside safe biological limits. Recruitment to the stock is at a historically low level and there is 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 until a recovery of the stock is achieved.

Recruitment in recent years has been especially low. All glass eel recruitment-series demonstrate clear and marked decadal reductions since the early 1980s. For the last five years the series based on glass eel average between 1% (continental North Sea) and 7% (continental Atlantic) of 1960–1979 levels respectively. A difference in spatial pattern of recruitment is observed at most stations in the North Sea, where the decline is sharper than elsewhere. Recruitment of continental yellow eel has been declining continuously since the 1950s and is currently at 9% of 1960–1979 level.

Total landings data have been found to be unreliable and it is hoped that the implementation of the DCF and eel Regulation/CITES traceability schemes might improve this situation. There was a great heterogeneity among the landings data with incomplete and inconsistent reporting by countries and changes in management practices were found to have also changed the reporting of non commercial and recreational fisheries.

Stocking with glass eel has decreased strongly since the early 1990s and appears now to be at a relatively low level and still decreasing. This has partly been compensated for by an increasing number of young yellow eels stocked since the late 1980s.

The Working Group applied a modified ICES precautionary diagram to the EMU eel biomass data as reported in the Country Reports and the Eel Management Plans. The preliminary information clearly indicates the wide variation in stock status within and between countries, the need to standardize methodology and presentation, and the wide range in contributions to the eel stock of different EMUs and countries. The data allowed a preliminary assessment of stock status in 40 Eel Management Units. Many of the EMUs lie in the orange and red zones. For some EMUs, the %SPR is above 100%, so the anthropogenic mortality is estimated below zero. This situation is found when positive impacts occur (e.g. stocking).

A number of topics were reviewed in support of local assessment of eel stocks to further improve the estimation of silver eel production. Mark–recapture techniques for silver eel escapement tend to fall into one of two approaches: a/ single point assessments where M–R data are gathered and treated mathematically as closely as possible to a single point in space and time and b/ a new survival model approach under development for data with multiple mark and recapture sites over longer periods of time and distance and where multiple silver eel inputs to the population and/or losses occur throughout the assessment due to fishing and other mortality.

Methods used for determination of silvering stage were reviewed and compared to assess their practicality and efficiency as tools to evaluate the number of potential spawners in a sample. External objective criteria (such as body measurements) are more accurate than observations based on skin colour or the visibility of the lateral line. Commonly used indices were applied on several datasets consisting of yellow and downstream migrating eels (i.e. that were caught as they were moving downstream) in order to develop a tool for estimating silver eel biomass from appropriately timed yellow eel surveys or sampling. The silvering index, based on

eye diameters, pectoral fin length, body length and body weight, was preferred for an accurate description of the sample. A model that predicts the silvering rate based solely on length of eel gave very similar results and is very promising as a simple and reliable method of estimating the proportion of future spawners. Practical guidelines are specified to measure body parameters. Because silvering occurs over summer, the appropriate period for such a survey would be September, just before migratory movements. A seasonal trend in the mean size of silver eels was confirmed from several countries across Europe. Small eels (which are males in most cases) migrate earlier in the season, followed by larger females. The previous observations of Vøllestad (1992) that age and size of silver eels increase with latitude were also confirmed and there appears to be an increase in silver eel size over the years (since the 1940s).

On examining the gathering and use of eel data from Water Framework Directive and Data Collection Framework programmes in EU Member States, the WG concluded that both sampling programmes for eels can be useful but they (especially the DCF) should specifically include eel in scientific surveys to maximize the value of such work and properly address the needs of all eel stock assessments and reporting to the EU. It is recommended that a (series of) data workshop(s) be held as soon as possible to provide support and coordination for data collection, analysis and reporting.

Analysis of the use of wetted area models for estimating silver eel production revealed a lack of consistency within and between countries on how productive area is determined and reported. The types of habitats considered in these estimates varied between EMU's and countries and differences were found in the estimated areas and these create uncertainty for stock assessment at the international level. A consistent approach to including all types of natural eel habitat is necessary, and may require more data collection to inform this process.

The European Eel Quality Database (EEQD) integrates data of contaminants, diseases and parasites, and fat content. New data were incorporated in 2010 for 1361 records of contaminants, diseases or parasites, but the data do not yet support a comprehensive overview on the quality of eel throughout its distribution.

Trend analyses of contaminants in Belgium and the Netherlands reveal the expected decreases in average concentrations, but some pollutants clearly persist in the environment long after their use was banned (e.g. PCBs). *Anguillicoloides crassus* continues its spread across Europe and is pretty much ubiquitous.

The development of an Eel Quality Index was initiated as a means to combine the effects of different quality pressures into an estimate of the overall quality of eels. The Index was illustrated using information on PCB levels in eels from case studies in four countries. The approach should be further developed to include other pollutants, diseases and parasites affecting the quality of eels. Some fisheries for eel (and other species) have been closed in Belgium, France and Germany because pollution levels are so high as to be a risk to the health of consumers.

An extensive range of scientific papers have been published in the peer reviewed literature since the WGEEL 2009 meeting, a bibliography of which is presented. Given the current focus of WGEEL towards stock recovery it was decided to review only those scientific advances with direct relevance to stock management. These included recent genetic findings, artificial reproduction, advances in Japanese eel science, eel quality, stocking, hydropower and oceanic phase. While the review was informative it also highlighted gaps in current knowledge particularly with reference to stocking, and mitigation measures to reduce the impact of hydropower.

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 2010 session of the Joint EIFAC/ICES Working Group on Eels which took place in Hamburg, Germany, hosted by the Johann Heinrich von Thünen-Institut (vTI/FOE), from 9 to 14 September 2010.

In this section, the main outcomes from the report are summarized, a forward focus is proposed in the light of observed declines in many Anguillid stocks and the implementation of the EU Regulation for the Recovery of the Eel Stock and the main recommendations are presented by WGEEL.

The Working Group in 2010, along with SGIPEE, has focused on five main themes, updating the recruitment and stocking time-series, including a spatial analysis, undertaking a preliminary post-evaluation at the EMU and international level as a model for future post-evaluations, providing support for local population assessments and filling methodological gaps in surveys in support of estimating biomass and mortality, updating the EEQD and making preliminary assessments of spawner quality and summarizing some advancements in the scientific basis for advice and eel conservation.

The objective of eel stock assessment is to quantify the biomass of silver eel escaping from the Eel Management Unit (EMU) in order to assess compliance with the EU target of 40% of pristine biomass without anthropogenic mortality. Given that it will be impractical to directly assess silver eel biomass and mortality in many rivers, yellow eel stock assessment will also be required. In conjunction with SGIPEE and POSE, the Working Group identified a number of areas where gaps in knowledge existed (i.e. silver eel assessment, yellow to silver transformation, quantification of habitat) and focused on these in order to provide support for local stock assessments.

Summary of this report

From the information available, indications are that the eel stock is at a historical minimum, continues to decline and is outside safe biological limits. Recruitment to the stock is at a historically low level and continues to decline with no obvious sign of recovery. Current levels of anthropogenic mortality, thought to be high on both juvenile (glass eel) and older eel (yellow and silver eel), are not sustainable and there is an urgent need that these should be reduced to as close to zero as possible until a recovery of the stock is achieved.

Recruitment in 2008, 2009 and 2010 has been especially low. In 2009 the decrease was sharper than ever; especially in the northern part of the distribution area, with a further drop of around 50–60% for glass eel landings between 2008 and 2009. The glass eel landings data in 2010 were higher than in 2009, but remain at a low level.

All glass eel recruitment-series demonstrate clear and marked decadal reductions since the early 1980s. For the last five years the series based on glass eel average between 1% (continental North Sea) and 7% (continental Atlantic) of 1960–1979 levels respectively. A difference in spatial pattern of recruitment is observed at most stations in the North Sea, where the decline is sharper than elsewhere. There is no current explanation for that observation. Recruitment of continental yellow eel has been declining continuously since the 1950s and is currently at 9% of 1960–1979 level.

Total landings data have been found to be unreliable and it is hoped that the implementation of the DCF and eel Regulation/CITES traceability schemes might improve this situation. There was a great heterogeneity among the landings data with incomplete and inconsistent reporting by countries. It was, therefore, considered inappropriate to analyse trends. Changes in management practices were found to have also changed the reporting of non commercial and recreational fisheries.

Stocking with glass eel has decreased strongly since the early 1990s and appears now to be at a relatively low level and still decreasing. However, this has partly been compensated for by an increasing number of young yellow eels stocked since the late 1980s, the amount of which has varied widely in recent years.

In conjunction with SGIPEE, the Working Group applied a modified ICES precautionary diagram to the EMU eel biomass data as reported in the Country Reports and the Eel Management Plans. The Modified Precautionary Diagram, and the summation method used to derive an integration of the national assessments, is a consistent procedure of presenting the available information, but it does not produce independent and verifiable outputs. It is primarily a method of communicating the information on the stock status, including the lack of information from over half the Eel Management Units. In this modified diagram, the spawning stock is plotted on a logarithmic scale, while the annual fishing mortality is replaced by the lifetime cumulative anthropogenic mortality ΣA. As in the standard diagram, the horizontal axis quantifies the status of the stock. The vertical axis, however, quantifies the anthropogenic impacts, as opposed to only fishing impacts in the standard diagram.

The preliminary information presented here clearly indicates the wide variation in stock status within and between countries, the need to standardize methodology and presentation, and the wide range in contributions to the eel stock of different EMUs and countries.

The data presented allowed a preliminary assessment of stock status in 40 Eel Management Units. Many of the EMUs lie in the orange and red zones. For some EMUs, the %SPR is above 100%, so the anthropogenic mortality is estimated below zero. This situation is found when positive impacts occur (e.g. stocking).

The Working Group reviewed a number of topics in support of local assessments of eel stocks in order to further improve the estimation of silver eel production. Mark–recapture techniques for silver eel escapement tend to fall into one of two approaches: a/ single point assessments where M–R data are gathered and treated mathematically as closely as possible to a single point in space and time and where this approach is not appropriate to dataseries with multiple mark and recapture sites over longer periods of time and distance and where multiple silver eel inputs to the population and/or losses occur throughout the assessment due to fishing and other mortality – b/ a new approach to analysis is under development for such data, using tag recovery data as indicative of survivorship between points, built into a larger scale model. Case studies using classic mark–recapture methods and survival model approaches are presented.

Methods used for determination of silvering stage were reviewed and compared to assess their practicality and efficiency as tools to evaluate the number of potential spawners in a sample. Methods using external objective criteria (such as body measurements) are more accurate than observations based on skin colour or the visibility of the lateral line. Commonly used indices were applied on several datasets consisting of yellow and downstream migrating eels (i.e. that were caught as they were moving downstream) in order to develop a tool for estimating silver eel biomass from appropriately timed yellow eel surveys or sampling. The silvering index, based on eye diameters, pectoral fin length, body length and body weight, was preferred for an accurate description of the sample. A model that predicts the silvering rate based solely on length of eels gave very similar results and is very promising as a simple and reliable method to estimate the proportion of future spawners. Practical guidelines are specified to measure body parameters. Because silvering occurs over summer, the appropriate period for such a survey would be September, just before migratory movements. A seasonal trend in the mean size of silver eels was confirmed from several countries across Europe. Small eels (which are males in most cases) migrate earlier in the season, followed by larger females. The previous observations of Vøllestad (1992) that age and size of silver eels increase with latitude were also confirmed and there appears to be an increase in silver eel size over the years (since the 1940s).

On examining the gathering and use of eel data from Water Framework Directive and Data Collection Framework programmes in EU Member States, the WG concluded that both sampling programmes for eels can be useful but they (especially the DCF) should specifically include eel in scientific surveys to maximize the value of such work and properly address the needs of all eel stock assessments and reporting to the EU. It is recommended that a (series of) data workshop(s) be held as soon as possible to provide support and coordination for data collection, analysis and reporting.

Analysis of the use of wetted area models for estimating silver eel production revealed a lack of consistency within and between countries on how productive area is determined and reported. The types of habitats considered in these estimates varied between EMU's and countries and differences were found in the estimated areas and these create uncertainty for stock assessment at the international level. A consistent approach to including all types of natural eel habitat is necessary, and may require more data collection to inform this process.

The European Eel Quality Database (EEQD) integrates data of contaminants, diseases and parasites, and fat content. New data were incorporated in 2010 for 1361 records of contaminants, diseases or parasites, but the data do not yet support a comprehensive overview on the quality of eel throughout its distribution.

Trend analyses of contaminants in Belgium and the Netherlands reveal the expected decreases in average concentrations, but some pollutants clearly persist in the environment long after their use was banned (e.g. PCBs). *Anguillicoloides crassus* continues its spread across Europe and is pretty much ubiquitous. Climate change may also affect the abundance and virulence of diseases and parasites in eels.

The development of an Eel Quality Index was initiated as a means to combine the effects of different quality pressures into an estimate of the overall quality of eels. The Index was illustrated using information on PCB levels in eels from case studies in four countries. The approach should be further developed to include other pollutants, diseases and parasites affecting the quality of eels. Some fisheries for eel (and other species) have been closed in Belgium, France and Germany because pollution levels are so high as to be a risk to the health of consumers.

An extensive range of scientific papers have been published in the peer reviewed literature since the WGEEL 2009 meeting, a bibliography of which is presented at the end of Chapter 6. However, given the current focus of WGEEL towards stock recovery it was decided to review only those scientific advances with direct relevance to stock management. These included recent genetic findings, artificial reproduction, advances in Japanese eel science, eel quality, stocking, hydropower and oceanic phase. While the review was informative it also highlighted gaps in current knowledge particularly with reference to stocking, and mitigation measures to reduce the impact of hydropower.

Forward focus

This report is a further step in an ongoing process of documenting eel (*Anguilla anguilla* and *A. rostrata*) stock status and fisheries and developing a methodology for giving scientific advice on management to effect a recovery in the European eel stock. The European plan for recovery of the stock was adopted in 2007 by the EU Council of Ministers (Council Regulation No. 110/2007). To this end, Member States had to develop Eel Management Plans for the stock on their territory, aiming at a silver eel escapement of 40% in biomass terms, relative to the pristine state. Further scientific advice will be required for the implementation, monitoring and post-evaluation of the Regulation at both national and international levels. The implementation of the management plans formulated under the Regulation should continue to improve and extend the information on stock and fisheries. Improved reliability and better spatial coverage will also happen along with breakpoints in several currently available time-series; correction procedures. In 2012, EU Member States will report on protective measures implemented in their territories, and their effects on the stock, a process for which assessment methodology is currently limited. For effective evaluation of change in stock at the International level, the working group will need access to data gathered within the framework of national/regional management plans. Gaps have been identified where these data may fall short of that required. There will be a need for an international database compiled from regional components; and post-evaluation procedures for measuring the impact of corrective actions on the stock.

The EU Eel Regulation and associated eel management plans, CITES and the EU DCF for Eel are likely to force radical change in management of eel. In 2009, the WGEEL clearly mapped a forward focus strategy for the period 2010–2012.

During the 2010 Working Group session, a number of additional priority issues were identified where new research initiatives will provide useful information in coming years, or where additional effort or attention is required.

The EU Eel Regulation obliges Member States to protect the eel stock, to monitor and register the anthropogenic impacts, and to report on the status of the stock by 2012 along with the reduction in impacts achieved. Monitoring data are collected within the framework of the DCF, the WFD and national programmes (Section 4). The national reports in 2012 will report on the overall status of the stock, which must at least supply the minimal information (B_o, B_{best}, B_{post}); however, for quality assurance reasons, the basic data used for the national assessment (and the method used) will need to be made available to the international level too. Timely coordination of the data collection, storage, analysis and reporting will facilitate the evaluation process in 2012; project POSE will develop best practice manuals for target development (though not for post-evaluation). It is therefore suggested to organize a (series of) international workshop(s) on eel data collection, to support local programmes, to coordinate and standardize, and to explore post-evaluation methods for local eel stocks; the prime focus of these workshops should be on the EMU level, thus setting the scene for the international post-evaluation. Noting the close link to DCF (and WFD), the (series of) workshop(s) would probably be best organized under the umbrella of STECF.

Ultimate recovery of the stock will have to be measured in terms of recovery of the glass eel immigration from the ocean, which is now consistently below 7% of the historical level. National monitoring of glass eel immigration may be useful for local stock assessment, but its primary information relates to the global status of the stock.

Analyses of the historical time-trends in recruitment (Section 2) have demonstrated, that trends can be extracted, and spatial coherence patterns detected, though some statistical uncertainty remains. At this moment in time, it is not yet clear what recovery in eel recruitment is to be expected following the implementation of the Eel Regulation, at what time delay, and with what statistical power. A single year of higher recruitment (as in 2010) can easily be misinterpreted as a sign of recovery. It is therefore suggested that the next meeting of WGEEL considers the analysis of recruit time-series, with the aim of defining statistical power, expected recovery, time delays, and sequential detection of first order discontinuities.

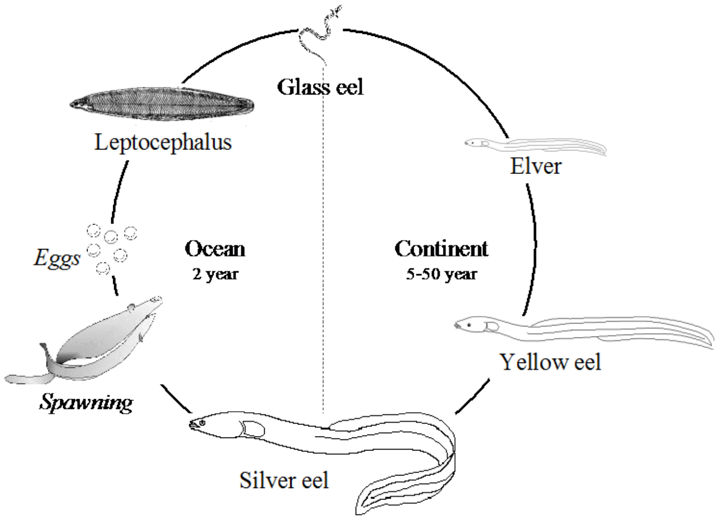
Main recommendations

- Because overall 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 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.
- The 2001 meeting of WGEEL (ICES 2002) recommended the formation of an international commission that could act as a clearing house for handling and coordinating data collection & storage, stock assessment, management and research. Noting the urgent need to plan and coordinate the data collection and tool development for the 2012 post-evaluation; this recommendation is re-iterated.
- In particular, it is recommended to organize a (series of) workshop(s) in relation to local eel stock monitoring, with a focus on standardization and coordination, preparing for the 2012 post-evaluation, setting the scene for the 2013 international stock assessment.

The Working Group also provided advice on the data requirements for future stock assessment and post-evaluation with particular reference to the reporting requirement of the EU Regulation in 2012 (Annex 5) and a proposal for a project (study group or workshop) on Sustainable (eel) Fisheries (Annex 7).

Glossary

Eel 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.

Glossary of Terms

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 or Eel Management Unit	"Member States shall identify and define the individual river basins lying within their national territory that constitute natural habitats for the European eel (eel river basins) which may include maritime waters. If appropriate justification is provided, a Member State may designate the whole of its national territory or an existing regional administrative unit as one eel river basin. In defining eel river basins, Member States shall have the maximum possible regard for the administrative arrangements referred to in Article 3 of Directive 2000/60/EC [i.e. River Basin Districts of the Water Framework Directive]." EC No. 1100/2007

River Basin District	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.
Trap and transport	Traditionally, the term trap and transport referred to trapping recruits at impassible obstacles and transporting them upstream and releasing them. Under the EMPs, trap and transport (or catch and carry) now also refers to fishing for downstream migrating silver eel for transportation around hydropower turbines.

Eel reference points/population dynamic	
Anthropogenic mortality after management (Apost)	Estimate of anthropogenic mortality after management actions are implemented
Anthropogenic mortality before management (Apre)	Estimate of anthropogenic mortality before management actions are implemented
Best achievable biomass (Bbest)	Spawning biomass corresponding to recent natural recruitment that would have survived if there was only natural mortality and no restocking; that is
Interim Target for biomass (Binterim)	Pragmatic intermediate goals for spawner escapement biomass; set by managers.
Interim Target for mortality (Ainterim)	Pragmatic intermediate anthropogenic mortality goal; set by managers.
Limit anthropogenic mortality (Alim)	Anthropogenic mortality, above which the capacity of self-renewal of the stock is considered to be endangered and conservation measures are requested. (Cadima, 2003)
Limit spawner escapement biomass (Blim)	Spawner escapement biomass, below which the capacity of self-renewal of the stock is considered to be endangered and conservation measures are requested. (Cadima, 2003)
Precautionary anthropogenic mortality (Apa)	Anthropogenic mortality, above which the capacity of self-renewal of the stock is considered to be endangered, taking into consideration the uncertainty in the estimate of the current stock status.
Precautionary spawner escapement biomass (Bpa)	The spawner escapement biomass, below which the capacity of self-renewal of the stock is considered to be endangered, taking into consideration the uncertainty in the estimate of the current stock status.
Pristine biomass (Bo)	Spawner escapement biomass in absence of any anthropogenic impacts..
Spawner escapement biomass after management (Bpost)	Estimate of spawner escapement biomass after management actions are implemented

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

Bbetter (a get well message)

B the best you were

B the best you can

And then **B** the best you are

While we eat **B**wurst

We need the **B******* numbers

For biomass bubbles red

Before going to our slumbers

(and before the eels are dead)

B***** - my sore head.

Bbard

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1 Introduction

1.1 The 2010 WGEEL ToRs

At the 97th Statutory Meeting of ICES (2009) and the 26th meeting of EIFAC (2010) it was decided that:

2009/2/ACOM18 The **Joint EIFAC/ICES Working Group on Eels** [WGEEL] (Chaired by: Russell Poole, Ireland), will meet in Hamburg, Germany, 9–14 September 2010, to:

a) assess the trends in recruitment and stock, for international stock assessment, in light of the implementation of the Eel Management Plans;

b) develop methods to post-evaluate effects of management actions at the stock-wide level (in conjunction with SGIPEE);

c) 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 (in conjunction with SGAESAW 2);

d) provide practical advice on 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;

e) review and develop approaches to quantifying the effects of eel quality on stock dynamics and integrating these into stock assessments;

f) respond to specific requests in support of the eel stock recovery Regulation, as necessary; and

g) report on improvements to the scientific basis for advice on the management of European and American eel.

WGEEL will report by 21 September 2010 for the attention of WGRECORDS, SGEF and ACOM.

Thirty-nine people attended the meeting, from 15 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, 2008 and 2009).

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 will require a shift from fisheries-based to scientific survey-based assessments. This challenging situation continued through 2009 and 2010 with the evaluations of submitted management plans taking place. The evaluation of eel management plans has been carried out by the ICES Secretariat as a technical evaluation and review service. Eel experts from the ICES communities, especially the Joint EIFAC/ICES Working Group on Eel, have been involved on an *ad hoc* technical/expert consultant basis.

The structure of this report does not strictly follow the order of the Terms of Reference for the meeting. The meeting, and consequently the report, was organized in five subgroups using the Agenda in Annex 2. The subgroups, under the headings of "Data trends, data quality and international databases", "International Stock Assessment and *ex post*-evaluation", "Local Stock Assessment", "Eel Quality" and "Advances in Eel Science" addressed the Terms of Reference as follows:

Chapter 2 presents trends in recruitment, stock, fisheries and aquaculture (ToR a). Chapter 2 also undertakes a series of analyses investigating the spatial patterns in recruitment and provides a brief overview on glass eel landings and trade at the European level (ToR a, d).

Chapter 3 continues the line of development on the concept of post-evaluation and stock assessment at the international level. Chapter 3 presents a summary of the SGIPEE report and makes advances by presenting for the first time ICES style precautionary diagrams adapted for eel. Chapter 3 also provides guidelines on the data requirements in the reporting of the Eel Management Plans in 2012 (ToR a, b and f).

Chapter 4 provides support for locally based stock assessment and post-evaluation of the impact of local management actions on yellow eel stock and silver eel escapement/biomass. Gaps in methodologies and data/information identified in National monitoring plans, the EU POSE project and WGEEL are addressed. (ToR a, c and d).

Chapter 5 updates the European Eel Quality Database (EEQD) and discusses the importance of the inclusion of spawner quality parameters in stock management advice (ToR d and e).

Chapter 6 reviews any significant new research findings, particularly in relation to advances in artificial reproduction, oceanic factors, spawning, eel quality and impacts on the stock. Reference is made to other *Anguillid* species (ToR g).

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 DCF is fully implemented for the eel fisheries across Europe. It is envisaged that additional and improved data will become available under the Eel Regulation and Data Collection Framework. An initial review was undertaken in 2009 and recommendations for data reporting to the EU in 2012 are made by ICES (2010 SGIPEE) and these are further developed in Chapters 2, 3 and 4.

1.2 Workshop on Age Reading of European and American Eel (WKAREA 2)

The **Workshop on Age Reading of European and American Eel [WKAREA-2]** (Chair: Françoise Daverat, France) will exchange information by correspondence in 2010 and meet in Bordeaux, France in March 2011:

a) to exchange samples (>100 per species) of European and American eel otolith pictures, including known age eels, with samples prepared using different protocols and representing a range of eel subpopulations, and environment types encountered in the range of both species;

b) to apply the age estimation criteria defined during the previous meeting in an inter-calibration process involving the exchanged images and a significant number of readers (>20);

c) to analyse readings and interpret the results of the inter-calibration of European and American eel age reading;

d) to make recommendations and feedback on the age estimation criteria to increase age estimation precision and accuracy and improve the inter reader agreement;

e) to incorporate the findings with the report and manual developed by WKAREA 2009 for formal publication; and

f) to address the generic ToRs adopted for workshops on age calibration (see 'PGCCDBS Guidelines for Workshops on Age Calibration').

WKAREA-2 will report by 1 May 2011 for the attention of WGRECORDS, WGEEL, SGEF and PGCCDBS.

The Workshop will exchange information by correspondence in 2010 and meet in Bordeaux, France in March 2011. A sample of 100 European eel otolith pictures and a sample of 50 American eel otolith pictures, including eels of known age, with samples prepared using different protocols and representing a range of eel subpopulations, and environment types encountered in both species range have been gathered into an online shared database. These pictures will be read by a significant number of readers (>20), applying the age estimation criteria defined during the previous meeting in an inter-calibration process involving the exchanged images in the current of year 2010. The analysis of readings and interpretation of the results of the inter-calibration of European and American eel age reading will be carried out during the 2011 meeting.

1.3 Study Group on Anguillid Eels in Saline Waters (SGAESAW)

2009/2/SSGEF22 The **Study Group on Anguillid Eels in Saline Waters** (SGAESAW), chaired by [to be announced] will meet in VENUE, DATE [to be announced] to:

a) extract and examine eel data from general fish stock surveys in open marine waters;

b) review and develop local stock assessment methods in anguillid eels in saline waters with reference to habitat use, demographic characteristics and sampling techniques and in comparison with these features in freshwaters;

c) make recommendations on the use of habitat-specific demographic characteristics in population models (e.g. SPR, biomass targets, silver eel escapement rates), and on overall conservation approaches that embrace salinity-based differences;

d) define research and analytic approaches for anguillid eels in saline waters that will advance progress towards constructing robust stock-wide management models.

This Study Group did not meet in 2010.

1.4 Study Group on International Post-Evaluation on Eels (SGIPEE)

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

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

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

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

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

This Study Group was intended to design, test, analyse and report on a method of scientific *ex post*-evaluation of applied management measure at the stock-wide level. The report of the 2010 meeting was the first step towards that objective and mainly focused on designing the appropriate framework and the methods for eel *ex post*-evaluation and reviewing available data.

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

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

NOTE: See Chapter 3 of this report for a preliminary application of the methods developed in SGIPEE.

2 Data and trends

Chapter 2 addresses the following Terms of Reference:

a) assess the trends in recruitment and stock, for international stock assessment, in light of the implementation of the Eel Management Plans;

and also links to:

b) develop methods to post-evaluate effects of management actions at the stock-wide level (in conjunction with SGIPEE);

c) 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 (in conjunction with SGAESAW 2);

d) provide practical advice on 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.

2.1 Recruitment

2.1.1 Temporal trends in recruitment

Information on recruitment is provided by a number of datasets and these relate to various stages, (glass eel and elver (young of the year) and young yellow eel), recruiting to continental habitats (Dekker, 2002). The recruitment time-series data in European rivers and a description of the dataseries are presented in Annex 4, Tables 2.1 and 2.2.

The time-series used for recruitment analysis come from 48 rivers in eleven countries (Figure 2.1). They were updated to the last season available, 2009; and in some cases 2010. However, it was decided not to use 2010 data in the analyses, because the number of available data in this year was lower than in previous years (Figure 2.2) and these could interfere in the trends. Some of the series have been discontinued, due to the lack of recruits for fishery based survey (the Ems, Germany) and some others due the lack of financial support (the Tiber, Italy). This year, a new long-term series has been added; a scientific survey since 1972 in the Netherlands (Den Burg), which determined yellow eel cpue using fykenets.

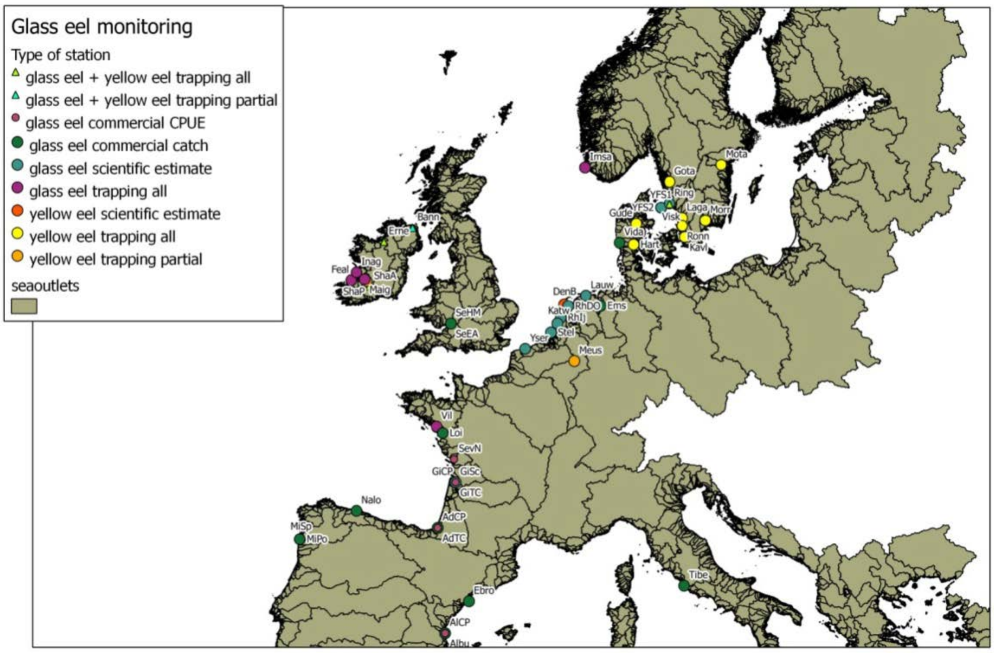


Figure 2.1. Location of the recruitment monitoring sites in Europe; the station codes and descriptions are in Annex 4, Table 2.1.

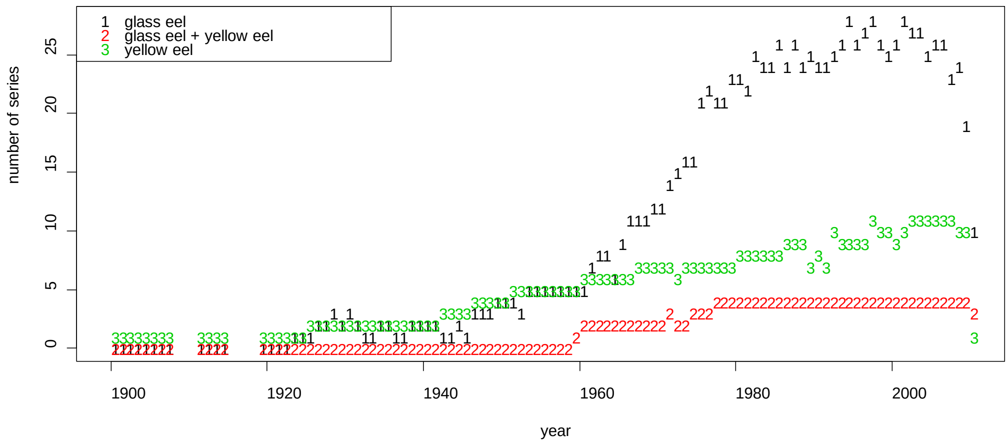


Figure 2.2. Trend in number of available dataseries per stage.

The recruitment time-series data were derived from fishery-dependent sources (i.e. catch records) and also from 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 to the beginning of 20th century (yellow eel, Göta Älv Sweden).

The series have been classified according to the type of data: commercial cpue, commercial total catch, scientific estimate, trapping partial (i.e. only a part of the glass eel or yellow eel are caught) and trapping all (all glass eel and yellow ascending a particular point of the river are caught). They have also been classified according to area: Baltic, continental North Sea, continental Atlantic, British Isles, and Mediterranean. The Baltic area does not contain any pure glass eel series.

For graphical presentation, the series are scaled to 1979–1994 as it is not possible to set an appropriate reference earlier than 1994 for most of the series. But, the reconstructed values when using the GLM analysis (Generalised Linear Model) are given in reference to the mean reconstructed estimate of the 1960–1979 period. Declining trends are still evident over the last two decades for all time-series. After high levels in the late 1970s, there was a rapid decrease that still continues to the present time (Figures 2.3–2.10; Note that these are presented twice in logarithmic and linear formats). However, in 2009 the decrease was sharper than ever; with a further drop of around 50–60% for glass eel landings between 2008 and 2009. The glass eel landings data in 2010 were higher than in 2009, but remain at a low level.

The spatial analysis leads us to consider two separate areas for recruitment trends, the North Sea and elsewhere in Europe. Two separate trends are provided: one for glass eel and another one for yellow eel; although a clear separate glass eel and yellow eel trend was not apparent from the analysis.

For the last five years the series based on glass eel average between 1% (continental North Sea) and 7% (elsewhere in Europe) of 1960–1979 levels respectively, (Annex 4, Table 2.3, Figures 2.7 and 2.8).

The series for yellow eel recruitment are currently at 9% of their mean of 1960–1979 levels respectively (Figures 2.9 and 2.10; Annex 4, Table 2.3).

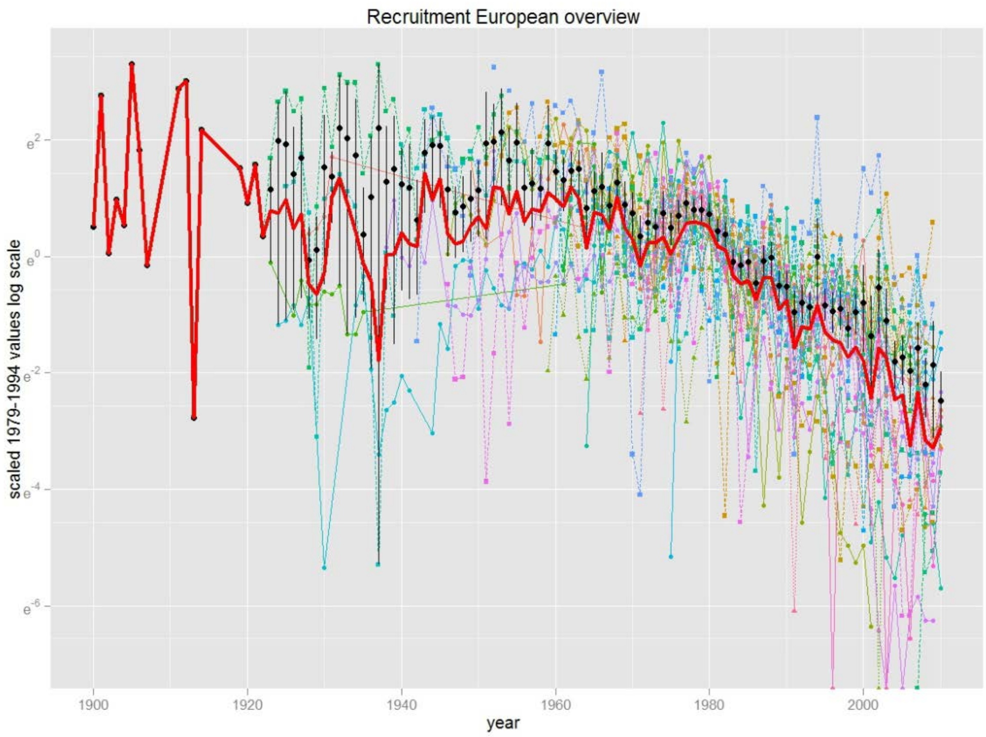


Figure 2.3. Time-series of monitoring glass eel and yellow eel recruitment in European rivers with dataseries >35 years (26 rivers). Each series has been scaled to its 1979–1994 average. Note the <u>logarithmic scale</u> on the y-axis. The mean values and their bootstrap confidence interval (95%) are represented as black dots and bars. Note: for practical reasons, not all series are presented in this graph, whereas the following analysis is done on all series. Geometric means are presented in red.

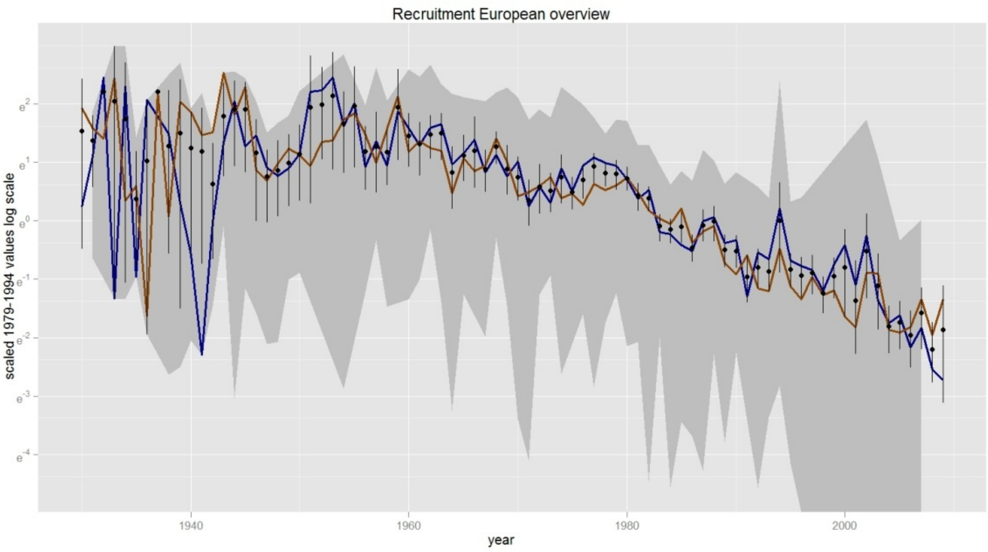


Figure 2.4. Time-series of monitoring glass eel and yellow eel recruitment in European rivers with dataseries >35 years (24 rivers). Each series has been scaled to its 1979–1994 average. Note the <u>logarithmic scale</u> on the y-axis. The mean values and their bootstrap confidence interval (95%) are represented as black dots and bars. The brown line represents the mean value for yellow eel while the blue line represents the mean value of the glass eel series. The range of the series is indicated by grey shading. Note that individual series from Figure 2.3 were removed for clarity.

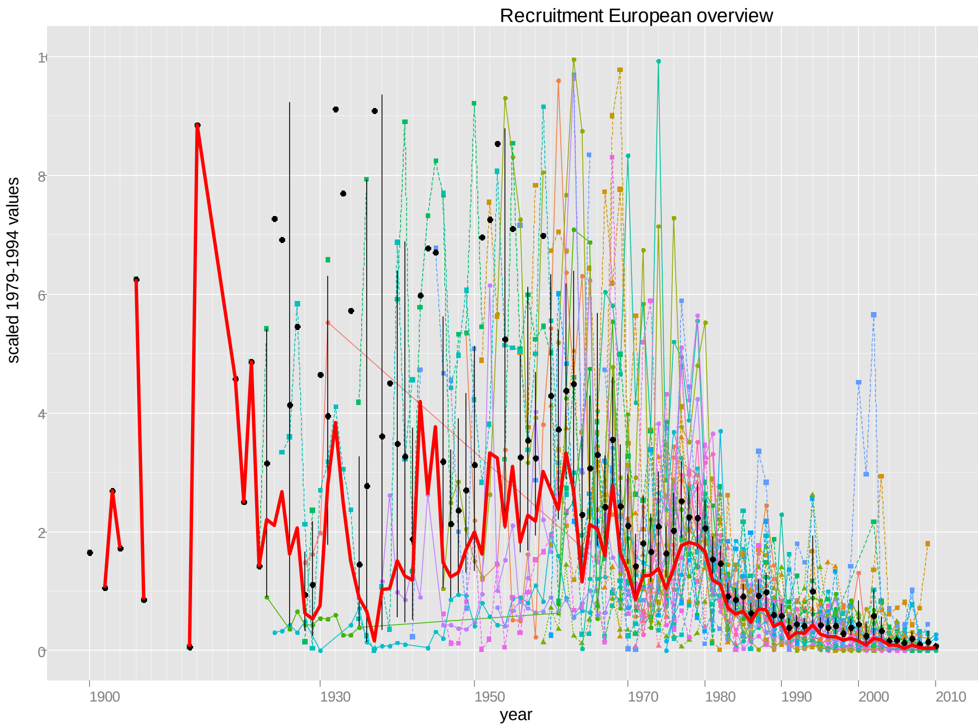


Figure 2.5. Time-series of monitoring yellow eel and glass recruitment in European rivers with dataseries >35 years (26 rivers). Each series has been scaled to the 1979–1994 average on a <u>linear scale</u>. The mean values and their bootstrap confidence interval (95%) are represented as black dots and bars. The geometric means are presented in red. The graph has been rescaled to [0.10].

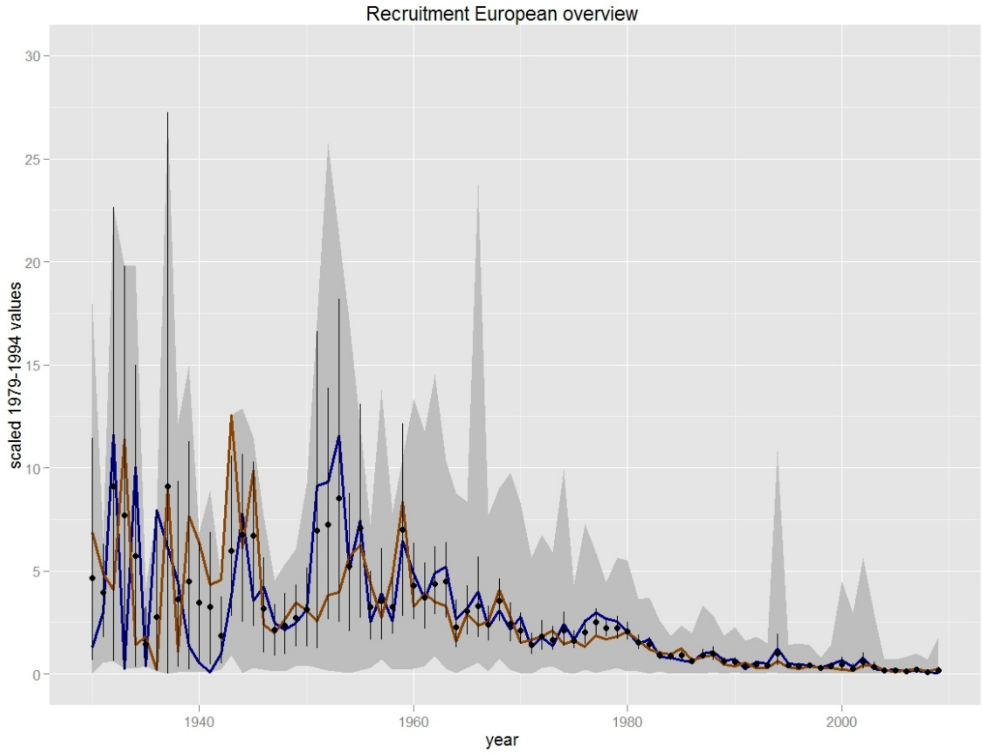


Figure 2.6. Time-series of monitoring yellow eel and glass recruitment in European rivers with dataseries >35 years (24 rivers). Each series has been scaled to the 1979–1994 average on a linear scale. The mean values and their bootstrap confidence interval (95%) are represented as black dots and bars. The brown line represents the mean value for yellow eel while the blue line represents the mean value of the glass eel series. The range of the series is indicated by grey shading. Note that individual series from Figure 2.5 were removed for clarity.

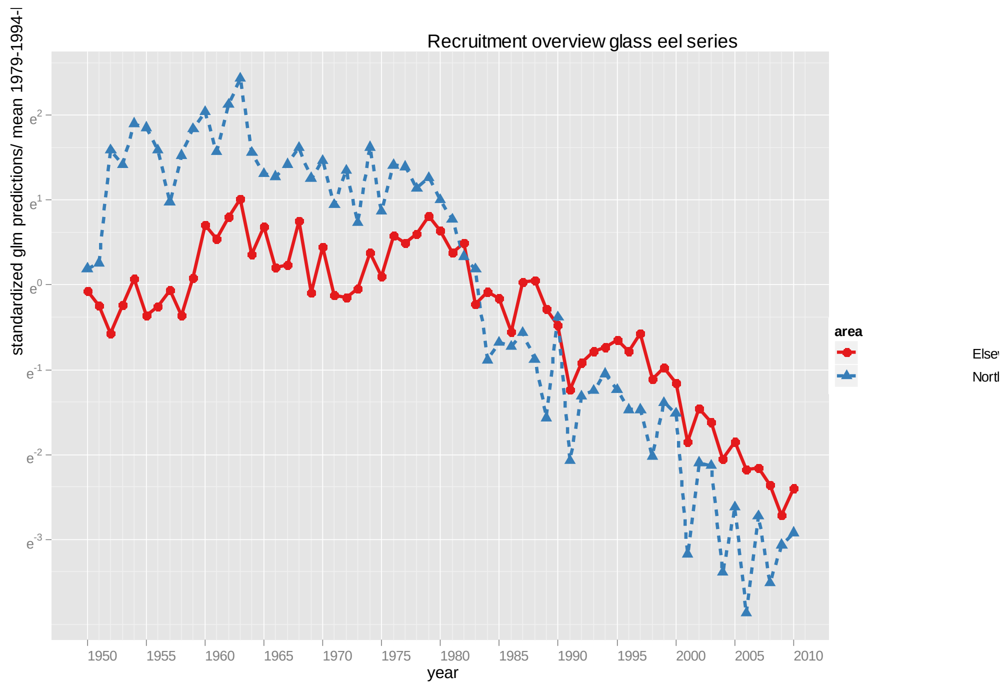


Figure 2.7. Mean of estimated (GLM) glass eel recruitment for each area in Europe. The GLM (recruit=area:year+site) was fitted to all glass eel series available and scaled to the 1960–1979 average. No series for glass eel are available in the Baltic area. Note logarithmic scale.

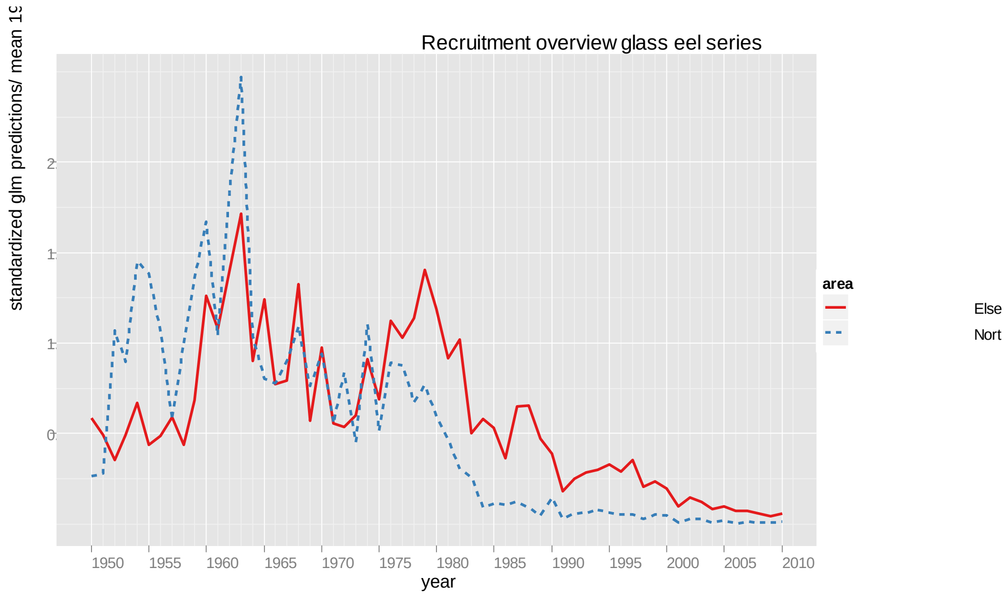


Figure 2.8. Mean of estimated (GLM) glass eel recruitment for each <u>area</u> in Europe. The GLM (recruit=area:year+site) was fitted to all glass eel series available and scaled to the 1960–1979 average. No series for glass eel are available in the Baltic area.

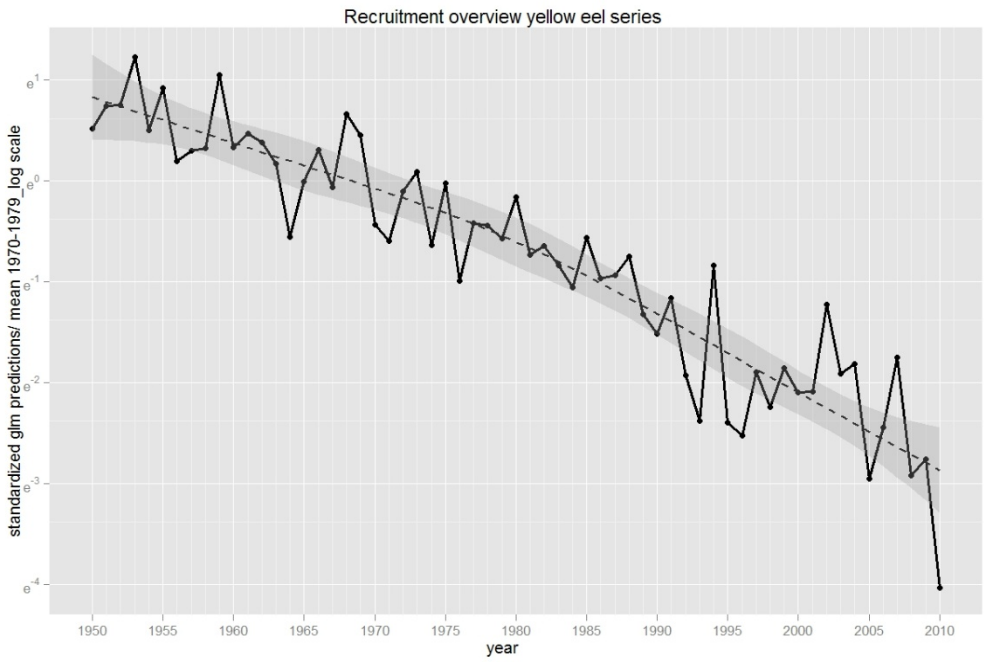


Figure 2.9. Mean of estimated (GLM) yellow eel recruitment and smoothed trends for Europe. The GLM (recruit=area:year) was fitted to all yellow eel series available and scaled to the 1960–1979 average. Note <u>logarithmic scale</u>. Band show 95% point-wise confidence interval of the smoothed trend.

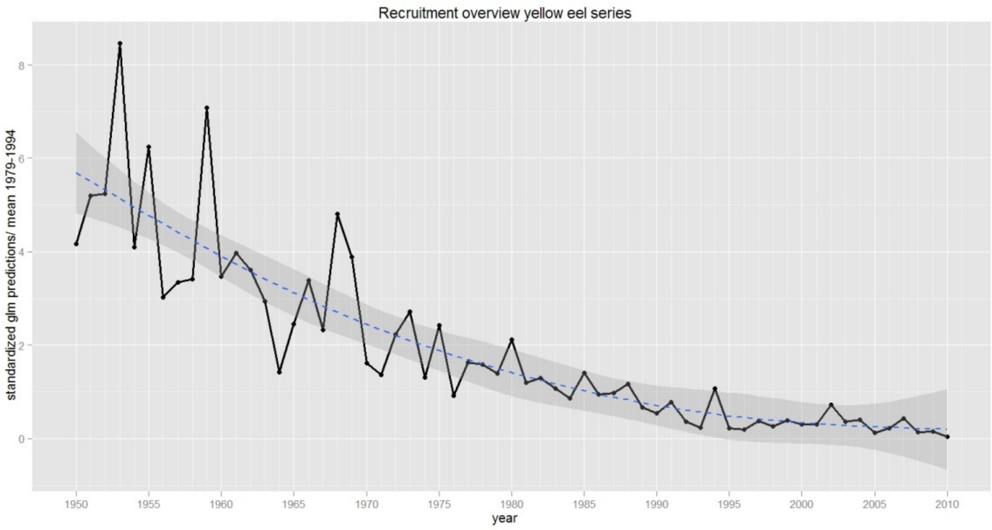


Figure 2.10. Mean of estimated (GLM) yellow eel recruitment and smoothed trends for Europe. The GLM (recruit=area:year) was fitted to all yellow eel series available and scaled to the 1960–1979 average. Note linear scale. Band show 95% point-wise confidence interval of the smoothed trend.

2.1.2 Data discontinuities

Analysis of recruitment time-series has been the main tool in the past for assessing the overall status of the eel stock. It was cautioned by the EIFAC/ICES Working Group on Eel (WGEEL, 2008; 2009) that data discontinuities, particularly related to data from commercial fisheries, can be expected following implementation of EMPs (e.g. management measures affecting fishing effort, season quota, size limits), and CITES restrictions, although at that time it was unknown to what extent this might impact on the dataseries. A preliminary review was undertaken by the Study Group on International *Ex post*-evaluation on Eels (ICES, 2010).

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

The yellow eel time-series remain largely unaffected by any changes due to the implementation of management measures: none have closed and only two appear vulnerable.

The expected changes to the recruitment time-series due to the implementation of management measures, particularly the glass eel time-series, would reduce the data available for analysis by almost half. This means the provision of scientific advice on changes to the stock based on recruitment-series is now vulnerable to change in the coming years and it is unlikely that statistical modelling will be able to correct for this. The current analysis was unaffected by these probable changes.

2.1.3 Spatial pattern in eel recruitment

The trend in recruitment for the European eel is derived from long-term chronological series collected in estuaries scattered over all of Europe. These recruitment-series are the best indicator of the status of the stock, as there is no pan-European evaluation of the silver eel stock output. The evaluation of eel management actions taken by the different countries will have to take into account the trend in recruitment, as this recruitment will affect the expected output after a delay determined by the local growth rate of eel. Therefore, knowing if there is a spatial variation in recruitment is of importance, both for the management of the stock and general understanding of its biology.

An analysis of the longest recruitment-series demonstrated that there was no consistent spatial clustering of the dataseries in Europe, and that series distant geographically were demonstrating similar trends while other geographically close series differed (Dekker, 2002). The author found that five series (Motala, Erne, Severn, Bann and possibly Imsa) differed from the general trend and speculated that these variations probably reflected variations in local conditions rather than a different trend.

The Working Group on Eel (2008) analysed the trends in recruitment in relation to the year as a categorical factor, the life stage, the type of monitoring and the geographical area (ICES, 2008). Given the spatial distribution of the sampling techniques models (commercial fisheries in the South, trapping mostly in the north), it was not possible to test both geographical areas and the sampling technique together so two GLM models were tested concurrently: one with sampling techniques, one with the area.

The outcome was that the 'area effect' model explained more deviance than the 'capture technique' model and that some of the spatial pattern found could not be explained by differences in sampling techniques (Figure 2.11). However, the conclusion was not definite. There might still be some biases linked with the technique, as for instance, in the Biscay Area, a lot of series have been based on landings and these might have varied according to change in fishing effort.

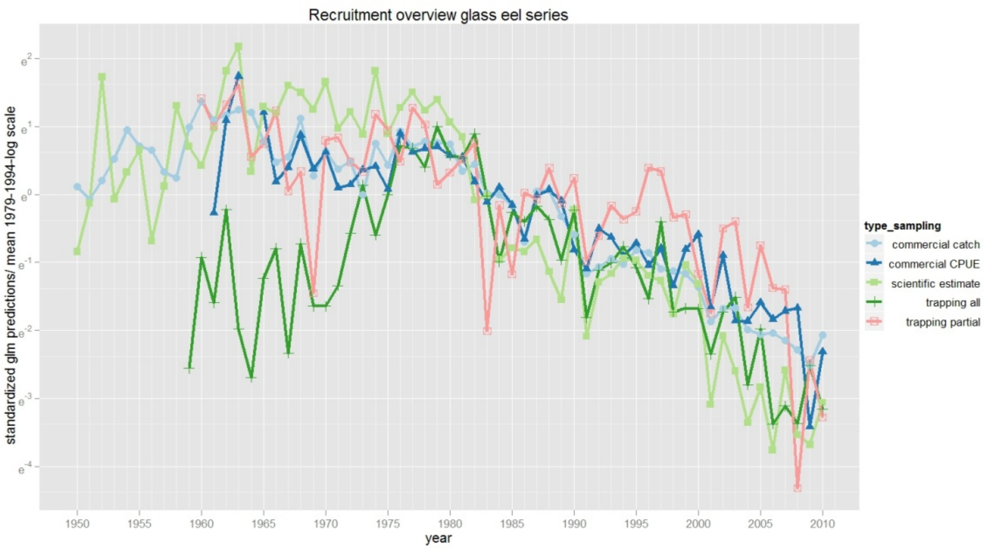


Figure 2.11. Mean of estimated (GLM) glass eel recruitment per type of sampling in Europe. The GLM (recruit=sampling_type:year+site) was fitted to all glass eel series available and scaled to the 1979–1994 average. No series for glass eel are available in the Baltic area.

It was thus recommended to collect additional unpublished archive dataseries to try to solve both questions (ICES, 2008).

Some series have been first made available in 2009 in Europe, for yellow eel in Belgium, and in Spain and Ireland, and one experimental series on yellow eel was made available in 2010 for the Netherlands. However, those series follow the previous spatial structure, which is based on largely on fishery series in the south, and trapping series elsewhere.

Considering the absence of new data, it was decided in 2010 to re-run the analysis by Dekker (2000) i.e. to use cluster analyses, PCA, and MDS techniques to investigate whether a consistent spatial trend could be displayed for the different recruitment-series.

2.1.3.1 Data analysis

2.1.3.1.1 Hierarchical clustering 1995–2008, 35 series

The analysis is focused on the most recent period 1995–2008 that was not analysed by Dekker (2002), but which provides the largest number of series (Figure 2.2). The data are scaled and log transformed.

Following Dekker (2002), the correlation between the series is calculated. Series that commenced or ceased in the middle of the selected period were removed, leaving 35 series in the analysis. A hierarchical clustering (McQuitty, 1966) has been performed using the Ward's minimum variance method.

The clustering dendogram resulting from the classification does not show any clear spatial pattern (Figure 2.12) and the grouping of series into six groups when cutting at height=2 is illustrated in Table 2.1. The mixture of lines from different geographical areas is obvious and there is no clear pattern to the grouping.

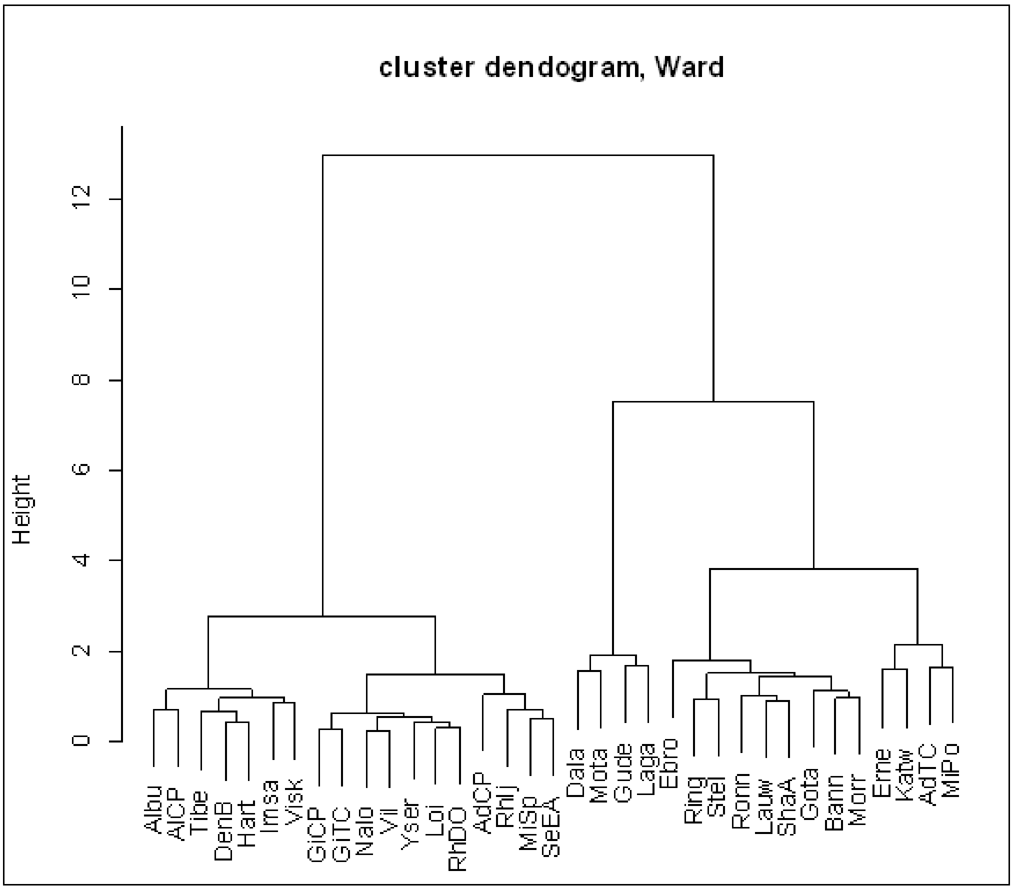


Figure 2.12. Cluster analysis on 35 series of recruitment for the period 1995–2008. The composition of six groups, along with the full name of the station issued from a cut of the tree at a height of 2 is provided in Table 2.1.

Table 2.1. Groups resulting from the cluster analysis using Ward's algorithm at height=2. Colours according to the groups and spatial area.

abreviated	groups	area	sampling_type	stage	name
AdCP	1	Atlantic Ocea	commercial C	glass eel	Adour Estuary (CPUE) commercial CPUE
AdTC	1	Atlantic Ocea	commercial c	glass eel	Adour Estuary (catch) commercial catch
Albu	1	Mediterannea	commercial c	glass eel	Albufera de Valencia commercial catch
AlCP	1	Mediterannea	commercial C	glass eel	Albufera de Valencia commercial CPUE
Bann	1	British Isle	trapping parti	glass eel + yel	Bann Coleraine trapping partial
Dala	1	Baltic	trapping all	yellow eel	Dalälven trapping all
DenB	1	North sea	scientific estir	yellow eel	Den Burg fyke net (CPUE)
Ebro	1	Mediterannea	commercial c	glass eel	Ebro delta lagoons
Erne	1	British Isle	trapping all	glass eel + yel	Erne Ballyshannon trapping all
GiCP	1	Atlantic Ocea	commercial C	glass eel	Gironde Estuary (CPUE) commercial CPUE
GiTC	1	Atlantic Ocea	commercial c	glass eel	Gironde Estuary (catch) commercial catch
Gota	2	North sea	trapping all	yellow eel	Göta Älv trapping all
Gude	2	North sea	trapping all	yellow eel	Guden Å Tange trapping all
Hart	3	Baltic	trapping all	yellow eel	Harte trapping all
Imsa	3	North sea	trapping all	glass eel	Imsa Near Sandnes trapping all
Katw	3	North sea	scientific estir	glass eel	Katwijk scientific estimate
Laga	3	North sea	trapping all	yellow eel	Lagan trapping all
Lauw	3	North sea	scientific estir	glass eel	Lauwersoog scientific estimate
Loi	3	Atlantic Ocea	commercial c	glass eel	Loire Estuary commercial catch
MiPo	3	Atlantic Ocea	commercial c	glass eel	Minho portugese part commercial catch
MiSp	4	Atlantic Ocea	commercial c	glass eel	Minho spanish part commercial catch
Morr	4	Baltic	trapping all	yellow eel	Mörrumsån trapping all
Mota	4	Baltic	trapping all	yellow eel	Motala Ström trapping all
Nalo	4	Atlantic Ocea	commercial c	glass eel	Nalon Estuary commercial catch
RhDO	4	North sea	scientific estir	glass eel	Rhine DenOever scientific estimate
RhIj	4	North sea	scientific estir	glass eel	Rhine Ijmuiden scientific estimate
Ring	4	North sea	scientific estir	glass eel	Ringhals scientific survey
Ronn	4	North sea	trapping all	yellow eel	Rönne Å trapping all
SeEA	4	British Isle	commercial c	glass eel	Severn EA commercial catch
ShaA	5	British Isle	trapping all	glass eel + yel	Shannon Ardnacrusha trapping all
Stel	5	North sea	scientific estir	glass eel	Stellendam scientific estimate
Tibe	5	Mediterannea	commercial c	glass eel	Tiber Fiumara Grande commercial catch
Vil	5	Atlantic Ocea	trapping all	glass eel	Vilaine Arzal trapping all
Visk	6	North sea	trapping all	glass eel + yel	Viskan Sluices trapping all
Yser	6	North sea	scientific estir	glass eel	Ijzer Nieuwpoort scientific estimate

2.1.3.1.2 Multidimensional scaling and k-means 1995–2008, 35 series

On the same dataset, a MDS (multidimensional scaling) (Borg and Groenen, 1997) analysis with a Kmeans (Forgy, 1965) classification has been performed. The results are illustrated on a plot showing the statistical distance between points and on a plot showing the true geographical positions of the stations (Figure 2.13). Again, in this second analysis, groups are formed from a mixture of stations from various origins without indicating a clear spatial pattern in the recruitment.

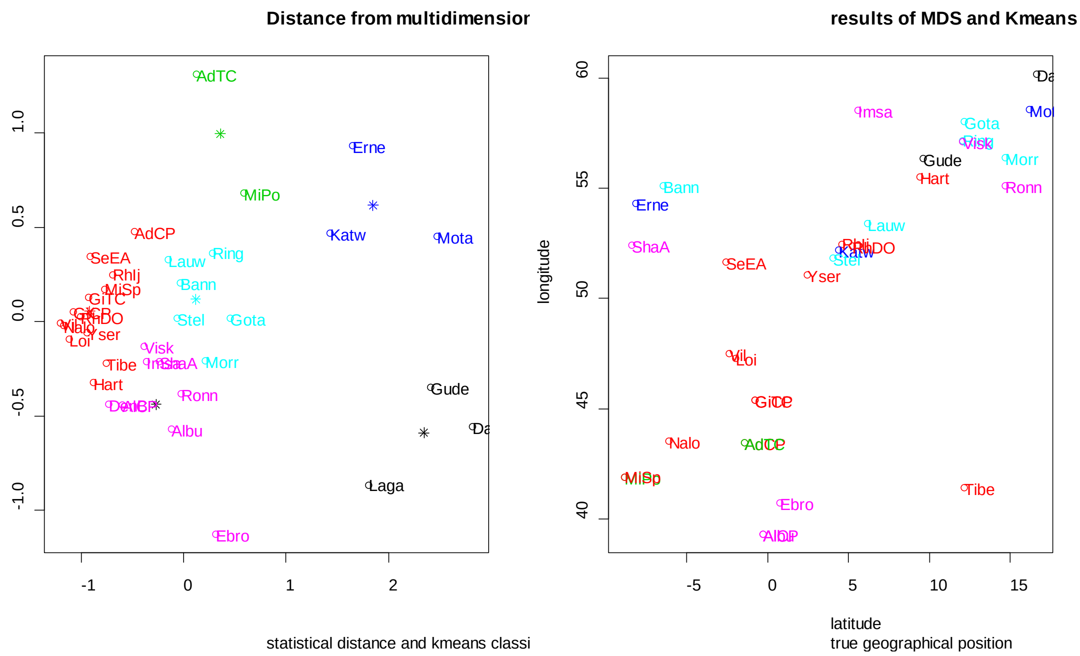


Figure 2.13. Multidimensional scaling and Kmeans classification with 6 starting nodes.

2.1.3.1.3 PCA analysis, full case dataset, 1980, 2008, 19 stations

A longer dataset has been selected for the period corresponding to the start of the decline in recruitment and finishing in 2008, the period for which most data are available (Figure 2.2.).

The first factor weights 79% of the information and stands clearly apart from the others (Figure 2.14), as found in the previous analysis (Dekker, 2002). The first plan (two factors) weights 82% (Figure 2.14 A). The second plan only adds minor weight (3%) (Figure 2.14 B). The first axis (Figure 2.14 C, D) clearly reflects the temporal trend in recruitment, and some stations (Erne, Motala Ström, Stellendam) have atypical years which make them deviate on the second and third factors (Figure 2.14 A, B) from a common trend displayed by the other series. Their correlation (communality) with the first axis is lesser than the others, similar to the results obtained from 1964 to 1994 by Dekker. The second and third axis (Figures 2.14 A and B) will put forward some years (1976, 2006) where some stations had a particular result but again there is no clear spatial pattern.

There is no clear segregation of the stations on the first factorial plan although the stations from the North Sea do stand apart and their position indicates a sharper trend than the others (Figures 2.7; 2.14 D and 2.15).

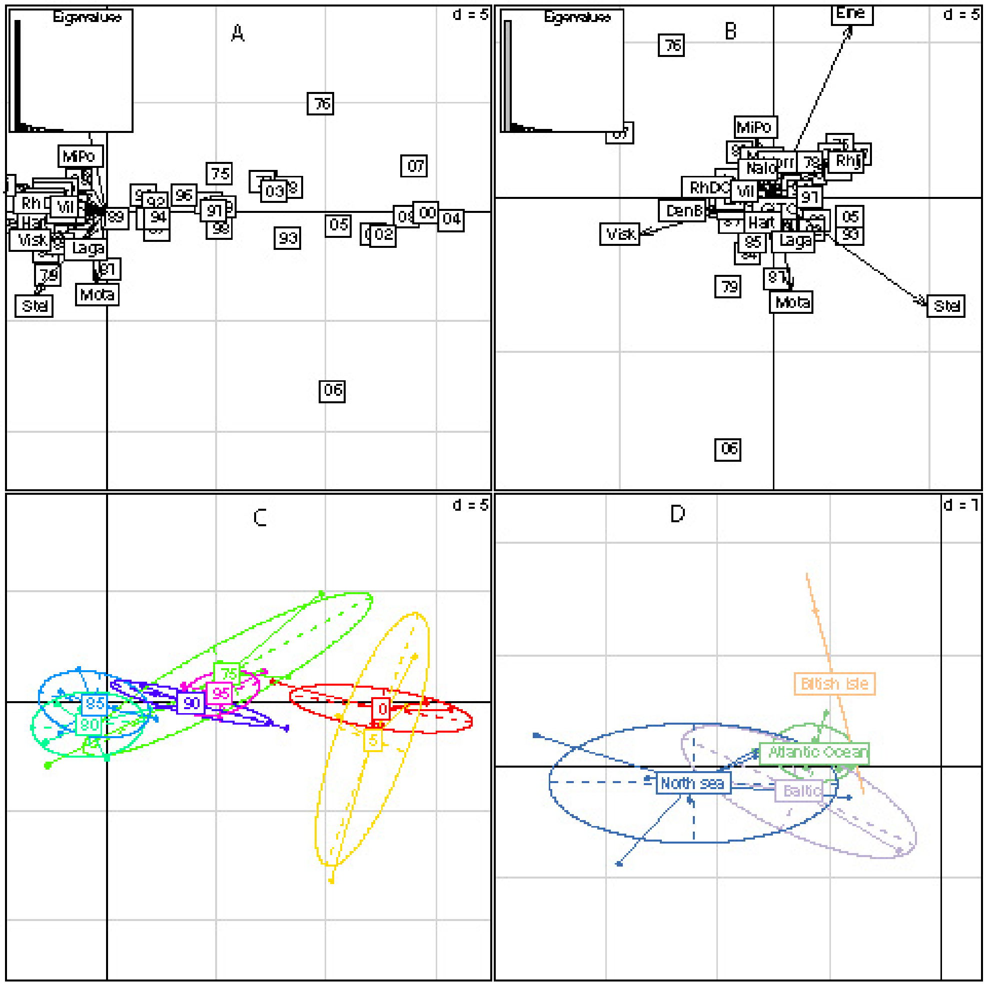


Figure 2.14. PCA analysis of 19 series of recruitment from 1980 to 2008. A: first factorial plan, and eigenvalues. B: second factorial plan and eigenvalues. C: Years grouped by 5 year period on the first factorial plan. D: stations grouped by geographical areas on the first factorial plan.

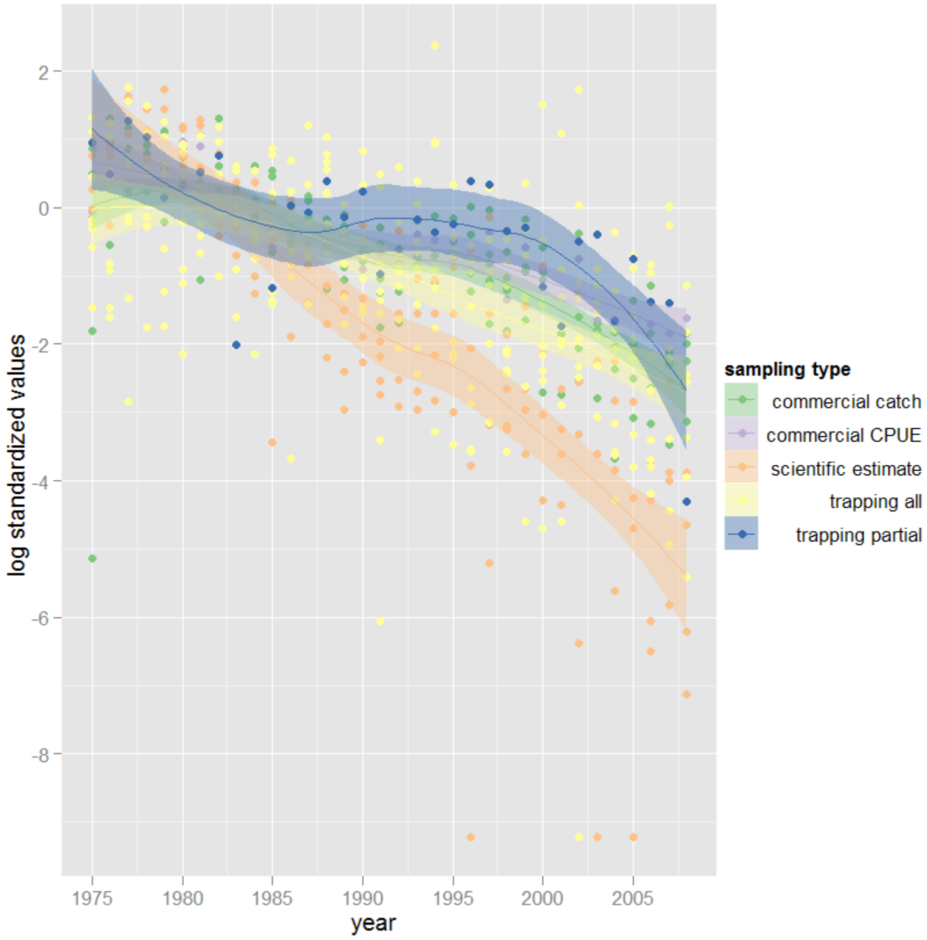


Figure 2.15. Trend in recruitment for different types of series and smoothed trend.

2.1.3.1.4 Analysis of the slope using Mandel's bundle of straight lines, 1960–2008, 46 stations

The lack of a spatial pattern demonstrated in the previous analyses does not rule out a possible difference in the general slope of the series. Indeed there might be a general common trend found in all the series, with some years having better recruitment than the others, but with a different slope between the series, that might have escaped in the previous analyses. Therefore, we use Mandel's bundle of straight lines to extract the deviation from a common slope, and analyse whether it is spatially consistent.

Statistical model: *Generalised Linear Model of the recruitment index as a function of the year and station*. The spatial pattern is coded by a simple class variable (station). The existence of a deviation from the common trend is analysed by a so-called «Mandel`s bundle of straight lines» model (Mandel, 1959; Milliken and Johnson, 1989). This is essentially a two-step fitting procedure. In the first step, a simple model is fitted:

$$recruitment\_index = \exp^{\,\mathrm{year}+station} + \varepsilon$$

where year, and station are class variables and ε is an error term with a quasi-poisson distribution. The Poisson error distribution and logarithmic link function accommodate multiplicative effects, while allowing for zero observations. From this first simple model fit, parameter estimates for each year are derived, which are subsequently added to the dataset as an extra explanatory variable, using the parameter estimate corresponding to the year of each record. Subsequently, a second model is fitted, including this extra variable in interaction with other variables of interest:

$$recruitment\_index = \exp^{\text{year}+station+Mandel(year)*station} + \varepsilon$$

where Mandel(year) indicates the parameter estimate of the year concerned in the first model. This procedure allows the estimation of the deviation from the common trend in decline, while using a very limited number of parameters.

This model assumes a common trend from year to year between all the series, consistently with what was found in the MDS, PCA, and clustering analyses. However it allows for different slopes between locations.

Results of analysis of the slope using Mandel's Bundle of straight lines

For the selected period, 1885 lines were used corresponding to 46 stations. The deviation from the common trend is summarized in Figure 2.16 and Table 2.2. Only the series for glass eel in the North Sea stand apart from the others. The rate of deviation from the mean value is on a log scale. The mean value of exponential of the coefficient varies a as following: 1.16 in the British Isles, 1.28 (Atlantic Ocean), 1.16 (British Isles), 2.12 (Mediterranean Sea) where the high mean value is explained by the drop observed in the Tiber series, and 3.73 in the North Sea. For the yellow eel series, the value is 0.99 Baltic, 0.71 for the British Isles and 1.4 for the North Sea.

The variability within each geographical unit is high, and there is no clear pattern in the trend of recruitment between the series, except for the North Sea which stands apart with series demonstrating a much more pronounced declining trend, as demonstrated by the glm analysis (Figures 2.7–2.8). This sharper decline in recruitment is observed for series in the Kattegat (YFS2), a scientific young fish survey, on the Dutch coast (Ems, Rhine IJmuiden, Stellandam) and in Denmark (Vida) and Norway (Imsa). Surprisingly, this sharper decline is not observed in the Baltic area.

The decline might, in some places, be explained by diminishing fishing effort (Ems, Vida) but not for the scientific estimates (YFS2, Rhine IJmuiden, Ijser, Stellendam). It must also be noticed that other stations, geographically close to the other Dutch recruitment stations (Lauwersoog, Katwijk) and the Ringhals nuclear power station series, have similar trends to the mean of the other European series (Figures 2.7–2.8; Table 2.2).

An alternative model was tested using log($x+\alpha$) transformed values, ε as a gaussian error, and identity link, with αnegligible when compared with the minimum value yields almost no difference in the results. Also an analysis on a more limited time frame 1975–2009 yielded similar results with the North Sea stations standing apart from the others.

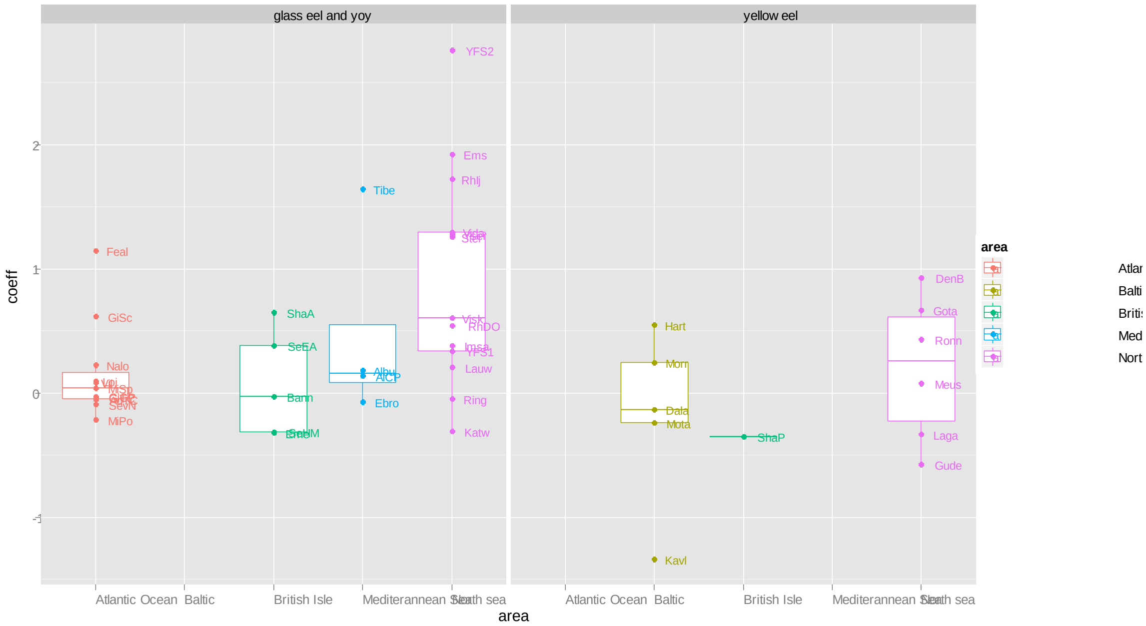


Figure 2.16. Detailed coefficient from the analysis, i.e. the effect estimated by the model for *Mandel(year)*station* effect are presented (in a log scale) in Table 2.2.

Table 2.2. Coefficient of deviation from the common trend for European series. Glass eel and yellow eel series have been ordered by value, and separated for clarity.

short name	coefficient	area	sampling type	name
YFS2	2.76444878	North sea	scientific estimate	IYFS2 scientific estimate
Ems	1.92310941	North sea	commercial catch	Ems Herbrum commercial catch
RhIj	1.72447573	North sea	scientific estimate	Rhine Ijmuiden scientific estimate
Tibe	1.64563227	Mediterannea	commercial catch	Tiber Fiumara Grande commercial catch
Vida	1.29511343	North sea	commercial catch	Vidaa Højer sluice commercial catch
Yser	1.27925751	North sea	scientific estimate	Ijzer Nieuwpoort scientific estimate
Stel	1.25830112	North sea	scientific estimate	Stellendam scientific estimate
Feal	1.14727731	Atlantic Ocea	trapping all	River Feale
ShaA	0.65322916	British Isle	trapping all	Shannon Ardnacrusha trapping all
GiSc	0.6226225	Atlantic Ocea	scientific estimate	Gironde scientific estimate
Visk	0.60430072	North sea	trapping all	Viskan Sluices trapping all
RhDO	0.54320615	North sea	scientific estimate	Rhine DenOever scientific estimate
SeEA	0.38208813	British Isle	commercial catch	Severn EA commercial catch
Imsa	0.38203058	North sea	trapping all	Imsa Near Sandnes trapping all
YFS1	0.33748715	North sea	scientific estimate	IYFS scientific estimate
Nalo	0.22862308	Atlantic Ocea	commercial catch	Nalon Estuary commercial catch
Lauw	0.20963453	North sea	scientific estimate	Lauwersoog scientific estimate
Albu	0.18476026	Mediterannea	commercial catch	Albufera de Valencia commercial catch
AlCP	0.14087243	Mediterannea	commercial CPUE	Albufera de Valencia commercial CPUE
Loi	0.09849349	Atlantic Ocea	commercial catch	Loire Estuary commercial catch
Vil	0.08323979	Atlantic Ocea	trapping all	Vilaine Arzal trapping all
MiSp	0.03962989	Atlantic Ocea	commercial catch	Minho spanish part commercial catch
GiCP	-0.02540831	Atlantic Ocea	commercial CPUE	Gironde Estuary (CPUE) commercial CPUE
Bann	-0.02693764	British Isle	trapping partial	Bann Coleraine trapping partial
GiTC	-0.03068014	Atlantic Ocea	commercial catch	Gironde Estuary (catch) commercial catch
Ring	-0.04353778	North sea	scientific estimate	Ringhals scientific survey
AdTC	-0.05215184	Atlantic Ocea	commercial catch	Adour Estuary (catch) commercial catch
Ebro	-0.06793322	Mediterannea	commercial catch	Ebro delta lagoons
SevN	-0.08994593	Atlantic Ocea	commercial CPUE	Sèvres Niortaise Estuary commercial CPUE
MiPo	-0.20946421	Atlantic Ocea	commercial catch	Minho portugese part commercial catch
Katw	-0.30706682	North sea	scientific estimate	Katwijk scientific estimate
SeHM	-0.31041112	British Isle	commercial catch	Severn HMRC commercial catch
Erne	-0.31508082	British Isle	trapping all	Erne Ballyshannon trapping all

yellow eel series				
short name	coefficient	area	sampling type	name
DenB	0.93069946	North sea	scientific estimate	Den Burg fyke net (CPUE)
Gota	0.67111654	North sea	trapping all	Göta Älv trapping all
Hart	0.54891173	Baltic	trapping all	Harte trapping all
Ronn	0.43421918	North sea	trapping all	Rönne Å trapping all
Morr	0.24766959	Baltic	trapping all	Mörrumsån trapping all
Meus	0.08088632	North sea	trapping partial	Meuse Lixhe dam trapping partial
Dala	-0.13085823	Baltic	trapping all	Dalälven trapping all
Mota	-0.23510575	Baltic	trapping all	Motala Ström trapping all
Laga	-0.32995312	North sea	trapping all	Lagan trapping all
ShaP	-0.34859477	British Isle	trapping partial	Shannon Parteen trapping partial
Gude	-0.57244737	North sea	trapping all	Guden Å Tange trapping all
Kavl	-1.33373919	Baltic	trapping all	Kävlingeån trapping all

2.2 Data on commercial landings

In WGEEL 2009, data on eel landings obtained from Country Reports were presented, along with data on official eel landings from FAO sources. Those two datasets did not include aquaculture production. A comparison was conducted between the two datasets by comparing the mean values for corresponding periods.

Discontinuities have been noted in both the dataseries, i.e. data officially reported to FAO and the best estimates presented in the Country Reports. Implementation of the EU Eel Regulation will require Member States to implement a full catch and effort registration system, along with the DCR Framework. This should lead to considerable improvement of the coverage of the fishery, i.e. underreporting will probably reduce markedly.

However, at the present 2010 status, dataseries from the Country Reports continue to be incomplete and are still unreliable. A review of the catches and landing reports in the CR (Sections 2: Time-series and Section 3; Catches and landings) demonstrated a great heterogeneity in reporting landing data, with countries making reference to an official system, some of which report total landings, others report landings by Management Unit or Region, and countries without any centralized system. Furthermore, some countries have revised their dataseries, with extrapolations to the whole time-series, for the necessities of the Eel Management Plan compilation (Poland, Portugal). Others could not give total landings for all life stages and all water areas.

2.2.1 Collection of landings statistics by country

The data on landings is reported in Annex 4. Annex 4, Table 2.4 presents the total landings (all life stages) as compiled from the 2009 Country Reports submitted to the WGEEL 2010 and Annex 4, Table 2.5 presents the total landings (all life stages) only for the countries present in the WG, source FAO FishStat 2010. The following is a synopsis.

Norway: No data available on eel landing statistics collection in Norway. All commercial fisheries were stopped from 1 January 2010. A 50 t research quota was implemented.

Sweden: Data on eel landings are based on daily logbooks and monthly journals. Fishing for eels in private waters was not reported before 2005. Data from logbooks and journals are stored at the Swedish Board of Fishery.

Estonia: The catch statistics are based on logbooks from inland and coastal fisheries.

Latvia: Eel landing statistics were collected on coastal fishery by voluntary reporters in period from 1924–1938, by fishing enterprises (state and cooperative) official reports from 1946–1992, by monthly logbooks (daily records of catch) from legal and private persons using professional fishing gear until now. Eel landing statistics in inland waters were collected from state fishing companies from 1946–1992, by monthly logbooks (records by fishing day catch) from legal persons using professional fishing gear until now. Formats of logbooks are formalized and defined by Cabinet regulation. Coastal eel fishery data are stored in ICIS database administered by Department of Fisheries Ministry of Agriculture.

Lithuania: Landing statistics are based on logbooks data, collected by local fishery officials and stored and processed by Fisheries Department of Agriculture Ministry.

Poland: The data on inland catches were obtained by surveying selected fisheries facilities, then extrapolating the results for the entire river basin. These data are thus approximate. The data from the lagoons were drawn from official catch statistics (logbooks).

Germany: Eel landings statistics form coastal fishery is based on logbooks. There were no centralized eel landings statistics in country until 2009. Data were collected by states authorities, only part of this statistics were catch reports.

Denmark: The yellow and silver eel catches are reported by commercial fisheries.

Netherlands: There is no general registration of landings yet. For Lake IJsselmeer, statistics from the auctions around Lake IJsselmeer are kept by the Fish Board. For the inland areas outside Lake IJsselmeer, no detailed records of catches and landings were available until 2010. Catches and landings in marine waters are registered in EU logbooks. Landings registrations are available for the years since 1995; on data prior to 1984 reference source not found. An obligatory catch registration system was introduced in the Netherlands in January 2010 by the Ministry of Agriculture, Nature and Food Quality.

Belgium: There is no commercial eel fishing in Belgium.

UK: UK: In England and Wales, the Environment Agency collects the data and it is a legal requirement that all eel fishers submit a catch return. Licensees are required to give details of the number of days fished, the location and type of water fished, and the total weight of eel caught and retained, or a statement that no eel have been caught. Annual eel and elver net licence sales and catches are summarized by gear type and Agency region (soon to be RBDs) and reported in their "Salmonid and Freshwater Fisheries Statistics for England and Wales" series.

www.environment-agency.gov.uk/research/library/publications/33945.aspx

All eel caught by recreational fishing must be returned to the water alive. In Scotland, commercial and recreational fishing for eel requires a licence from the Secretary of State for Scotland, and there is a general presumption against the granting of such licences. In Northern Ireland, catch returns from Lough Neagh are collated annually by LNFCS and updated for the Inland Fisheries Management Authority (DCAL) and to AFBI for scientific analysis.

Ireland: Until 2008 eel landing statistics in Ireland were collected from voluntary declarations although these were improved in 2005 with the introduction of a reporting form. From 2009 commercial fishing of eel is closed and anglers are required to release eels alive.

France: Landings statistics are collected by two different administrations in France, whether they belong to inland or maritime fisheries. The dataset used for landings estimates were from logbooks, declared catches, trader's reports and EU trade statistics. A new centralized system has been developed from 2009 on catch and effort data collection in marine waters. Unfortunately due to delays in implementation, data on eel catches were not available at the level of detail required for analysis.

Spain: Data on eel landings in country mostly are collected from fishermen's guilds reports and fish markets (auctions). The precision of the information of the catches and landings differs greatly among Autonomies.

Portugal: Fisheries managed by DGPA have obligatory landing reports, contrary to catches from inland waters that are not reported.

Italy: Eel landing statistics are based on reports on eel fishing in lagoons. Limited information available on eel fishery in inland waters, because catch and landings statistics form lakes, rivers and reservoirs are not registered in state statistical system ISTAT.

2.3 Recreational fisheries

Data for recreational fisheries were incomplete and the Working Group was unable to undertake any new analysis. The ICES Planning Group on Recreational Fisheries Surveys met in June 2010 (Bergen, Norway). In time this group should be able to provide reliable data on recreational catches of the target species listed below to improve the international stock assessments. The legal framework for collection of recreational fisheries data by EU Member States is given by the EU Data Collection Framework (Council Regulation (EC) No 199/2008 and Council Decision 2008/949/EC). The Council Decision specifies that:

- For the recreational fisheries targeting the species listed in Appendix IV (1 to 5), Member States shall evaluate the quarterly weight of the catches.
- Where relevant, pilot surveys as referred to in Chapter II B (1) shall be carried out to estimate the importance of the recreational fisheries.
- Data related to annual estimates of the catches in volumes must lead to a precision of level 1 (level making it possible to estimate a parameter either with a precision of plus or minus 40% for a 95% confidence level or a coefficient of variation (CV) of 20% used as an approximation).

The species for which recreational fishery data are to be collected in each area are:

- Baltic (ICES Subdivisions 22–32): Salmon, cod and eels;
- North Sea (ICES Division IV and VIId) and Eastern Arctic (ICES Division I and II): cod and eels;
- North Atlantic (ICES Division V–XIV): Salmon, sea bass and eels;
- Mediterranean and Black Sea: bluefin tuna and eels.

In the near future sharks and rays will be added to the list of species for which Member States will have to provide estimates of recreational catches.

The terms of reference of the PG included:

1) Develop guidelines for best practices for sampling recreational fisheries, and formulate procedures for identifying and quantifying biases in sampling and survey schemes and precision of estimates, for inclusion in the ICES Quality Assurance framework;
2) Review sampling strategies, protocols, and levels to be proposed for implementation within the EU Data Collection Framework and national centres responsible for sampling recreational fisheries;

3) Agree a work plan for 2011 for further developing and finalizing standards and best practices for sampling recreational fisheries, including recommendations for appropriate workshops.

2.4 Glass eel landings and trade

The trade analysis was done after querying the Eurostat database. Data for both imports and exports were compiled for three reporting countries, France, the United Kingdom, and Spain, as they are the main producers of glass eel in Europe. The separation between glass eel and yellow eel was done according to Briand *et al.* (2008). The Eurostat database has its limitations when dealing with glass eel which is traded in small weights as all data are rounded to the nearest 100 kg and many batches of glass eel are exchanged below that weight level.

The trade value can be different for import and export data, and this only reflects the fact that the trade value appearing in the statistics is the one that is declared by enterprises within the country. So for instance, Spanish middlemen might buy glass eel directly to the French fishers and this trade would be only reported as an import and not as an export from France. So we chose to use the maximum reported trade from either side of the frontier as the 'real' export value.

The objective was to check the overall destination of eel and the current state of trade both inside the EU, and outside. The landings for UK, France and Spain, as reported to the working group for the 2009–2010 seasons, are estimated to be 1.3 t, 41 t and 6.4 t respectively for commercial fishers and an additional 0.6 t for recreational catches in Spain (Figure 2.17). When removing from that figure the weight of the exported glass eels and the weight stocked within the country, the weight of glass eel remaining within the country is 3.6 t, -2.4 t, 9.9 t for UK, Spain and France respectively. This amount might be due to the fact that the latest trade values (i.e. June 2010) were not available at the time of analysis, and further trade would be expected as exports of glass eel from the UK previously imported from France and Spain.

The analysis of the glass eel price demonstrates that the weighted means has dropped in 2009 but increased in 2010 to 541 €/kg (Table 3.2).

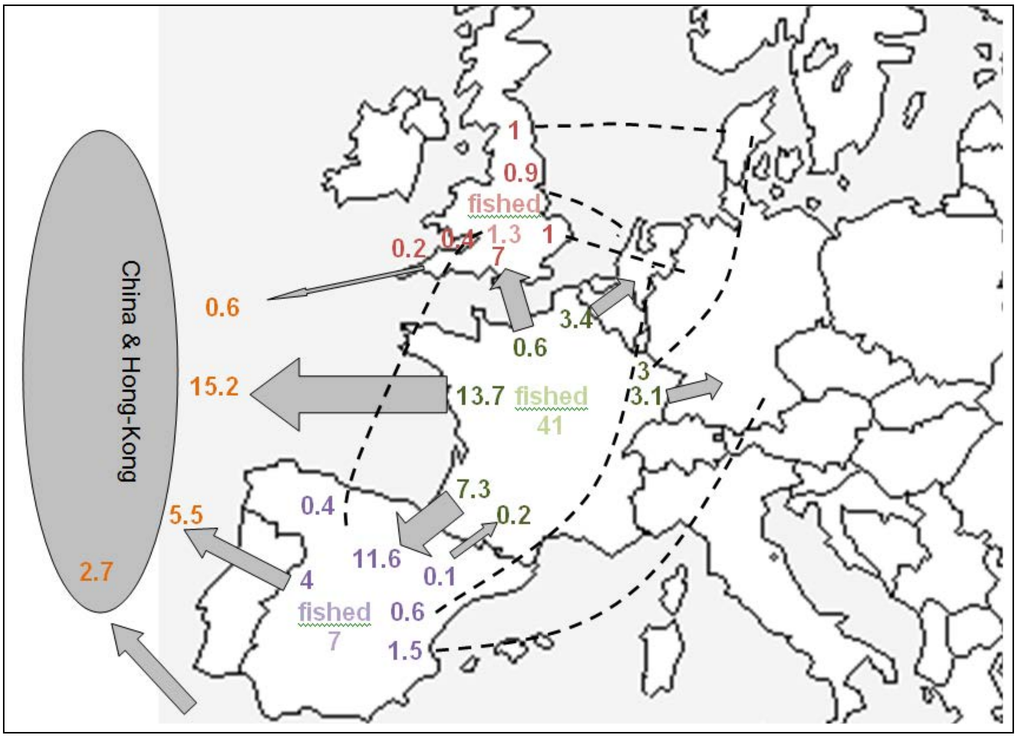


Figure 2.17. Landings and trade in Europe from November 2009 to May 2010. The arrows indicate the quantities traded declared by Spain, France and the United Kingdom. Both imported and exported quantities are provided. China and Hong Kong data requested from China and Hong Kong Statistics Department are kindly supplied to the working group by TRAFFIC. The arrow at the bottom indicates trade from Morocco.

Table 2.3. Recent trend in glass eel and yellow eel trade price computed from the Eurostat database (NC8). Prices corrected from inflation using price index in France.

	Glass eel (€/kg)	Yellow eel (€/kg)
2000	197.4	4.6
2001	290.8	6.4
2002	218.8	5.7
2003	220.6	5.8
2004	417.3	6.3
2005	723.1	5.3
2006	365.9	6.5
2007	455.1	6.0
2008	288.4	5.2
2009	314.1	6.1
2010	541.9	5.6

2.5 Trends in stocking

Data on stocking were obtained from a number of countries, separated for glass eels and for young yellow eels.

An overview of data available up to 2009 (partly 2010) is compiled in Annex 4, Tables 2.6 and 2.7. Stocking in other EU countries, for which there are no time-series data, and which hence are not included in the Annex, are also summarized below.

Note that various countries use different size and weight classes of young yellow eels for restocking purposes.

2.5.1 Stocking review notes

Sweden:	Since 2006 only imported and quarantined glass eels are eligible for stocking supported with public money. From 2009 all glass eels are marked with strontium chloride ($SrCl_2$) in their otoliths.
Poland:	Nowadays restocking is conducted only by private stakeholders. Stocking on a national level will start in 2011.
Germany:	There is no central database on restocking, but some data are available. The quantity of young yellow eels stocked to the waterbodies is significant.
Denmark:	Glass eels are imported mostly from France and are grown to a weight of 2–5 gramme in heated culture before they are stocked. Restocking is done as a management measure.
Netherlands*:*	Glass eel and young yellow eel are used for restocking inland waters since time immemorial, mostly by local action of stakeholders.
Belgium:	Glass eel restocking is proposed as a management measure in the EMP for Flanders.
N. Ireland:	In 2010 the 996 kg of glass eel purchased from *Glass Eel UK* originated from fisheries in San Sebastian, Spain and the west coast of France.
Ireland:	No stocking of imported eel takes place in Ireland.
France:	The first large-scale restocking action started in 2009 in the Loire River. Glass eel came from a CITES seizure.
Spain:	No stocking on a national level. Each autonomous region has its own rules and experience concerning restocking.
Portugal*:*	No stocking on a national level.

Stocking with glass eel has decreased strongly since the early 1990s and appears now to be at a relatively low level and still decreasing (Figure 2.18). 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 indicated an increase but dropped again in the late 1990s (Figure 2.19). During recent years, another increase in stocking young yellow eels was observed.

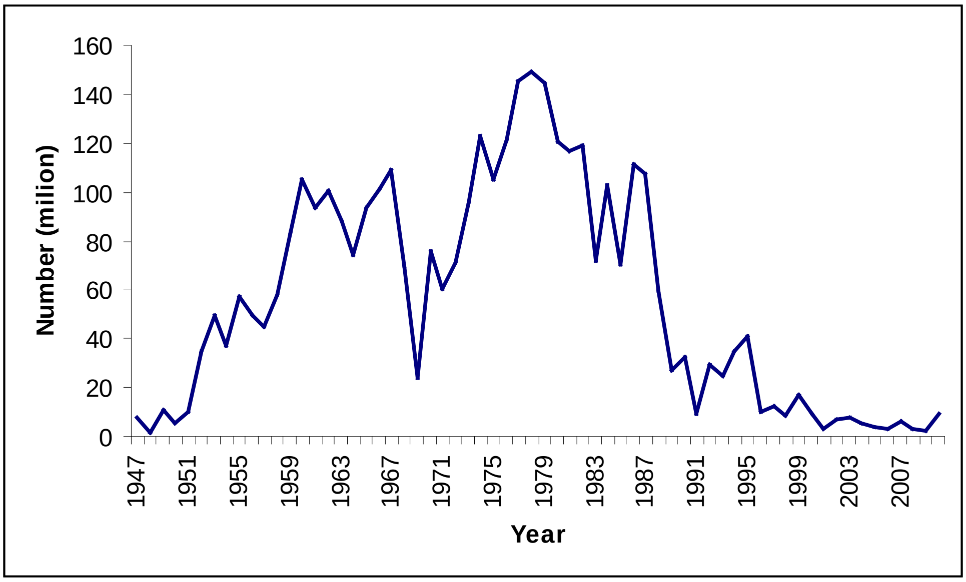


Figure 2.18. Stocking of glass eel in Europe (Sweden, Finland, Estonia, Latvia, Lithuania, Poland, Germany, the Netherlands, Belgium, Northern Ireland, France and Spain) in millions restocked.

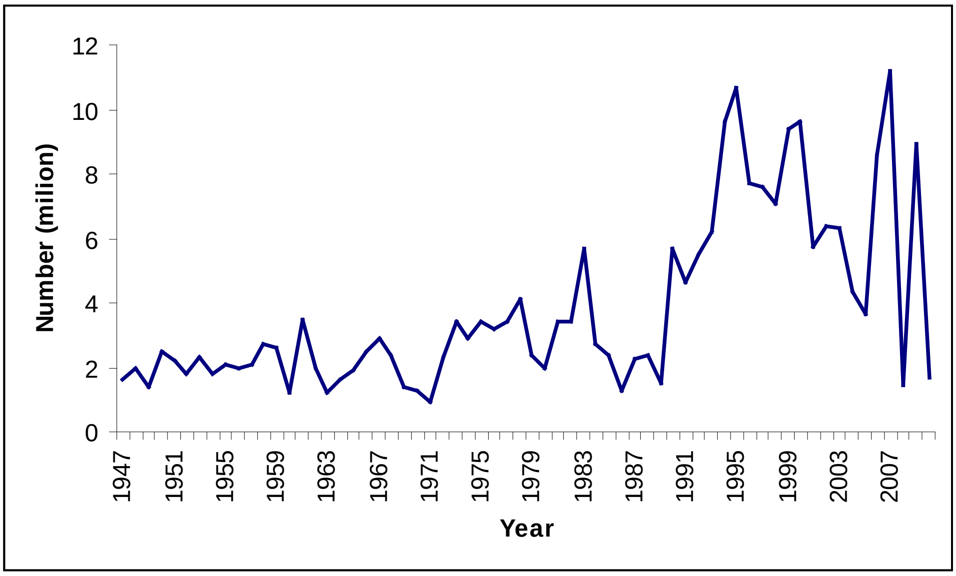


Figure 2.19. Stocking of young yellow eel in Europe (Sweden, Finland, Estonia, Latvia, Lithuania, Poland, Germany, Denmark the Netherlands, Belgium, and Spain), in millions stocked.

2.6 Aquaculture production

Aquaculture data were not complete for 2008 or 2009 (Annex 4, Table 2.8) and was therefore not analysed by the Working Group in 2010.

2.7 Conclusions and recommendations: Data and trends

2.7.1 Data statistics and trends

The declining trend in recruitment continues. All glass eel recruitment series demonstrate a clear recruitment decline since about the 1980 without sign of recovery.

A difference in spatial pattern of recruitment is only observed in the North Sea, where the decline is sharper than elsewhere. There is no current explanation for that observation.

There needs to be an improvement in the data collected and reported, particularly data on landings and on stocking. The traceability requirements under the EU Regulation (Comm 1100/2007) and CITES have increased the quality of data on glass eel trade, though some portion still remains unexplained.

The WG expects that more data and information should become available in the near future as a consequence of the implementation of the eel management plans.

The quality of data on landings or restocking should be improved.

2.7.2 Recommendations

It is recommended that;

- the effects of management actions on those glass eel fisheries that provide recruitment indices are critically analysed with the objective of calibrating future data against historical data collected prior to the implementation of EMPs;
- long-term series be continued and/or recommenced if already ceased, especially in the Mediterranean.

The WGEEL recommends that an analysis of trends in local yellow eel and/or silver eel be undertaken. This could include, for example, local stock parameters, such as fykenet survey catches, cpues, escapements (biomass or numbers).

The Working Group recommends that an analysis (e.g. power analysis) be conducted on glass eel recruitment time-series to determine criteria for defining a recovery.

3 International stock assessment and post-evaluation

Chapter 3 continues the line of development commenced in the 2008 report, the concept of post-evaluation and stock assessment at the international level. In conjunction with SGIPEE, the Study Group on International *Ex post*-evaluation on Eels, chapter 3 addresses the following Terms of Reference:

a) assess the trends in recruitment and stock, for international stock assessment, in light of the implementation of the Eel Management Plans;

b) develop methods to post-evaluate effects of management actions at the stock-wide level (in conjunction with SGIPEE);

f) respond to specific requests in support of the eel stock recovery Regulation, as necessary;

and has links to:

c) 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 (in conjunction with SGAESAW 2);

d) provide practical advice on 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.

3.1 Introduction on international post-evaluation

Management of the European eel stock is necessarily an international responsibility; the EU Eel Regulation sets international targets and will post-evaluate internationally by 2012. This chapter focuses on the international post-evaluation, in particular on the methodology. The results presented in this chapter build upon and extend the work done by the Study Group on International *Ex post*-evaluation on Eels (SGIPEE) in May 2010 (Paris).

In this chapter, two aspects will be considered. First, SGIPEE suggested the application of a Modified Precautionary Diagram (Dekker, 2010) to evaluate overall stock status, but gave no real application; in this chapter, the estimates given in the 2009 Eel Management Plans will be used for that purpose; the explanations pertaining to the Modified Precautionary Diagrams below repeat and extend the text given in the SGIPEE report.

Secondly, the application of a Precautionary Diagram hinges on the availability of a set of consistent estimators of comparable quality and methodology, within and between countries; the estimates given in the 2009 Eel Management Plans will be explored, to check for consistency and comparability.

3.2 The Precautionary Diagrams used by ICES

The Eel Regulation sets a limit reference for biomass as a percentage (40%) of the pristine biomass, and leaves it up to the Member States to determine actual reference points for the part of the stock within their territory. Effectively, the limit of the Regulation being formulated as a percentage, this condenses to a limit mortality, unless density-dependence is to be taken into account (note that restocking can be interpreted as a negative mortality, see Section 2.5.3 in the SGIPEE report).

In its advice on fisheries management, ICES (2004b) applies a 'traffic light' colouring scheme, signalling the status of the stock and the impact of exploitation. The information on the stock status and the reference points are summarized in a so-called Precautionary Diagram (Figure 3.1). This diagram presents the status of the stock (horizontal, low vs. high spawning-stock biomass determining whether the stock has achieved full reproductive potential) and the impact of fishing (vertical, low vs. high fishing mortality determining whether the exploitation is sustainable or not).

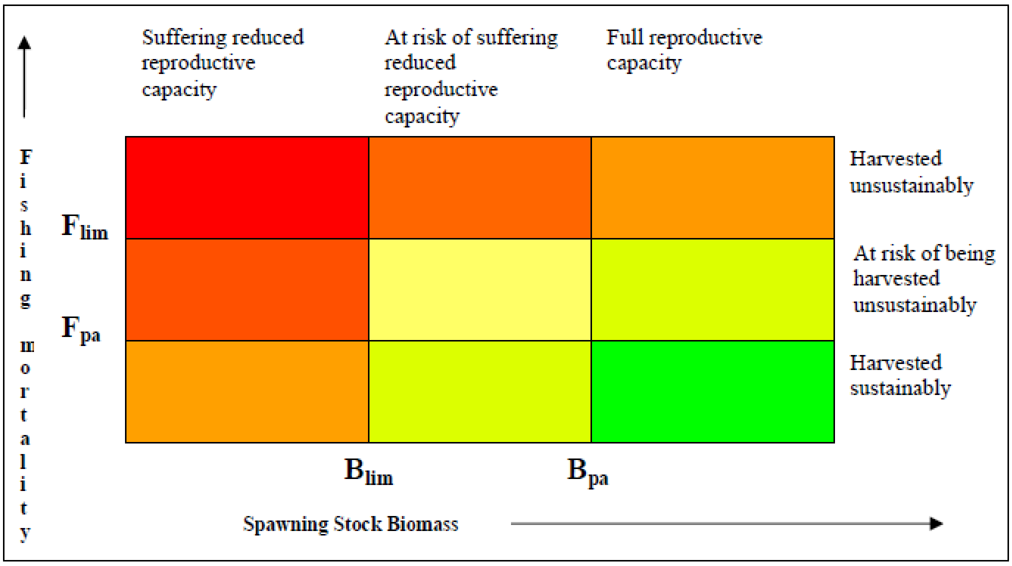


Figure 3.1. In its scientific advice on fish stock management, ICES applies a standard terminology to qualify the status of the stock (horizontal) and the impact made by fishing (vertical). Source: ICES 2004b (diagram p. 1–7).

3.3 A modification of the Precautionary Diagram

3.3.1 The inadequacy of the traditional Precautionary Diagram for eel

The ICES Precautionary Diagram presupposes a stock status in the neighbourhood of the reference points, which unfortunately does not happen for the eel stock. For the eel, the stock is (assumed to be) suffering from reduced reproductive capacity, and anthropogenic impacts are (assumed to be) outside safe biological limits (ICES, 1999). Applying the Precautionary Diagram in an actual case study on eel (Dekker, 2010) results in a diagram with all data points arranged in a narrow vertical strip along the y-axis, which does not provide a useful presentation of the stock status. A modification of the Precautionary Diagram to suit the eel case was adopted by SGIPEE for its international stock assessment. In this modified diagram, the spawning stock is plotted on a logarithmic scale, while the annual fishing mortality is replaced by the lifetime cumulative anthropogenic mortality ΣA. As in the standard diagram, the horizontal axis quantifies the status of the stock. The vertical axis quantifies the anthropogenic impacts, as opposed to only fishing impacts in the standard diagram.

Dekker (2010) presents two versions of the Modified Precautionary Diagram, differing in their vertical axes: one with %SPR (the current spawner escapement as a percentage of the maximal attainable escapement under current recruitment), the other with cumulative anthropogenic mortality ΣA. The %SPR version allows for easy integration of separate spatial units into a total, but does not adequately express the reduction in mortality required; for the ΣA version, the reverse applies. Noting the large number of Eel Management Units considered in the international post-evaluation below, the simple graphical interpretation is not easily done, and hence, the ΣA version was preferred because of its adequate representation of the required changes in anthropogenic mortality ΣA. This deviates from the diagrams presented in the SGIPEE report (%SPR version).

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

3.3.2 The relation between %SPR and mortality

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

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

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

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

Where N_t the number of silver eel escaping in year t

S_a the fraction of eels of age a silvering

R_t the recruitment in year t, in numbers

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

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

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

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

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

For the density-independent case, %SPR expressed in numbers[1] thus equals:

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

and hence

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

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

For a %SPR based on biomass rather than on numbers, the relationship between %SPR and mortality is much more complex, but numerical simulation indicates that the relationship comes close to that specified above (Dekker, 2010).

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

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

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

The Modified Precautionary Diagram, as presented in the report of SGIPEE, demonstrates %SPR on the vertical axes. Though this does allow for a quick and easy interpretation of the contribution various EMPs make to the overall stock status, this vertical axis does not indicate what changes in anthropogenic impacts are required. The non-linear relation between lifetime anthropogenic mortality ΣA and %SPR implicates that disproportionate reductions are required in cases where %SPR is far below the target, i.e. the severity of those cases is not adequately demonstrated. Alternatively, the lifetime anthropogenic mortality ΣA can be plotted (Dekker 2010); this approach will be followed here. In density-dependent cases, the interpretation of %SPR might be simpler (the ratio of B_{post} to B_{best}), but without a clear relation to (required) management actions, this is a trivial advantage. Hence, the Modified Precautionary Diagram based on lifetime anthropogenic mortality ΣA is preferred, which adequately demonstrates the severity of the most depleted cases, while still allowing the inclusion of density-dependent cases (calculations via %SPR).

3.3.3 Integration of disaggregated assessments into a higher level assessment

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

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

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

$$\%SPR_{post} \rightarrow = \frac{B_{post}}{B_{best}}$$

$$= \frac{B_{south,post} + B_{north,post}}{B_{south,best} + B_{north,best}}$$

$$= \frac{\frac{B_{south,post}}{B_{south,best}} \times B_{south,best} + \frac{B_{north,post}}{B_{north,best}} \times B_{north,best}}{B_{south,best} + B_{north,best}}$$

$$= \frac{\%SPR_{south} \times B_{south,best} + \%SPR_{north} \times B_{north,best}}{B_{south,best} + B_{north,best}}$$

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

3.4 Data requirements

Summing up, the international stock assessment can be based on lower-level stock assessments, if those lower-level assessments supply the following estimates (Annex 5):

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

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

c) $\mathbf{B}_{best}$, the estimated biomass in the assessment year (tons), based on the recently observed recruitment, but assuming no anthropogenic impacts have occurred (neither positive nor negative impacts). Alternatively, one can report lifetime cumulative mortality (as a rate), which is equal to the logarithm of the ratio of B_{best} to B_{post}.

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

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

3.5 Available data, data quality and reliability

To implement the SGIPEE approach and to test the adequacy of the Modified Precautionary Diagram, a dataset was compiled of biomasses (or numbers, if biomass estimates were unavailable), taking information from the Eel Management Plans, and the Country Reports in Annex 9, covering nearly 50% of the total number of Eel Management Units. It should be emphasized that data were taken at face value. Information available in the Working Group indicates that some estimates might contain errors, some might be less reliable, some might be inconsistent (e.g. pristine and current biomasses estimated by different methods, making the results incomparable), and in many cases might cover the stocks only incompletely.

The aim of the current exercise is to implement and test a procedure for international post-evaluation of the stock status and anthropogenic impacts. To this end, data are collected from countries/regions, and integrated into an international estimate. Consequently, the international post-evaluation depends on the data availability and data quality as delivered by the countries. In the long run, this will necessitate a data quality assessment; in other words, a check on the quality, consistency and comparability of data supplied by the countries. However, such a quality assessment is currently out of reach: time did not allow a thorough test of all data. More importantly, the data have not been compiled with this international aim in mind, and applying a rigorous test now might easily lead to an apparent disqualification of individual countries, which would go beyond the remit of the current Working Group. Consequently, the data analysed below were taken at face value, and results should be considered to be illustrative rather than final.

Analysis of the Eel Management Plans, and the Country Reports in Annex 9, yielded estimates for 40 Eel Management Units out of a total of 86. For the current purposes, that is a reasonable testing dataset. However, we also note that 46 EMUs did not supply the minimum information required for a stock assessment (B_{post}, B_{best} and Bo). The post-evaluation foreseen by 2012 will not be feasible without minimal information. It is therefore recommended that countries produce the minimal information required as soon as possible, and that international quality criteria are developed for the data and methodology used (Annex 5).

3.6 A preliminary implementation of the Modified Precautionary Diagrams

The data presented in the national Eel Management Plans and the Country Reports allowed the assessment of stock status in 40 Eel Management Units. Figure 3.2 presents the results per Eel Management Unit, while Figure 3.3 presents the results summed per country. For some EMUs, the %SPR is above 100%, the anthropogenic mortality is estimated below zero. This situation occurs, when positive impacts occur. In the cases revealed, the natural eel stock is low due to the long distance to the sea, while the current eel stock has been augmented by restocking. It is the combination of a low natural stock and restocking that causes the extraordinary situation of a negative anthropogenic impact. Because of the low natural stock, these EMUs have only a limited impact on the overall situation. Additionally, some of these EMUs are situated inland, discharge into other EMUs/countries, and subsequent mortality on the silver eels escaping has not yet been considered.

In the second diagram (by country) (Figure 3.3), the overall status is dominated by France. It should be noted that non-represented countries might have a considerable contribution too, changing the overall picture and reducing the apparent French dominance. The position of the total, assuming anthropogenic mortality is reduced to zero (i.e. B_{post} is set to B_{best}; this is represented by an empty bubble), indicates that recovery to the level set in the Eel Regulation is unachievable within a single generation; however, the information used here is preliminary and incomplete.

The Modified Precautionary Diagram, and the summation method used to derive an integration of the national assessments, is a consistent procedure of presenting the available information, but it does not produce independent and verifiable outputs. As such, it is primarily a method of communicating the information on the stock status, including the lack of information from over half the Eel Management Units. The preliminary information presented here clearly indicates the wide spread in stock status between and within countries, the need to standardize methodology and presentation, and the wide range in biomass contributions of different countries.

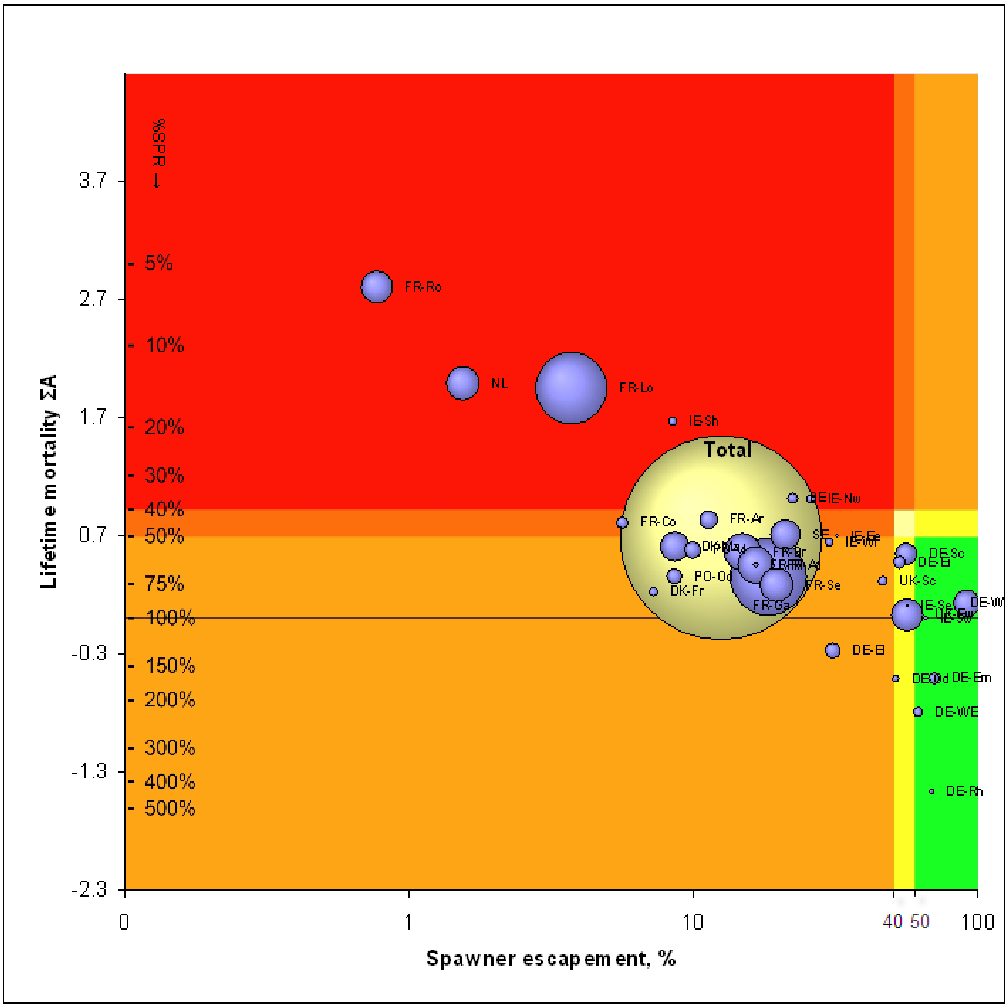


Figure 3.2. Modified Precautionary Diagram, presenting the status of the stock and the anthropogenic impacts, per Eel Management Unit (label=country code plus management unit code). For each, the size of the bubble is proportional to B_{best}, the best achievable spawner escapement given the recent recruitment, while the centre of the bubble gives the stock status relative to the targets/limits. The horizontal axis represents the status of the stock in relation to pristine conditions, while the vertical axis represents the impact made by anthropogenic mortality. Data from national Eel Management Plans, supplemented by Country Reports. Note that data might be incomplete, inconsistent, or false; though problems are known, no corrections have been made.

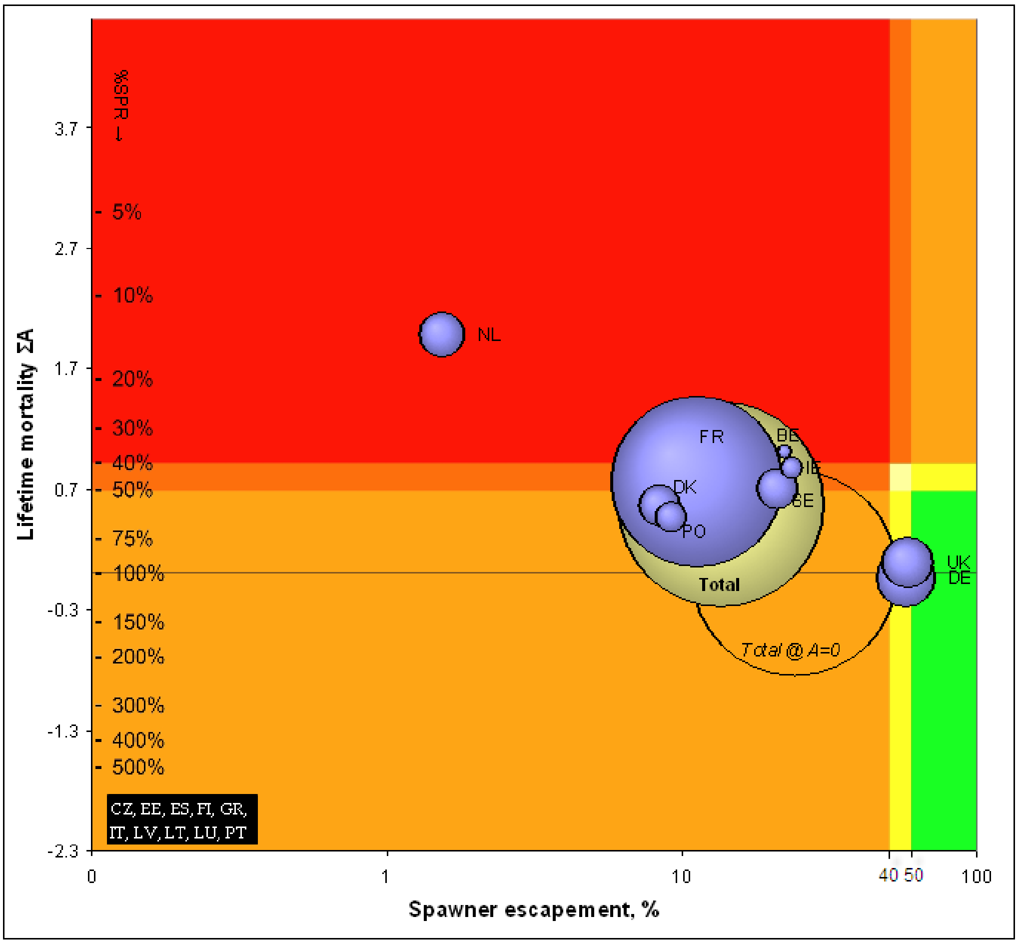


Figure 3.3. Modified Precautionary Diagram, presenting the status of the stock and the anthropogenic impacts, per country (label=country code). For each, the size of the bubble is proportional to B_{best}, the best achievable spawner escapement given the recent recruitment, while the centre of the bubble gives the stock status relative to the targets/limits. The horizontal axis represents the status of the stock in relation to pristine conditions, while the vertical axis represents the impact made by anthropogenic mortality. Data from national Eel Management Plans, supplemented by Country Reports. Note that data might be incomplete, inconsistent, or false; though problems are known, no corrections have been made. Countries for which no estimates were available are listed in the black box. For the sum of the countries represented, the empty bubble gives the best achievable status, if all anthropogenic mortality is reduced to zero.

3.7 Consistency of stock indicators

This section aims at analysing the first estimates of Bo and Bbest, two of the three B-values requested by the Modified Precautionary Diagram (MPD). Biomass before management action, directly linked with anthropogenic mortality and therefore more variable between EMU, will be directly analysed through the discussion of MPD application. We used the figures available in the Country Reports. We analysed information (Bo, Bbest, wetted area of the EMU) for nearly half the EMU in Europe (40 among 86 EMU).

3.7.1 Analysis of pristine biomass estimates (Bo)

Pristine biomass estimates, expressed in kg/ha, ranged from 0.5 up to 256 kg/ka demonstrating a high variability throughout Europe (Table 3.1).

Table 3.1. Ranked pristine biomass (Bo) for 40 EMU where data were available.

Country	EMU	Bo (kg/ha)
France	Garonne-Dordogne-Charente-Seudre-Leyre	256.4
France	Adour	237.3
France	Loire	207.4
France	Bretagne	179.4
France	Seine-Normandie	48.1
France	Artois-Picardie	41.8
Netherlands	Netherlands	19.4
Denmark	Freshwater EMU	18.5
England & Wales	South East	16.9
England & Wales	South West	16.9
England & Wales	Dee	16.9
England & Wales	North West	16.9
England & Wales	Solway Tweed	16.9
England & Wales	sumEMU	16.9
England & Wales	Humber	16.9
England & Wales	Anglian	16.9
England & Wales	Northumbria	16.9
England & Wales	Severn	16.9
England & Wales	Western Wales	16.9
England & Wales	Thames	16.9
Northern Ireland	Neagh/Bann	12.5
France	Rhin-Meuse	11.1
Germany	Ems	9.2
Germany	Weser	7.8
Germany	Elbe	6.9
Northern Ireland	Eastern	5.0
Ireland	ShIRBD	4.7
Germany	Meuse	4.5
Northern Ireland	NWIRBD	4.5
Germany	Rhine	4.3
Ireland	NWIRBD	4.0
Ireland	SERBD	3.8
Ireland	WRBD	3.4
Ireland	EEMU	3.1
Germany	Warnow/Peene	2.6
Ireland	SWRBD	2.4
Germany	Oder	2.4
Germany	Schlei/Trave	1.9
Scotland	Scotland	1.0
Germany	Eider	0.5

The highest values were calculated, or estimated, for French waters; the lowest for RBD's in the Baltic Sea region. In principle this would make sense, but the degree of variation/difference between the values cannot be judged at the present moment.

However, an evaluation of the estimates given in the EMPs and/or Country Reports will be necessary for a serious assessment of the eel stock and, hence, is needed as a prerequisite for post-evaluation.

Considering the huge variation in the estimates, we tried to determine the factors which may influence the values/estimates. It was supposed that the following three factors were the most likely to have an influence:

- geographical location;
- habitat type included (freshwater, brackish/transitional/lagoon, coastal areas);
- method used.

Notice that whereas the two first factors will have an influence in reality, the "method" employed is only a consequence of modelling choice and should not have an influence on the result, although in reality this is currently not the case.

First we analysed the distribution of the pristine biomass according to sea region where outputs of the EMU catchments go (Figure 3.4). We adapted CCM sea regions (Vogt *et al.*, 2007) by splitting "North Atlantic" into "Atlantic British Island", "Bay of Biscay" and "Iberian West Coast" change, by separating "Celtic Sea and Channel" into two regions. Two categories were added to take into account EMU which have output in two regions, "Channel/ Bay of Biscay category" for Brittany and "Atlantic British Island / North Sea" for Scotland. The median value is nearly 15 kg/ha because the mean, highly influenced by the Bay of Biscay value, is around 30 kg/ha. There is no clear geographic structure.

In a further step, it should be analysed, if the estimates for the single regions or RBD's are supported by historical information (e.g. historical catch levels without stocking).

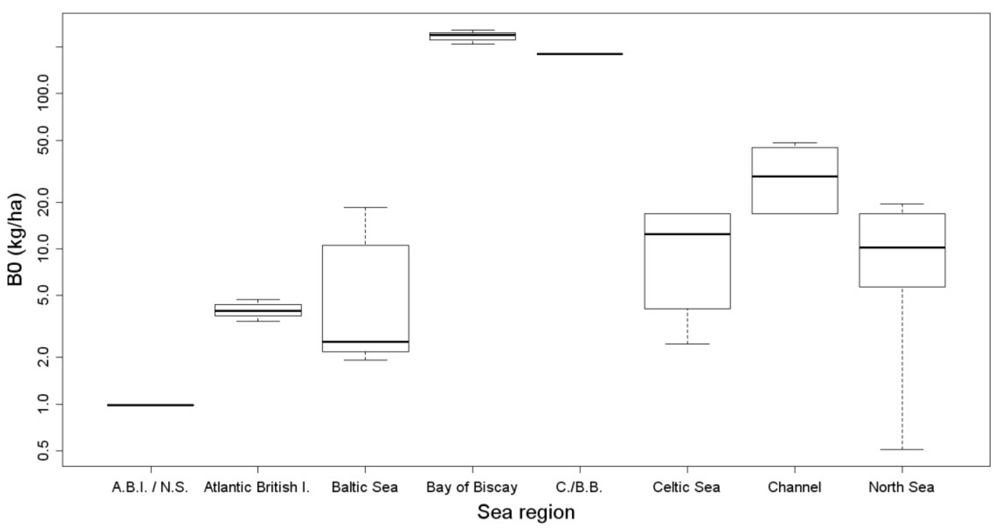


Figure 3.4. Distribution of EMU pristine biomass according to sea region of EMU output (A.B.I./N.S.: EMU with outputs in Atlantic British Island and North Sea regions, C./B.B.: EMU with outputs in Channel and bay of Biscay regions, notice that y-axis is in logarithm scale).

Figure 3.5 highlighted the influence of having included or not the transitional and coastal water in the EMU and in the calculations. There data provide evidence that within an EMU, Bo (and eel stocks in general) would be highest in transitional waters (brackish waters, lagoons, estuaries). This is in agreement with studies demonstrating a higher growth rate in brackish water (Edeline *et al*., 2005; ICES, 2009). The coastal waters with their low abundance of eels lead to the lowest EMU Bo. Nevertheless one should take care of how the coastal water surface is calculated to avoid discrepancies between EMUs that include different coastal waters (see Chapter 4.5). Regarding the factor "habitat type", it should also be noted that there are differences in the characteristics of the freshwater habitats, which have a great influence on eel production. Freshwater eel habitats include highly productive areas in slow-flowing downstream parts of rivers as well as lakes or small streams in mountain areas several hundreds of kilometres from the coast. This is reflected in the degree of natural immigration of eels and in the productivity of the waterbodies and hence in the values of Bo and B_{best}.

For future assessments of the eel stock, it could be helpful, if the countries would also provide information on the size of coastal habitats, which are not included in the EMU and the calculations of stock size and escapement. Even though the estimates of spawner production are low for coastal waters on a relative basis (kg/ha), the huge size of these habitats may result in a considerable total production of spawner biomass.

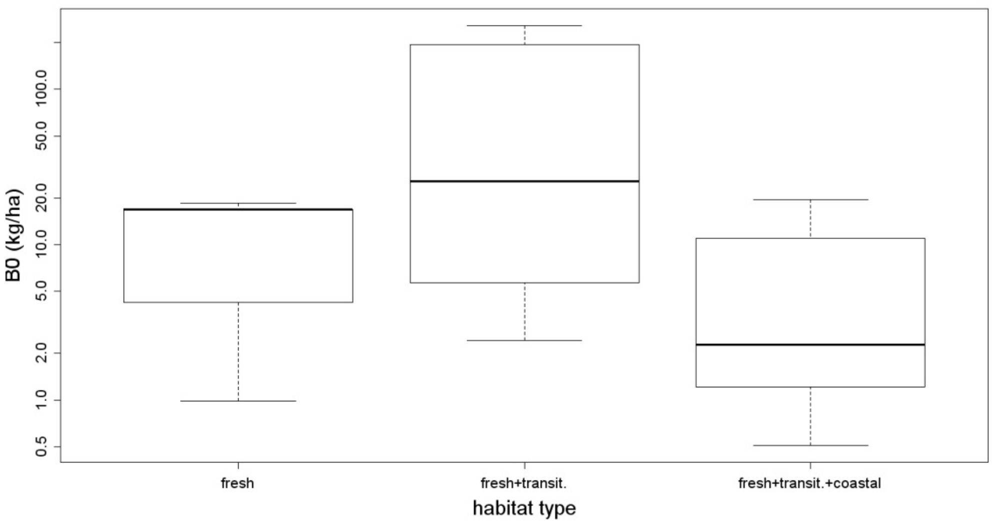


Figure 3.5. Distribution of EMU pristine biomass according to habitat type included in each EMU (fresh: freshwater, transit.: transitional waters, coastal waters).

Five methods were used to calculate pristine escapement. EDA, IMESE and GEM were described in previous WGEEL reports (ICES, 2008). Historical method corresponded to the compilation of historical data available in the EMU. Expert approach is based on the most appropriate values found in literature.

The estimates differences between these methodologies were great. The huge values, (> to 200 kg/ha) seem to be questionable and should be validated by comparison with historical data from the waters for which they were predicted. In general, all these estimates should be validated with literature data and historical information as much as possible.

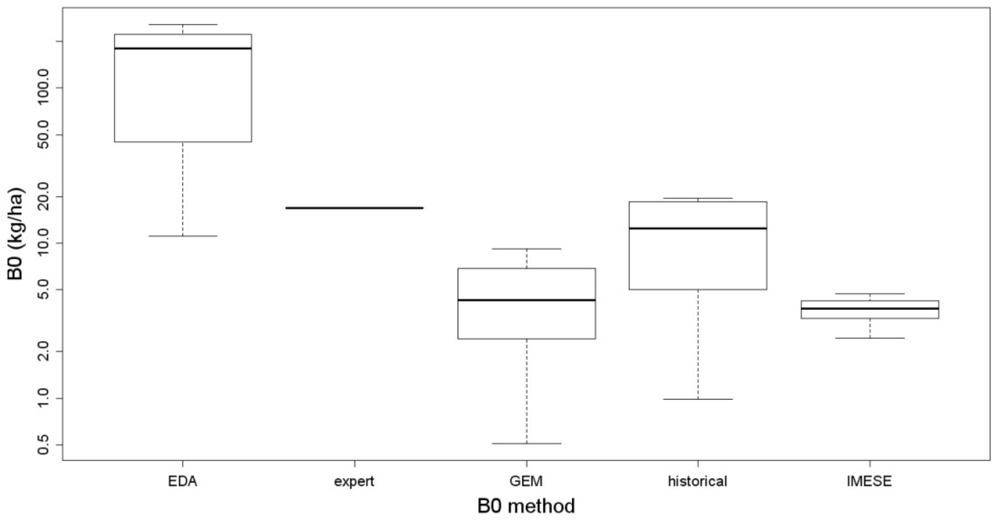


Figure 3.6. Distribution of EMU pristine biomass according to the methodology used.

We finally tested the joint effect of sea region, habitat type and method with a GLM (Gaussian distribution) (McCullagh and Nedler, 1989) after having log transformed the Bo values. All the effects were significant (Table 3.2) which is problematic for the methodology influence in the context of post-evaluation.

Table 3.2. Results the GLM of the logarithm of the Bo with sea region, habitat type and method effect.

	LR Chisq	D.f.	Pr(>Chisq)
Sea region	53.390	7	3.105e-09 ***
Habitat	32.474	2	8.877e-08 ***
Method	93.940	4	< 2.2e-16 ***

This analysis highlighted the variability of pristine eel spawner escapement in Europe but most of all reinforces the interest of inter-calibration between methods (refer to DG MARE pilot Study to Estimate Silver Eel production & Escapement – EU POSE). After that, research to better understand this variability is needed to propose standard range of values of pristine escapement. A better confirmed knowledge of "pristine" stocks and escapement would clearly help to put the future stock assessment and post-evaluation on a more solid ground.

3.7.2 Analysis of the relationship between pristine escapement (Bo) and best escapement with present recruitment and no anthropogenic impacts (B_{best})

We then analysed the relationship between the two "B" values, considering no anthropogenic impacts; the first one in pristine conditions (Bo) and the second one with present decreased level of recruitment (B_{best}). This ratio, not used in the MPD, can be useful to detect possible inconsistencies between these two B's. Theoretically, because this relationship is linked to the rate of recruitment decrease, values above or very close to the first diagonal (Bo on x-axis and B_{best} on the y-axis) are at least questionable (Figure 3.7). This questionable result can occur e. g. (i) when methods to calculate Bo and B_{best} were different and partly inconsistent, (ii) when historical recruitment data available were not adapted to describing the effective recruitment in pristine conditions or (iii) when B_{best}, due to the long life cycle of eels, still includes recruitment data from up to 20 years ago, when recruitment was higher than at present..

Geographical analysis of the ratio B_{best}/Bo revealed a high variation between sea regions (Figure 3.8) which cannot be easily explained by the spatial pattern of recruitment described in Chapter 2.1.3.

Again, deeper analysis of the methodology used is needed. Therefore, the way how Bo and B_{best} (and more generally the three B's) are linked in the computation process should be well documented before the 2012 post-evaluation process.

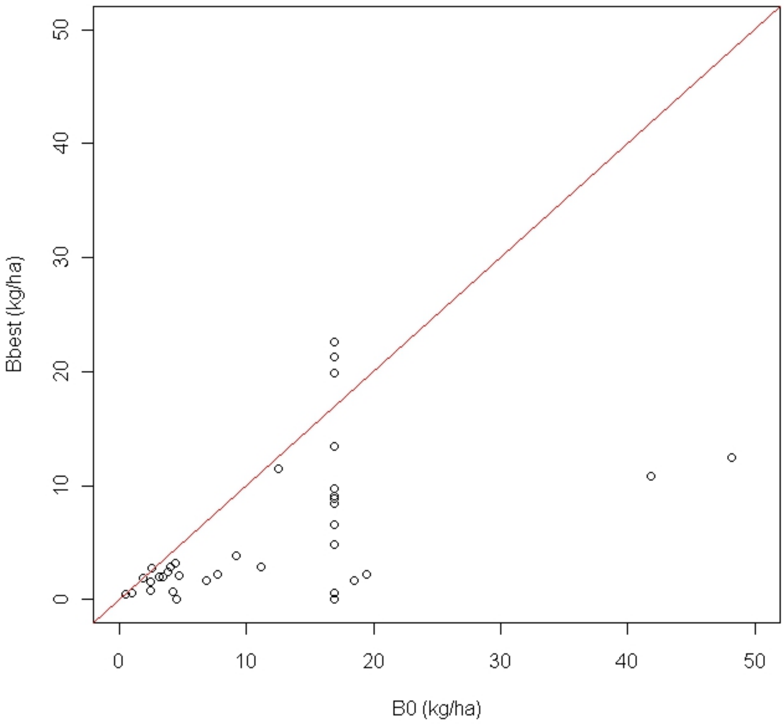


Figure 3.7. Relationship between pristine biomass and pre-management biomass (red line corresponds to 1:1 ratio, scale limited to Bo inferior to 50 kg/ha).

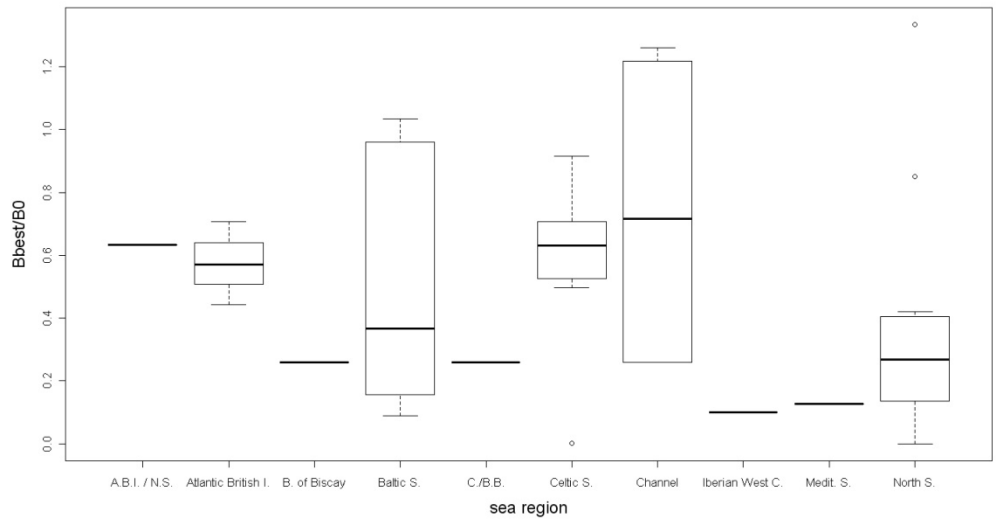


Figure 3.8. Distribution of EMU ratio of pre management biomass to pristine biomass according to sea region of EMU output (A.B.I./N.S.: EMU with outputs in Atlantic British Island and North Sea regions, C./B.B. : EMU with outputs in Channel and bay of Biscay regions).

3.8 Recommendations on international stock assessment

Based on the above discussions, and the preliminary results presented, it is recommended:

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

4 Quantitative assessment of the status of local eel populations

Chapter 4 addresses the following Terms of Reference:

a/ assess the trends in recruitment and stock, for international stock assessment, in light of the implementation of the Eel Management Plans;

c/ 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 (in conjunction with SGAESAW 2);

d/ provide practical advice on 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.

and has links to:

b/ develop methods to post-evaluate effects of management actions at the stock-wide level (in conjunction with SGIPEE);

f/ respond to specific requests in support of the eel stock recovery Regulation, as necessary.

4.1 Introduction to assessments of local eel populations

The objective of the assessment is to quantify the biomass of silver eel escaping from the Eel Management Unit (EMU) in order to assess compliance with the EU target of 40% of pristine biomass without anthropogenic mortality. Silver eel production/escapement can be estimated directly from catching or counting eels or indirectly from yellow eel population and mortality data. The WGEEL undertook a review of assessment methods in 2008 (ICES, 2008). These have subsequently been reviewed by the ICES Working Group Study Group on International *Ex post-evaluation* on Eels (SGIPEE) (ICES, 2010) and by the DGMARE funded project POSE (Pilot project to estimate potential and actual escapement of silver eels).

How these initiatives interrelate is shown diagrammatically in Figure 4.1. At the centre of the hub is WGEEL providing direct advice on methodologies for local assessment of stocks with direct links to POSE where the aim is to test, evaluate and improve the methods for monitoring escapement. The output from this chapter has direct relevance to EMPs and will feed into the work being undertaken by POSE and SGIPEE which are looking at post-evaluation and assessment of compliance and outcomes from the management plans, needed for the EMP reporting in 2012.

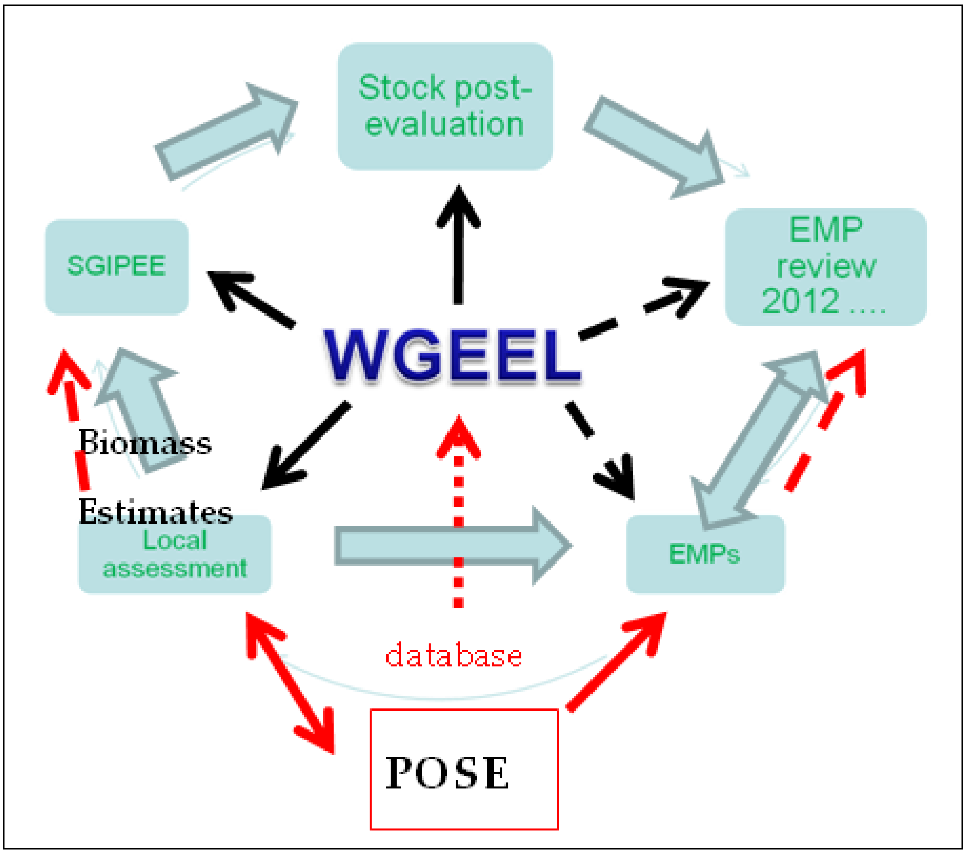


Figure 4.1. The interrelationship between WGEEL, the Study Group working on *Ex-post* evaluation (SGIPEE) and the pilot project on silver eel escapements (POSE). The solid lines indicate direct involvement and dotted lines show where the involvement is through influence. The biomass estimates refer to B_{post}, B_{best}, Bo and/or B_{lim}.

The reviews undertaken by ICES (2008, 2010) and in EU POSE indicate that the local assessment will either be through a direct estimate of escapement at the silver eel stage or a modelled output from the yellow eel stage.

Total escapement estimates, where the whole run of silver eel is intercepted will be rare and generally estimates have to be derived from a mark–recapture study or direct counts. For yellow eel estimates of the total biomass in an EMU would in most cases be derived from a combination of sampling using electrofishing and fykenets. How these data can be used to estimate biomass was outlined in ICES (2010). The methods EDA (Eel Density Analysis, Hoffmann, 2008; French EMP) and SMEPII (Walker, A., unpublished) are focused mainly on rivers and estimates from lakes and coastal areas and their integration into the overall assessment have yet to be included. Details of the sampling strategies, in the various countries are needed; (a) to identify whether the data collected will meet the requirements of the *ex post*-evaluation, (b) to advise Member States (MS) on the approaches being adopted elsewhere and (c) for POSE, in relation to the data available to run the model(s).

The use of yellow eel data to estimate silver eel output depends on being able to determine the probability of an eel metamorphosing from the yellow eel to the silver eel stage. A number of morphological characteristics have been identified that indicate pre-migrant status of eel, i.e. that they should be expected to emigrate as silver eels in the next migrant season (Feunteun *et al.*, 2000; Durif *et al.*, 2005). It is possible therefore to estimate silver eel production from a watercourse based on the numbers of such pre-migrant eels (Feunteun *et al.*, 2000; Acou *et al.*, 2009). The feasibility of this approach is examined in Section4.4.3.

Most of the work of WGEEL and other EGs has focused on the methodologies used for estimating the biomass of silver eel escaping. There has been little attention paid as to how the wetted area is determined. This has major implications in relation to transferring/comparing outputs from one system to another.

The aims of this chapter are to provide:

- examples (case studies) where mark–recapture has been used to estimate (a) silver eel escapement and (b) the standing stock of yellow eel in lakes, estuaries or coastal waters and to identify strength and weaknesses in the approach;
- an overview of sampling strategies specifically to identify (a) whether WFD and DCF sampling will provide an input to the estimation of silver eel production and escapement, (b) eel specific monitoring programmes and (c) gaps between what is being collected and that needed for the *ex post*-evaluation;
- an update on (a) the use of morphological characteristics of yellow eel to estimate escapement of silver eel and (b) the spatial and temporal variability of the size of migrating silver eel;
- a synopsis of the approach(s) used to estimate wetted area and to examine the implications of inconsistencies.

4.2 Assessment of silver eel biomass using mark–recapture

This report section arises from compilation of new information on current mark-recapture work for eel stock assessment, discussed by WGEEL 2010. Most of the new work is, unsurprisingly, associated with estimating silver eel stock and/or escapement for the purposes of compliance with the EU eel regulation and management plans (Table 4.1). A selection of these examples were presented in subgroup and discussed in detail (Annex 6). The experiences of their practitioners were shared to examine the usefulness of tagging programmes and to highlight strengths and weaknesses. It is intended that this discussion will inform others intending to take up this approach in the near future. The following discussion brings together common issues, strengths and weaknesses and suggests solutions where SG members have addressed problems.

It should be noted that in the following sections, different approaches to mark–recapture are discussed. Classic single point short time interval estimates fail to yield information on mortality or on populations with additional inputs of fish, so new approaches using adapted survival models are being developed.

Table 4.1. Summary of current uses no M–R in eel assessments.

Country and location	Purpose	Tag types use	Approx. no. of animals marked per year
UK Northern Ireland - Bann	Silver eel escapement estimate	Floy	500–1000
UK Scotland Girnock	Silver eel escapement estimate	PIT	50
UK Scotland Girnock	Yellow eel mutuality, growth, silvering, movements	Elastomer , PITS	400
Ireland-Corrib	Silver eel escapement estimate	PIT	400
UK/Ireland Transboundary-Erne	Silver eel escapement estimate	PIT Floy	2000 300
Ireland-Shannon	Silver eel escapement estimate	PIT	1000
Sweden Coastal waters	Silver eel escapement estimate	Carlin Floy	500
Germany-Elbe	Silver eel escapement estimate	Elastomer	500
Denmark-Baltic	Silver eel fishery mortality	Carlin	2200 (single year)
Denmark-Gudenaa	Hydropower mortality	PITS Acoustic	800 50
France-Vilaine	Silver eel escapement estimate	PIT	60
France-Fremur	Silver eel escapement estimate		
France-Bages-Sigeon Med. lagoon	Silver eel escapement estimate	Paint batch barking	300 000
Holland-Rhine	Silver eel escapement estimate (Planned)	Not decided, probably visual detection	Not yet known
Germany-Rhine (2008)	Silver eel escapement	PIT	450
Belgium-Meuse	Silver eel mortality estimate	PIT	

4.2.1 Different approaches in the use of M–R for silver eel

The decision tree shown in Figure 4.1 Indicates, in simple terms, an essential difference noted in discussions of examples of M–R studies presented to the WG. Uses of M–R for silver eel assessments are essentially of two types: i.e. single point assessments where data are gathered and treated mathematically as closely as possible to a single point in space and time for mark and recapture, and those with multiple mark and recapture sites where this approach is not possible. Single point studies can be analysed using classical "simple" methods for M–R analysis, with a focus on the eel not recaptured as local escapement past the particular site. Multi point (in space and time) M–R recapture data requires a different approach, where the recaptures are the focus – and are perhaps best treated as a proxy for survival between points. The difference between these two approaches is discussed in more detail below. The individual case studies (Annex 9) indicate where data analysis is discussed and which approach is adopted.

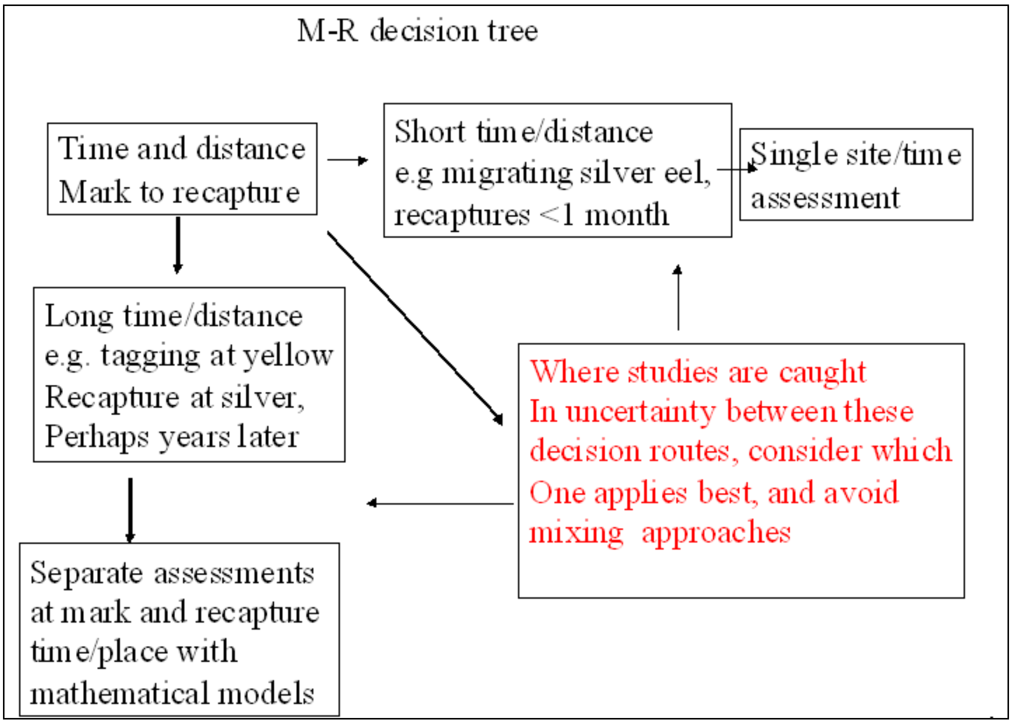


Figure 4.2. Deciding on how to gather and use M–R data for silver eel.

4.2.2 Key points arising from the case studies presented

The Importance of experimental design

Some common ideas emerge when examining these case studies presented and in discussions at WGEEL 2010. The most important consideration is achieving the right combination of experimental design and data analysis and the need to adopt the most appropriate methods to the local situation.

Use of existing fishery sites

As a common starting point, where there are existing fishery sites for intercepting silver eel, these are often already at the best locations and have arrived at effective means for catching silver eel. Using the fishery experience is almost always helpful. Where fisheries are closed for conservation reasons, a number of countries are permitting and funding the continued use of former commercial silver eel fishing sites for the purpose of mark–recapture estimation of the silver eel emigration.

Site-specific choice of tagging method

The choice of tagging method is also a site-specific consideration. Where eels are still commercially handled in such a way that individuals are inspected, external (Floy tags and visible implanted elastomer tags are the most commonly used) tags are inexpensive and can be used in large batches. Where there is doubt over whether or not externally tagged eels will be seen and recovered, such as in conservation “trap and transport” fishing, automatically detected tags are more appropriate. Passive Internal Transponder (PIT) type tags are now by far the most commonly used, as they allow identification of individual fish in relatively large numbers for an automated system. The expertise of staff or third parties available to recover or record tags is also a relevant factor in tag choice. Visual external marking is by far the most simple and low-tech system, whereas on-site trained scientific staff may be required for higher levels of technology.

To hold or not to hold eels

The question of how and how long to hold eels, before tagging and afterwards to allow eels to recover before release to allow resumption of "normal" behaviour is a difficult one. The one point all participants at WGEEL agree upon is that eels should not be released while still under the influence of anaesthetic. Different approaches are adopted for silver eel release in short term, ranging from the release of fully recovered eel directly into flowing water situations where they can mix quickly with natural runs, to release of eel into slack flow areas adjacent to run of river flows, the view being to allow the eel to "decide" by itself when to rejoin the migration route. As a general rule, for local short-term M–R approaches, to determine catch rates of individual gears, marked eels should be released as close as possible to the gear, but must be thoroughly mixed with unmarked eel. This will reduce mortality between point of release and point of recapture to as close to zero as possible.

A lack of experimentation

Despite the differences in M–R release strategies for short-term assessment, and uncertainty over which is the best option, few respondents are conducting experimentation to optimize their experimental design. The recent pressures for data and time-series data imposed by the EU eel regulation are often given as a reason. Once a tagging and recapture protocol is set up, the tendency in recent years has been to stick with one experimental design. This is despite the fact that some variables which could clearly have an impact on recapture rate are inadequately investigated. Examples include whether to release to flowing or static water, how far upstream to relocate before release back to a single point assessment site, which anaesthetic, how long to hold eels for recovery. While almost all sites for short-term silver eel M–R escapement estimation have some individual characteristics restricting options, there is nevertheless a strong case for carrying out coordinated experimentation to improve protocols and produce guidance on protocols.

Supporting studies with behavioural telemetry

The use of telemetric tagging to determine behaviour patterns of small batches of individual eel can be very informative, but is difficult and expensive to do on a scale that leads to any quantitative assessment of population. However, use of such technology, (radio and/or acoustic tracking systems) for migrating silver is seen by the WG as a very helpful support to larger quantity M–R work with Floy or PIT Tags to lend reassurance to assumptions over routes taken, for instance around or through a power station or fishery site or to check average velocity to assist with determining the optimal distance between point of release and recapture. Similarly, some users are trialling high frequency acoustic cameras (e.g. DIDSON units) to check on numbers of eel passing fixed points. The latter method can be particularly effective in examining artificial channels with engineered simple profile sides or walls.

Strengths and weaknesses of mark–recapture silver eel escapement estimates

Mark–recapture provides a technique for estimating the size of a population in a large waterbody. It provides a population estimate where you it is not possible to have a direct count.

The most common problems raised include:

- Uncertainties over tagged eel (and wild eel) mortality between mark and recapture;
- That the population is not closed, where there is additional "recruitment" of silver eel between sampling times and tagging;
- Bias toward overestimation or underestimation of escapement;
- Variable reversion of tagged silver eel to yellow eels subsequent to silver emigrations;
- Tag loss.

Mortality

Silver eels, when in active migration, can prove very difficult to hold in tanks or cages, even when not handled or tagged. This makes experimental comparison of mortality between tagged and untagged eel even more difficult. Indications from at least one study (Bann, Northern Ireland) indicate no differential mortality between retained tagged and untagged silvers from a tagging batch, but with the inherent problem that both tagged and untagged eels suffered high mortality after two weeks of holding and prevention from migration. What happens when eels are allowed to continue migration is unknown, and often an assumption is simply made that escaping eels are potential spawners when nothing is really known.

Bias

M–R programmes are especially prone to bias when the percentage of recaptures is low, even if absolute numbers are high. Where absolute numbers are low, but the percentage recapture is high, the opposite problem, error, pertains. Scientists must be aware that tendencies to bias can generate pressure either to inflate or reduce tag returns depending on individual cases. In the case studies presented to WGEEL 2010, reliance on return of tags by third parties is common, and scientists rarely have the resources to be present at all recaptures. Where the number of recaptures indicates fishery effectiveness, there can be pressures among fishers not to return tags in the hope of inflating escapement estimates. Conversely, where tag returns are a positive contributor to escapement estimates, such as when a fishery is being operated for trap and transport of silver eel around a hydropower station, or where tag recapture data are used as a proxy for survival in an escapement model, the reverse pressure might apply. As visually detected tags such as floy or carlin tags can be more prone to such bias, the solution to this type of problem can include the use of non visible tags (such as PIT or CWT). If there are cost issues, non visual tags may form a subset of tags for a verification experiment. In general, financial rewards for tag return made public in newspaper, radio, etc. also help maximize tag returns.

To reduce bias from the effect of changes in gear efficiency, it is important to have a measure of efficiency under different environmental conditions; water discharge, turbidity etc (see **Determination/checks on the M–R conditions).**

Reversion

Eel tagged as migrating silvers can, under certain circumstances, "revert" to yellow eel and/or delay migration to subsequent years. Rates of reversion/delayed migration range from a few percent in the case of the best situations to tens of % where silver status may not be as well defined. Tag–recapture programmes need to have sufficient long-term continuity to check for this phenomenon. Part 4.4 of this chapter discusses means of determining whether or not eel are truly silver eel, and those conducting tagging experiments should have regard to rejecting eels of dubious silver status. For Baltic silver eel producing areas, reversion to yellow may be linked to the point in their migration season at which they are sampled. Early season migrants travel furthest in space and time and by late season may stop and revert if migration to open sea is incomplete by onset of winter and ice cover.

Tag loss

External tags can be lost, and the proportion lost is very difficult to quantify. Most tags are probably lost early through softening of the tissues around the tag, and generally, the longer a tag remains on an eel, the more secure it is. Tag retention data "in the wild" or as near as possible to the wild, experiments are needed for eel for all external tag types.

4.2.3 Short-term vs. long-term mark–recapture; approach to mathematical analysis

The WG discussed strengths and weaknesses of tagging programmes presented. The best sites for silver eel mark recapture escapement assessment are typically where there are existing, or former, fisheries which can be used. It is relatively easy to see that a short-term single point and short time interval approach applies. Conversely, for datasets with multiple sites, long migration routes, long and variable time intervals, it is clear that alternative models with multiple single point assessments bulked to an overall model based on survivorship are more appropriate. A clear decision has to be made early which (or which combination) of these two approaches applies.

Mark–Recapture studies for silver eel escapement reported as in progress to WGEEL 2010 fall into two broad categories; depending on the time interval and distance between mark and recapture. For the silver eel stock assessment studies, the interval and distance were either "short", from studies aimed at an assessment as near as possible to a single time and place, or "Long", for open system studies with long time intervals and significant distance between mark and recapture. These different types of study require different approaches to data analysis.

"Short" time–distance mark–recapture studies

For examples see Annex 6: UK N Ireland (Bann), Ireland (Shannon), Ireland (Corrib), Scotland (Girnock), Denmark (Baltic and Gudenå) and Germany (Elbe).

The "short" time and distance mark recapture studies are typically aimed at quantifying escapement past a single point in a short interval silver eel migration. The escapement estimate centres on classical assumptions about eel not seen again:

- The population is "closed", i.e. without immigration, emigration or mortality;
- All animals have the same chance of capture in first and second capture;

- Marking does not affect catchability;
- Marks are not lost in the interval between mark and recapture;
- All marked fish recaptured are reported.

In order for these assumptions to be true for migrating silver eel studies, several additional conditions must apply to the time/distance intervals:

- Time interval from mark to recapture should be as low as possible;
- Time and Distance to translocation (usually back upstream from release point) should be long enough to allow for recovery from anaesthetic and handling;
- Time and Distance of translocation should not be so long/far that the chance of recapture falls significantly below chance of first capture.

Determination/checks on the M–R conditions

The further M–R study deviates from ideal conditions, the more uncertainty is introduced that the classical M–R experiment assumptions are met. This issue is of utmost importance for silver eel escapement estimates where the estimation of escapement depends on the assumption that the eels not seen again are all potential escaping silvers and have passed by the sampling gear. For every situation, at some point of deviation from one or a combination of conditions, the escapement assumption will weaken to the point of unacceptability.

The practical upper time limit for a single site escapement estimate based on tagged migrating eels taken back upstream, not recovered and assumed as escapement, is probably one silver eel migration season. In Northern Western Europe where most studies occur, migration might last for perhaps four months with eels migrating, often linked to river flow and/or moon phase cycles, from late summer into autumn. It is important to ensure that assessments cover the main migration period(s). For example when multiple peaks in migration occur (e.g. on the dark phases of the lunar cycle, high flows or as in the Elbe where there is a seaward migration in autumn and again in late winter/early spring run) one should aim at multiple in–season M–R tag batches corresponding to each of these phases/seasons. A total or average annual assessment of escapement can then take account of variable numbers moving over multiple events. This is not always possible and given the commonly unpredictable rainfall patterns in autumn on in North Western Europe where most of this work occurs, it will be common for M–R escapement assessments to miss some migration events due to severe weather events, particularly flooding. Other limitation can be imposed by local fishery conditions, for instance the availability of commercial fishery data only on a whole season basis without reduced intervals between catch record units. Whatever data are recorded, the intervals over which M–R data are recorded should match the minimum interval over which fishery data are available, to maximize the number of individual calculation periods of escapement, leading to the best possible statistical treatment of results and accounting for variability.

4.2.4 “Long” time-space interval mark–recapture studies; an alternative approach to classical single-site M–R approaches using survivorship data

For an example see Annex 6: Sweden (Baltic).

While the majority of M–R use for silver eel escapement estimation has a focus on what is not recaptured as the basis of an escapement estimate, alternative approaches are possible. Methods are under development using a long time-series of Swedish coastal silver eel fishery mark–recapture data. Here, the time interval and distances between release and recapture site of marked silver eel can be long, (up to several years and hundreds of kilometres) and the uncertainties over the fate of eel between tag and recapture are high. In contrast to studies from further West on the Atlantic seaboard, Baltic and Elbe silver eel migration can begin in one calendar year, be interrupted over winter by cold weather and even ice cover, and resume in warmer weather the following spring. This spread of migration over more than one season makes it difficult to reduce a M–R estimate period to a single seasonal time period. The focus in the method under development is on using the recapture data as a measure of survival, enabling the building of models for this long, essentially linear coastal migration route. The completed models will need to be capable of incorporating other data including additional "recruitment" of silver eel over time and space, and many possible tag recapture locations with varying point to point survival rates and even the possibility of eels by-passing some potential recapture sites. One feature of these data which lends confidence to the approach is the tendency toward recapture for eels which migrate furthest and for the longest time, encountering more potential recapture opportunities with increasing M–R in time and space. Other datasets are being sought, perhaps from long migrations down river, to apply and refine the approach. It is likely, from the geographical scale of the studies, that some of the M–R datasets and situations which require a multi point survivorship model approach as outlined here will be in long waterbodies often of a " transboundary" nature (e.g. River Rhine) or coastal marine migration routes (e.g. the Baltic).

4.3 Overview of EU Directives; WFD and DCF

There are two European-scale sampling programmes that are adopted by European countries and that ought to be potential significant sources of eel data: Water Framework Directive (WFD); Data Collection Framework (DCF). In addition, there are the national programmes in implementing the Eel Management Plans for the 'Eel Regulation'.

4.3.1 Water Framework Directive (WFD) and eels

The EU Water Framework Directive (Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy) was adopted in October 2000. The environmental objective of the WFD is to prevent deterioration and protect, enhance and restore all surface waterbodies. The directive commits European Union member states to achieve good qualitative and quantitative status of all waterbodies (including marine waters as defined in the Directive) by 2015.

Surface water is divided in four categories; Lakes, Rivers, Transitional and Coastal waters. Each category consists of several water types which are defined by size, altitude, geology, etc. (examples are shallow peat lakes or small rivers on sand). Each surface waterbody in a country is assigned to a specific type. In the Netherlands for example around 1000 waterbodies and 22 water types are distinguished.

The Directive defines 'surface water status' as the general expression of the status of a body of surface water, determined by the poorer of its ecological status (physical chemistry, hydro morphology, chemical parameters and biological quality elements) and its chemical status (priority substances). Thus, to achieve 'good surface water status' both the ecological status and the chemical status of a surface waterbody need to be at least 'good'. Good surface water status is defined locally as being lower than a theoretical reference point of pristine conditions, i.e. in the absence of anthropogenic influence.

To achieve good ecological status, values of the biological quality elements (fish, benthic invertebrate fauna, phytoplankton, vegetation) for the surface waterbody type must demonstrate low levels of distortion resulting from human activity, and must deviate only slightly from undisturbed conditions.

In most countries fish (one of the four biological elements) are regularly monitored in different surface water categories as part of the Water Framework Directive. Eel has not been assigned as an indicator species for any of the water types and receives, in general, low priority during WFD sampling events. The potential for eel as an indicator species of connectivity of a waterbody is limited, due to widespread translocation and stocking of eel in (isolated) rivers and lakes.

Eels are only used in basic calculations like general species richness or species richness of diadromous species, which usually form a minor part of the ecological classification of the fish community in a waterbody. Furthermore, in contrast to other fish species, absolute and relative densities of eel are not used to determine the ecological status of any of the water types. The common sampling gears (single pass electrofishing, seinenets, trawl, fykenets) used for fish monitoring are probably not suitable (low catchability) for reliable density estimates of eel.

4.3.2 Data Collection Framework (DCF) and eels

Commission Regulation 1581/2004 of 27 August 2004 first established the listing on European eel in the species list for recorded landings. Council Regulation 199/2008 of 25 February 2008 required Member States to implement multi-annual programmes for collection, management and use of biological, technical, environmental and socio-economic data concerning commercial and recreational fisheries for eels in community and inland waters. Member States are required to reporting on their collection programme annually, though are not required to provide the data to the Commission except in response to a specific request. The data remain the property of the Member State. Note that in WGEEL 2010 we consider only the requirements for collection of stock or fisheries specific data.

The Regulation required the collection of data on the length structure of the eel catch, and for individual eels, their length, age, weight, sex, maturity and fecundity. For yellow and silver eels separately, ages should be collected annually for a minimum of five individuals per cm length interval, and a minimum of 100 individuals sampled per management unit. Weight, sex and maturity should be collected every three years.

The aim of the new data collection framework was, as a starting point, to ensure continuity with the current obligations for eel fisheries monitoring then to collect the basic information required to assess the stock. However, the Eel Management Plans had yet to be submitted or formally adopted when these DCF sampling requirements were enacted, nor when Member States proposed their sampling programmes for 2009/2010 and, as such, their requirements for eel assessment data were not necessarily included in the provisions of the DCF. Where it was not possible to define quantitative targets for the eel sampling programmes, with respect to sample size and levels of precision, pilot surveys were allowed with the aim of establishing relevant protocols.

4.3.3 Data requirements for quantitative eel stock assessment

4.3.3.1 International stock assessment

The WGEEL Study Group on International Post-Evaluation of Eel (SGIPEE) have developed a method for stock-wide assessment of European eel (ICES, 2010), based on the following biomass estimates.

a) B_{post}, the biomass of the escapement in the assessment year;

b) Bo, the biomass of the escapement in the pristine state. Alternatively, one could specify B_{lim}, the 40% limit of Bo, as set in the Eel Regulation;

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

The ratio of items a) and b) determine the horizontal position for the lower-level assessment on the Modified Precautionary Diagram (Chapter 3.6). The ratio of items a) and c) determine the vertical position. Item c) is the weighting factor for the lower-level assessment in deriving integrated stock indicators.

Where estimates of B_{post} or B_{best} are available along with an estimate of anthropogenic mortality (A), the other B can be derived. It is anticipated that these three 'Bs' will be provided by the countries, and derived from local or national stock assessments (see Annex 5).

4.3.3.2 National stock assessment

Here we consider the likely data requirements for local/national stock assessment in terms of estimating biomass and mortalities, highlighting the specific data requirements in bold font. The text draws on the work of SGIPEE and the EU-POSE project for DG MARE, along with comment from delegates of WGEEL 2010.

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

We envisage that for many local eel stocks, a **recruitment index** and information on the **length composition** of the population will be available from point surveys and/or from fishery data. In such cases, a general modelling approach to estimate mortality would model the length–frequency distribution across the samples, given the past variation in recruitment, mortality and growth, and fit this to the observed length-frequencies of the local stock. The selectivity of the survey and catchability of the local stock will have to be taken into account in assuming that the site data are fully representative of the study population (see Bevacqua *et al*., 2007), as well as potential spatial structure in variations of the length distribution.

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

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

It is important to ensure that models used for post-evaluation are independent of the effect they are trying to evaluate. This may pose difficulties when using some of the models described below as many use default values for eel life-history processes or mortality inputs. This is especially problematical when incorporating the effects of density into eel life-history processes.

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

Total stock biomass can be estimated from survey data, for example by extrapolating biomass from area-specific survey data to the total wetted area. The EDA (Beaulaton, L. and Lambert, P. unpublished) and Probability Model (Knights, A. and Aprahamian, M. unpublished) family of models offer approaches to estimate eel biomass at various spatial scales. The life-history process models SMEP II (Walker, Apostolaki *et al.*, unpublished) and DemCam (Bevaqua *et al*. (2008) also offer this facility as part of a larger suite of options.

In summary, it appears that sampling programmes that provide length distributions and frequencies, numbers and weights of eels, and local population densities or cpue (as habitat conditions allow) as a minimum will support at least some of the local eel stock assessment methods employed across Europe at this time.

However, it should be noted that for careful post-evaluation of implemented management actions, models used should be independent of the applied actions. Post-evaluation should utilize methods that are more reliant on survey data and not on process based parameters, making them more appropriate to assessing changes in the local stock and being able to attribute changes to the various management actions.

4.3.4 Data collected under WFD and DCF programmes

Summary tables describing the data collected by nations for WFD, DCF and with national/local initiatives were constructed then completed after discussion with National Representatives at WGEEL 2010. Table 4.1 presents the eel data sources from WFD and/or DCR among countries represented at WGEEL 2010. Tables 4.2, 4.3 and 4.4 provide summary descriptions of the eel data collected through the WFD, DCF and other programmes, respectively, by the countries represented at WGEEL 2010.

Table 4.2. Eel data sources from WFD and/or DCF among countries represented at WGEEL 2010.

Country	Glass eel data		Yellow eel data		Silver eel data	
	WFD	DCF	WFD	DCF	WFD	DCF
Norway	N	N	N	N	N	N
Sweden	N	Y	Y	Y	N	Y
Finland	N	N	N	N	N	N
Latvia	N	N	Y	Y	N	Y
Poland	N	N	N	Y	N	Y
Germany	?	N	?	Y	?	Y
Denmark	N	N	N	Y	N	Y
Netherlands	N	Y	Y	Y	Y	Y
Belgium	N	N	Y	N	N	N
UK	Y	Y	Y	Y	Y	Y
Ireland	N	N	Y	N	Y	N
France						
Spain	N	Y Basque	Y	N	N	N
Portugal	N	N	Y	Y	N	N
Italy	N	N	Y	Y	Y	Y

Table 4.3. Summary of eel data collected within WFD.

Country	WFD Categories	# sites	Sampling frequency	gear	single/multiple pass	length	weight	number	total wt	comments
Norway	None									No eel sampling in WFD
Sweden	Inland rivers	75	yearly	electrofishing	3 fishings	all	not mandatory	y		All species - eel not target
Latvia	Inland rivers	80-100	yearly	electrofishing	single pass still waters, 3 passes elsewhere	all catch	all catch	y	y	
Denmark	None									No eel sampling in WFD
Germany										Sampling programmes run by the states, no central knowledge of the sampling regimes or the data available
Poland	None									No eel sampling in WFD
UK-Scotland	Rivers	210	6 yr rolling programme	electrofishing	single pass	all	all	y	y	some samples for Ac., separate sampling for Ac & contaminants
UK-Scotland	Lochs	~40	6 yr rolling programme	gill nets, hydroacoustic surveys		all	all	y	y	
UK-Scotland	Transitional waters									
UK-Scotland	Coastal waters									
UK-Northern Ireland	Rivers	20	yearly	electrofishing	multiple pass	all	n	y	n	
UK-Northern Ireland	loughs	30, 4	3 yr rolling programme	seine, gills, fykes		all	all	y	y	subsample aged, 10 per 1 cm length class
UK-Northern Ireland	Transitional waters	5	yearly	fykes, seines, trawls		all	all	y	y	
UK-Northern Ireland	Coastal waters	?								
UK (England & Wales)	Inland Rivers	1200	yearly	electrofishing	single pass	all catch		y		salmonid + coarse spp monitoring
UK (England & Wales)		110 (5 sites catchment)	yearly	electrofishing	multiple pass	all catch		y		specific eel sampling within WFD paid by DCF
UK (England & Wales)		4050	six yr rolling programme	electrofishing	multiple pass	all catch		y		salmonid + coarse spp monitoring
UK (England & Wales)	Inland Lakes	no								
UK (England & Wales)	Transitional waters	?	yearly	fykes (open water)		all catch		y		
UK (England & Wales)	Coastal Water	no								
Ireland	Rivers	122	3 yr rolling programme	electrofishing	3 fishings	all	all			A number of eel specimens are retained for further analysis in the lab. This is to determine the distribution of A. crassus but will not be continued in the repeat surveys
Ireland	Transitional waters	73	3 yr rolling programme	fyke nets, beach seine, beam trawl		all				A number of eel specimens are retained for further analysis in the lab. This is to determine the distribution of A. crassus but will not be continued in the repeat surveys
Ireland	Lakes	68	3 yr rolling programme	fyke nets, gill nets, surface floating nets, benthic braided single panel, hydroacoustic surveys		all	all			A number of eel specimens are retained for further analysis in the lab. This is to determine the distribution of A. crassus but will not be continued in the repeat surveys
Ireland	Canals	40		electrofishing						
Netherlands	Inland Rivers	16	yearly	trawl						
Netherlands	Inland Rivers	16	yearly	electrofishing	single pass					
Netherlands	Inland Lakes	2 lakes (40 sites)	yearly	trawl		max 200		y		
Netherlands	Inland Lakes	2 lakes (15 sites)	yearly	electrofishing	single pass	max 200		y		
Netherlands	Inland Lakes	2 lakes (10 sites)	yearly	beach seine		max 200		y		
Netherlands	Transitional waters	3	weekly Apr-Aug	fyke		some		y		
Netherlands	Inland Rivers	15	weekly Apr-Aug	fyke		some		y		
Netherlands	Inland Lakes	10	weekly Apr-Aug	fyke		some		y		
Netherlands	Inland Rivers and Lakes	800	every 3 to 6 years	electrofishing, seine, trawl	single pass	total catch		y		in principal all (~1000) waterbodies are sampled once every 3-6 years, multiple sites and gears per waterbody
Belgium	Inland Rivers	177 (500 sites)	every three years/six years f	electrofishing/electrofishing/fykes	single pass/fykes, two per site	max 100 per species/	max 100 per spe	y	y	
	Inland Lakes	15	every six year	electrofishing (shore)/fykes (open water)	single pass/fykes 48 h	max 100 per species/	max 100 per spe	y	y	
	Transitional waters	9	3/ year	fykes (shore)	two fykes/site for two days	max 100 per species	max 100 per spe	y	y	
	Coastal Waters	0								
France										
Italy	Inland rivers and coastal water	no	every three years	electrofishing	single pass	all catch		y	y	
Spain	None									
Portugal	Inland rivers	350	every three year	electrofishing	single pass	50		y		

Table 4.4. Summary of eel data collected within DCF.

							Fish measurements				Biological sampling			
Country	Fisheries or Surveys	Life stage (G, Y, S)	Region	# Sites	Sampling frequency	Stratification by gear type (Y/N)	length	weight	number	total wt	ageing	parasites	sex	Comments
Norway	None													
Finland	None											A.c.		
Sweden	Survey	G	West coast	4	yearly	drop traps	Y					A.c.		
Sweden	Survey	E	West coast	?	yearly	electrofishing	Y					A.c.		
Sweden	Fishery	Y	ICES SD 20	3	monthly May-Sep	Y (fyke nets)	600	400			400	400	400	
Sweden	Fishery	Y	ICES SD 21	1	monthly May-Sep	Y (fyke nets)	300	200			200	200	200	
Sweden	Fishery	Y	ICES SD 23	1	monthly May-Sep	Y (fyke nets)	300	200			200	200	200	
Sweden	Fishery	Y	ICES SD 27	1	yearly	Y (fyke nets)	200	200			200	200	200	
Sweden	Fishery	S	ICES SD 23	1	monthly Oct-Nov	Y (pound nets)	400	200			200	200	200	
Sweden	Fishery	S	ICES SD 24	1	monthly Sep-Oct	Y (pound nets)	400	200			200	200	200	
Sweden	Fishery	S	ICES SD 25	1	monthly Jul-Sep	Y (pound nets)	600	200			200	200	200	
Sweden	Fishery	S	ICES SD 27	1	monthly Aug-Oct	Y (pound nets)	600	200			200	200	200	
Sweden	Fishery	S	Freshwater	6	peak of season	Y (pound nets)	750	750			750	750	750	massive length sampling planned in 2011
Latvia	Fishery	Y/S	Coast	1	all season	Y (trap nets)	100-200	100-200				100-200	100-200	eye diameter, otoliths stored
Denmark	Eel pass monitoring	S	E Jutland	1	several times in autumn	Y (fish trap)	all							
Denmark	Fishery	Y	Ringköbing fjord	1	Nov	Y (fyke nets)	100	100			100	100	100	
Denmark	Fishery	Y	Arresö	1	Nov	Y (fyke nets)	100	100			100	100	100	
Denmark	Fishery	Y	Isefjord	1	Nov	Y (fyke nets)	100	100			100	100	100	
Germany	Fishery	Y	each RBD (7)		annual	N (electrofishing, stow nets, pots, fykes)	100	100	y	y	100	100	100	Ac and fat content
Germany	Fishery	S	each RBD (7)		annual	N (electrofishing, stow nets, pots, fykes)	100	100	y	y	100	100	100	Ac and fat content
Poland	Fishery	Y/S	Szczecin lagoon	1	spring and autumn	Y (fyke nets)	200	200			200	200	200	silver index
Poland	Fishery	Y/S	Vistula lagoon	1	spring and autumn	Y (fyke nets)	200	200			200	200	200	silver index
UK-Scotland	None													
UK-Northern Ireland	Survey	G	national	3	bi-monthly Feb-May	N(pass traps)	50	n	n	y	n	n	n	
UK-Northern Ireland	Fishery	Y	Lough Neagh	1	weekly Mar-Sep	N (fykes, long lines)	20	20	y	y	20	20	20	
UK-Northern Ireland	Fishery	Y	Lough Neagh	1	monthly Mar-Sep	N (fykes, long lines)	400-600	n	n	y	n	n	n	
UK-Northern Ireland	Fishery	S	Neagh/Bann	2	weekly Oct-Dec	N (traps)	400+	n	n	n	10	n	n	
Ireland	None													
UK-England & Wales	Survey	G	national	3	annual	N (pass traps)	n	n	n	y	n	n	n	see WFD
UK-England & Wales	Survey	Y	national (22 rivers)	220	2 yr rolling programme	N (electrofishing, fykes)	y	n	y	n	n	n	n	eel-specific surveys
UK-England & Wales	Survey	Y	national	4050	6 yr rolling programme	N (electrofishing, fykes)	y	n	y	n	n	n	n	multi-species surveys
UK-England & Wales	Survey	S	national	5	annual	N (traps, fykes, acoustic surveys)	y	n	y	n	n	n	n	see WFD
Netherlands	Fishery	Y	IJsselmeer	2	May/Jun and Aug/Sep	Y (3 gear types)	50	20			20	20	20	
Netherlands	Fishery	S	IJsselmeer	2	May/Jun and Aug/Sep	Y (3 gear types)	50	20			20	20	20	
Netherlands	Fishery	Y/S	Friesland	10	monthly Apr-Sep	N	150-200	20 Y, 20 S			20 Y, 20 S	20 Y, 20 S	20 Y, 20 S	
Netherlands	Fishery	Y/S	Main Rivers	8	monthly Apr-Sep	N	150-200	20 Y, 20 S			20 Y, 20 S	20 Y, 20 S	20 Y, 20 S	
Netherlands	Survey	G	national	1	daily for three months	lift net			y					
Netherlands	Survey	G	national	10	weekly for three months	lift net			y					
Netherlands	Survey	S	national	5	weekly Aug-Oct	fyke	all catch							
Belgium	None													
Italy	Fisheries	Y/S	EMU Latium (pilot)	r, 1 lake, 1	yearly	fyke nets	120/site (to	120	360		360	360	360	DCF, 2009 pilot for methodology
Spain	Fishery	G	Basque Country			Y				y				recreational fisheries
Portugal	Fishery	Y/S	RBD 4 (Aveiro and Ö	2	monthly	Y (fyke nets)	50-200	50-100	y		?	?	?	
France														

Table 4.5. National initiatives for collecting eel data.

							Fish measurements				Biological sampling			
Country	Fisheries or Surveys	Life stage (G, Y, S)	Region	# Sites	Sampling frequency	Stratification by gear type (Y/N)	length	weight	number	total wt	ageing	parasites	sex	Comments
Norway	Survey	E	River Imsa	1	yearly	trap			y					
Norway	Survey	Y/S	Skagerrak coast	20	yearly	beach seine	y		y					
Norway	Survey	S	River Imsa	1	yearly	trap			y					
Sweden	Surveys	Y/S	West coast	5	yearly Aug/Oct	Y (fyke nets)	y		y	y				
Sweden	Journals	Y	Baltic coast	2	yearly	Y (fyke nets)	n	n	y	y				Detailed statistics on catch and effort in commercial fisheries
Sweden	Journals	S	Baltic coast	3	yearly	Y (fyke nets)	n	n	y	y				Detailed statistics on catch and effort in commercial fisheries
Latvia	Journals	Y/S	Coast	10	all season	Y (all gears)				y				eye diameter, otoliths stored
Denmark	Surveys	G	N Jutland	3	yearly	electrofishing			y					Pilot study 2010
Germany	Monitoring	E	Brandenburg, RBD Elbe	1	May-Nov, daily	Fyke in fish pass	y	y	y			subsample	subsample	
Germany	Monitoring	E	Mecklenburg-Pomerania, RBD's Elbe, Warnow/Peene, Oder	1/3/1 (RBD´s)	Spring-autumn	Eel ladder	y	y	y					
Germany	Monitoring	G/E	Schleswig-Holstein, RBD Eider	3	??	??	??	??	??		??	??	??	
Germany	Monitoring	G/E	Schleswig-Holstein, RBD Elbe	3	??	??	??	??	??		??	??	??	
Germany	Monitoring	E	Saxony, RBD Elbe	1	??	??	??	??	??		??	??	??	
Germany	Escapement-Monitoring	E	Brandenburg, Sachsen-Anhalt RBD Elbe	3	continuous	Colour marking and hydroacoustics, recaptures with fyke, stow net, commercial fishery	y	y	y		y	y	y	
Germany	Escapement-Monitoring	S	Mecklenburg-Pomerania, RBD Warnow/Peene	1 or more	Continuous (except winter/ice)	Colour marking, from next year on hydroacoustics, combined with stow net	y	y	y		y	y	y	
Germany	Escapement-studies	S	North Rhine-Westfalia, RBD Rhine	stopped	continuous	NEDAP-Trail system, telemetry	??	??	??		??	??	??	
Germany	Stock Monitoring	Y/S	Schleswig-Holstein, RBD Schlei/Trave	1 or more?	continuous	Study to assess mortality factors in an restricted river system (coordinated by Reinhold Hanel)	y	y	y		y	y	y	
Germany	Stock Monitoring	Y/S	Saxony, RBD Elbe	1	??	??	y	y	y					
Germany	Stock Monitoring, some special questions	Y/S	Brandenburg	7 lakes	6 years	Fyke net, electrofishing	y	y	y		y	y	y	
Germany	Monitoring of eel stocks in costal waters	Y/S	Mecklenburg-Pomerania	??	??	Special system adapted to coastal conditions (See SGAESAW-Report), test phase	y	y	y		??	??	??	
Poland	Surveys	Y/S	Coast	3	yearly Apr-Oct	fyke nets	y	y	y	y	y	y	y	silver index, contaminants, start 2011
Poland	Surveys	Y/S	Lakes/rivers	15-Oct	yearly	electrofishing	y	y	y	y	y	y	y	silver index, contaminants, start 2011
UK-Scotland	Survey	S	Rivers	3	yearly	traps	y	y	y					life stage control
UK-Scotland	Survey	Y	Rivers	3	yearly	electrofishing	y	y	y					mark/recapture
UK-Scotland	Survey	E	Rivers	1	yearly	trap	y	y	y					mark/recapture
UK-Northern Ireland	None													
Ireland	Survey	Y/S	Lakes	18	1/3 yearly	fyke nets	y	y	y	y	y	y	y	silver index, contaminants
Ireland	Survey	Y/S	Transitional waters	2	1/2 yearly	fyke nets	y	y	y	y	y	y	y	silver index, contaminants
Ireland	Survey	S	Catchments	7	yearly	traps/fixed nets, cameras, acustics	y	y	y	y	y	y	y	silver index, contaminants, total S output
Ireland	Survey	G/S	Rivers	8	yearly	traps	y		y					
Ireland	Survey	S	Rivers	2 rivers x 3 sites	3 years	acustic tags								turbine mortality
UK-England & Wales	None													
Netherlands	None													
Belgium	Survey	G	Rivers	2	yearly	traps	y		y					
Belgium	Survey	Y	Rivers	1	yearly, continuously	trap	y		y					
Belgium	Survey	Y/S	Power station	1	yearly, continuously	trap	y		y					
Italy														
Spain														
Portugal														
France														

4.3.5 Assessment of WFD and DCF sampling strategies to estimate silver eel escapement and anthropogenic mortality

Quantitative sampling of local eel 'populations' is difficult, and therefore sampling regimes not targeted specifically at collecting eel data may significantly underestimate eel densities (Knights *et al*., 2001). Even the simplest form of data record – presence/absence – may be misleading because 'absence' might be correct, but might be because the sampling method was not effective at catching eel, or eel were caught but not recorded. The WFD fish sampling regime is not targeted at eel and though eel may be recorded as present, potential sampling biases (e.g. in densities, length distributions, cpue) should be carefully addressed when using WFD data within eel assessments.

The DCF is based on standard assessment of marine fishery data and, as such, focuses on estimating mortality (particularly fishing). Eel was added as a DCF species only in 2009. Although a subgroup reporting to STECF considered the data quality standards for DCF-eel (Dekker *et al*., 2005), this was prior to the final details of the EU Regulation (2007), of Member States developing their individual eel stock assessment methods, and SGIPEE developments in international stock assessment and the STECF group were unaware of the variety of assessment data that Member States and International Assessment would require.

The present data collection requirement for DCF provides the data appropriate to conduct 'classical' mortality-based stock assessments in 'stocks' where fishing mortality on yellow eels is a/the major factor limiting production. However, an assumption inherent in these classical methods is that the fish leave the stock only when they are caught or die of natural causes and they don't take into account emigration through the silvering process in eel or mortality in silver eel during migration. Thus, the present data programme does not necessarily provide appropriate data for those stock assessments that are based on yellow eel density and biomass estimations, especially where fishing mortality is a relatively minor mortality factor. Thus, the DCF sampling requirements for eels should be extended to include scientific surveys (like WFD in some countries) to properly address the needs of all eel stock assessments.

Despite some of the limitations of the current eel sampling within the WFD as mentioned above, it might be worthwhile on the national level to enhance communication and cooperation with the authorities responsible for the WFD programme. It is recommended to investigate to what extent (a) current WFD sampling can assist stock assessment by providing information on estimating eel standing stock and mortality, and (b) secondly if minor adaptations to national sampling protocols might enhance the quality and quantity of eel data.

Even if within a national WFD programme the eel density estimates are unreliable, the large spatial scale of sampling of most WFD programmes should allow for reasonably accurate presence/absence data of eel over all (sampled) waterbodies in a country. Basic, reliable presence/absence data from the WFD programme would be potentially useful for countries relying on survey data to estimate silver eel escapement using a habitat-based Yellow Eel modelling approach. Achieving robust presence/absence data should be relatively easy, if dialogue has been established between eel scientists and authorities responsible for the WFD programme.

Again, even if eel density estimates are unreliable, length frequency data can still be used in mortality estimates as long as catchability is independent of eel size. If catchability is not independent of size, the data will still be useful at least if the same (length biased) sampling methods are used year after year. Ensuring that within the WFD programme all eel are properly measured may be a further minor adjustment with significant benefits for eel mortality estimates.

One step further, to ensure the best possible eel density and length data are being collected within a WFD programme would be to adjust the sampling protocol to include eel-specific surveys. An example is the UK (Table 4.2), where in addition to the regular sampling; eel-specific surveys are conducted on 22 index rivers. These additional surveys are conducted by the same persons responsible for the regular WFD fish monitoring. This arrangement, using the same team and a selection of sites with the regular WFD programme, ensures maximum results for the least amount of additional resource. In the UK, the eel specific surveys within the WFD fish monitoring programme are funded by DCF. The UK, with a small, spatially restricted commercial eel fishery argued successfully that sampling just the eel landings would be insufficient to obtain the required data to conduct a stock assessment and estimate mortality. The close cooperation between DCF and WFD might function as an example for other countries and it is highly recommended to explore the possibilities for synergies between the two programmes on a national level.

4.4 Silvering

4.4.1 Introduction

The target for the EU Regulation is related to biomass of silver eel. In this context where the assessment is based on the yellow eel stage it is necessary to identify, as unambiguously as possible, the number of candidate spawning eels ready to migrate to the spawning grounds. In reality, the number of locations where silver eel biomass will be determined is low and heavy reliance will be placed on yellow eel fisheries and survey data. It is essential that methods are developed and validated to convert from yellow eel estimates to silver eel productions.

The change from a resident eel (yellow) to migrant eel (silver) is a pubertal event called silvering and it precedes the downstream migration and reproduction (Aroua *et al*., 2005). It marks the end of the growth phase and the onset of sexual maturation (Durif *et al*., 2009a). This transformation from yellow to silver eels is a gradual and crucial process, preparing the future spawners ready to embark on their seaward reproductive migration to the Sargasso Sea. Silvering involves both physiological and morphological modifications: changes in integument structure and colour (Pankhurst and Lythgoe, 1982, Fontaine, 1994), differentiation of the lateral line (Zacchei and Tavolaro, 1988), increase in eye diameter (Pankhurst, 1982) and fin length, increase of liver weight, and finally a regression of the alimentary tract partly related to natural starvation and cessation of body growth (Sorensen and Pankhurst, 1988). Gonad maturation takes place in both sexes but gonad weight increases mainly in females. Features attained at the end of the silvering process are generally distinctive, and different from these of residential yellow eels.

Some of these characteristics have been used to assess the developmental and migratory status of resident and migrating, by taking into account one or more of these features (Cottrill *et al*., 2002). Several classifying methods with a different number of stages for the silvering process have been developed: the silvering process has been divided into two (e.g. Pankhurst 1982), three (Feunteun *et al*., 2000; Acou *et al*., 2005), or five stages (Durif *et al*., 2005). Morphological characteristics including body colour are often used as criterion for staging silvering eels in many studies (Okamura *et al*., 2007). Despite this, a number of aspects remain largely unclear, such as the effective duration of the silvering process, the progression by intermediate phases, the effective relationship between internal modifications and external and livery changes.

4.4.2 Description of methods for silver stage determination (also see ICES, 2008)

4.4.2.1 Pankhurst's ocular index (Pankhurst, 1982)

During the silvering metamorphose the eye diameter increases unrelated to the body length as an adaptation for the migration to the spawning ground. The ocular index (OI) is based on the relationship between the total length of the eel and the mean eye diameter (Pankhurst, 1982). The OI is calculated as follows:

$$OI = \left[\frac{\left(\frac{A+B}{4} \right)^2 \pi}{L} \right] \times 100$$

where A and B are the horizontal and vertical eye diameters, L is the total body length. According to Pankhurst eels with an OI of >6.5 are classified as silver eels, whereas an OI of ≤6.5 indicates the yellow eel status.

4.4.2.2 Combining colour and ocular index (Acou *et al*., 2005)

A combination of three criteria is used to discriminating silver and yellow eels. The classification of the silvering status is based on two qualitative criteria, differentiation of the lateral line and the presence of a colour contrast, and the quantitative criterion of the ocular index (Pankhurst, 1982). Using a coding system based on the occurrence of each of the three criteria eel can be classified in three groups: yellow eel, pre-silver eel and silver eel (Table 4.6).

The field validation of this criteria demonstrated that only 35% of identified candidate or silver eels actually migrated that year.

Table 4.6. Characteristics and coding of the criteria used to describe the silvering state of eels (Acou *et al.*, 2005).

Criteria	Description	Modalities	Coding
Lateral line	Presence of at least one black corpuscle on the lateral line	True False	1 0
Colour contrast	Typical blackish brown back/silvery white belly Or Significant contrast between dorsal and ventral surfaces whatever the colours (except yellow or green)	True False	1 0
Eyes[1]	OI value	OI <6.5 6.5 ≤ OI < 8.0 OI ≥ 8.0	0 1 2

[1] The OI value of 6.5 corresponds to the minimal silvering threshold value of PANKHURST (1982) defined for female eels. The OI value of 8.0 corresponds to silvering threshold value defined by MARCHELIDON et al. (1999) and ACOU et al. (2003) resulting from the analysis of female eels.

4.4.2.3 Colour measurements using a spectrophotometer (Durif *et al.*, 2009a)

The relationship between changes in colour and "maturity" of eels were investigated using a spectrophotometer. Three measurements were taken on 194 individuals (comprising stages I, III, IV and V eels): on the back, on the belly, and just below the lateral line. Colour measurements on the back of eels could be directly linked to silvering. We found significant correlations (Pearson correlations, P<0.05) between colour measurements on the back and GSI (gonado-somatic index), DTI (digestive tract index), and EI (eye index). Luminance (L*) on the back was significantly correlated (p<0.05) with gonad weight, regression of the digestive tract, and eye diameter. Therefore, eels with a dark back (low L*) had a high GSI (gonado-somatic index), a low DTI (digestive tract index), and a high EI (eye index). Significant correlations were also found with b values (yellow component) on the back. Yellow decreased with gonad weight, and eye index, and increased with regression of the digestive tract. Values of a* also demonstrated significant correlations with DTI and EI indicating that regression of the digestive tract and eye size increased as "red" or bronze appeared on the back.

For each individual we evaluated the colour difference (ΔE) with a "yellow eel" using the Hunter-Scofield equation, which represents the distance in the Lab space between two colours: ΔE = ((ΔL*)2 + (Δa*)2 + (Δb*)2)1/2. Control values for the standard "yellow eel" were obtained from averaging the L*a*b* values of stage I eels. Results demonstrated that there was high individual variability within each stage. Only ΔE measured on the back demonstrated significant differences between stages (Kruskal–Wallis test, p<0.05). The colour change was perceptible only starting at stage IV because there was no significant difference between stage I and stage III eels. Stage IV revealed the highest colour difference with "yellow eels" (Figure 4.3). Whether colour components can be used to classify eels into silver stages has not yet been analysed.

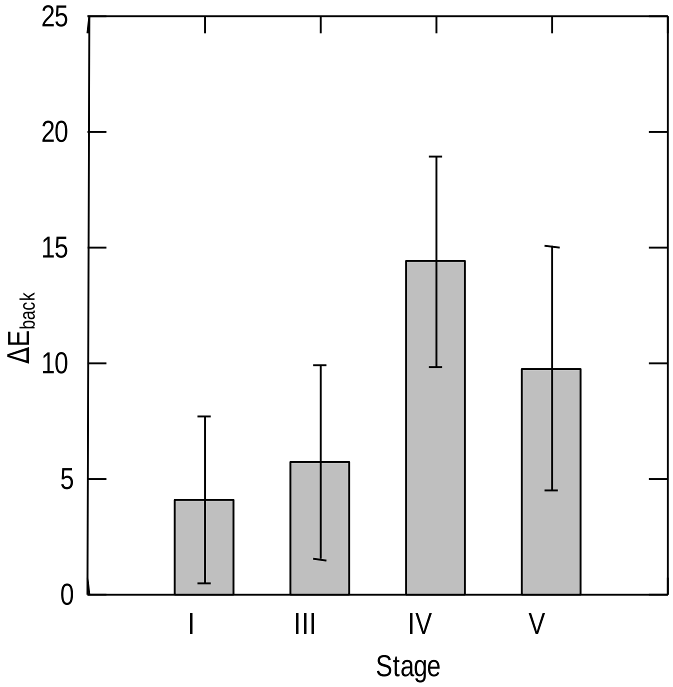


Figure 4.3. Variations (mean ±SD) in colour differences measured on the back (ΔE_{back}) of different staged eels (resident: stage I, premigratory: stage III, and migratory stages IV and V).

4.4.2.4 The silver index (Durif *et al.*, 2005, 2009b)

This index is based on four external measurements that are related to the morphological changes that are most apparent during silvering. Total body length (BL), wet body weight (W), length of the pectoral fin (FL), and mean eye diameter (MD) (Table 4.7). The pectoral fin length is measured from the insertion to the tip of the fin and corresponds to the greatest possible length (Figure 4.4). The mean eye diameter is calculated using vertical (Dv) and horizontal (Dh) eye diameters, measured along the visible part of the cornea.

Figure 4.4. Details of the body measurements (A. body length B. pectoral fin length; C. Horizontal eye diameter). Durif *et al.*, 2009b.

Table 4.7. Classification functions for stage determination (I to FV and MII) of eels. Values correspond to the weights to be assigned to each variable. c: Constant, BL (body length in mm), W (body weight in g), MD (mean eye diameter in mm), FL (fin length in mm).

	Yellow eels		Pre-silver females	Silver females		Silver males
	I	FII	FIII	FIV	FV	MII
c	-61.276	-87.995	-109.014	-113.556	-128.204	-84.672
BL	0.242	0.286	0.280	0.218	0.242	0.176
W	-0.108	-0.125	-0.127	-0.103	-0.136	-0.116
MD	5.546	6.627	9.108	12.187	12.504	12.218
FL	0.614	0.838	1.182	1.230	1.821	1.295

Classification scores for each case are computed for each stage according to the formula:

$$S_i = c_i + w_{i1}*x_1 + w_{i2}*x_2 + \ldots + w_{in}*x_n$$

Where I denotes the respective stage, n denotes the n variables, c is a constant (Table 2), w_{in} is the weight for the n[th] variable in the computation of the classification score for the i[th] group, and x_n is the observed value for the respective case for the n[th] variable. S_i is the resultant classification score. An eel was assigned to the stage for which it had the highest S_i. The efficiency of the analysis was evaluated through a classification matrix, which indicated the number of eels that were correctly classified and those that were misclassified.

The field validation demonstrated that in a sample of downstream migrating eels, that 81% were classified as pre-silver or silver and 19% at the yellow stage (Figure 4.5).

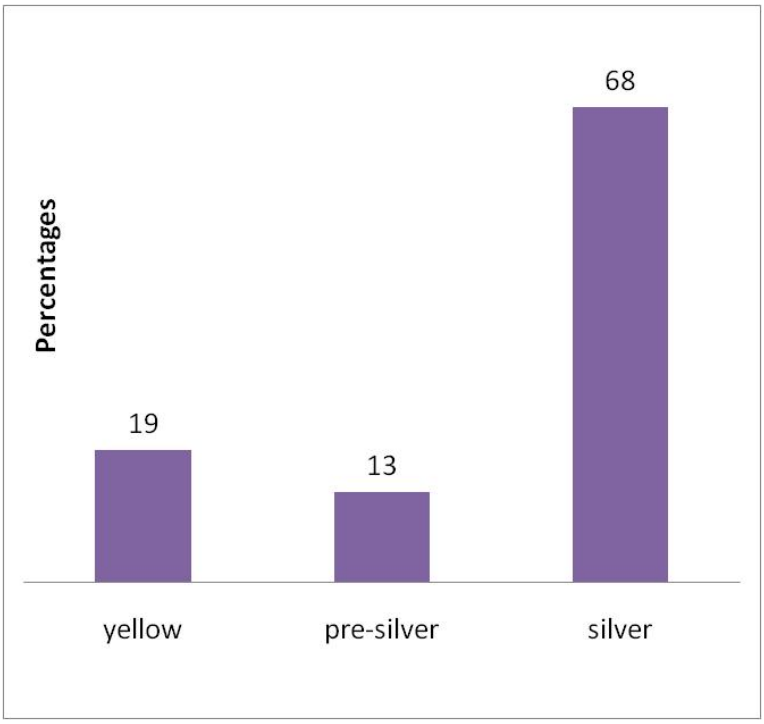


Figure 4.5. Stage composition of migrating eels (caught with stownets, or experimental traps targeting swimming eels).

4.4.2.5 Maturation rate model (Bevacqua *et al.*, 2006)

The method is based on a calculation of the silvering probability based on the length distribution of a sample. The silvering rate is assumed to be an increasing and saturating function of total body length. Because migration takes place in autumn, only data collected from September to November are used.

$$\gamma(L_T) = \gamma_{\max}\left[1 + e^{(\lambda - L_T)\eta^{-1}}\right]^{-1}$$

Where γ_{max}, λ is a semisaturation constant and η is a shape parameter which is inversely proportional to the slope of the curve at $Lt = \lambda$. A validation for this model is described later in this section.

4.4.3 Case studies

4.4.3.1 Example of the Galway silver eel fishery (C. O'Leary, unpublished data)

The Galway silver eel fishery, Ireland comprises a weir with 14 coghill nets. It is located on the lower section of the catchment with a large lacustrine habitat upstream. The coghill nets (large funnel shaped fixed station nets operated in rivers or lake outlets) are fished throughout the dark moon phases and may be lifted during periods of very high water. This fishery was purchased by the state in 1978 and has been fished consistently since then. In 2009 a number of biological measurements were recorded for the eels caught in October and November. The silver eel catch in 2009 had an average length of 485 mm with a maximum length of 730 mm and a minimum length of 308 mm. The sex ratio of 66% female and 34% male was found. This dataset was used to compare the methods described in the previous section.

A simple approximation of silvering involves comparing mean eye diameter and total length of eel, as during the maturation process, the eye diameter of eels increase. However when mean eye diameter for yellow and silver eels are plotted there is no clear distinction between yellow eels and silver eels (Figure 4.6). A similar pattern is seen with the same data using Pankhurst's Ocular Index (Figure 4.7). There is considerable overlap between the yellow and silver eels as seen in the plot using Ocular Index. Many of the silver eels are located under the OI index of 6.5 indicating yellow or pre silvers within the silver eel catch although it should be noted that the use of 6.5 as a cut off point may not be applicable in the Corrib, as based on this criteria 46.84% of silver eels captured in the Corrib would be classified as sexually immature (n = 52).

Acou *et al.*, 2005 consider a silver eel that is ready to migrate in the following season to have a differentiated lateral line, a contrasting dorso-ventral colour and an Ocular Index of >6.5. In addition there are eels caught in the run with only one silver eel criteria (n = 48) and with an OI of <6.5.

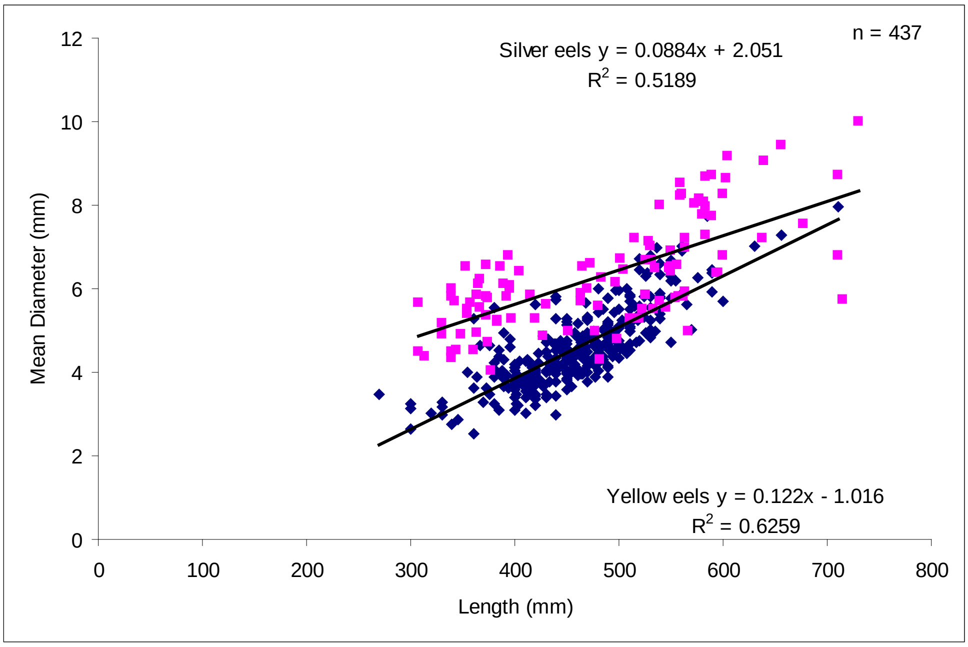


Figure 4.6. Fishery Independent yellow and fishery dependent silver eel measurements from the Corrib Catchment in 2009.

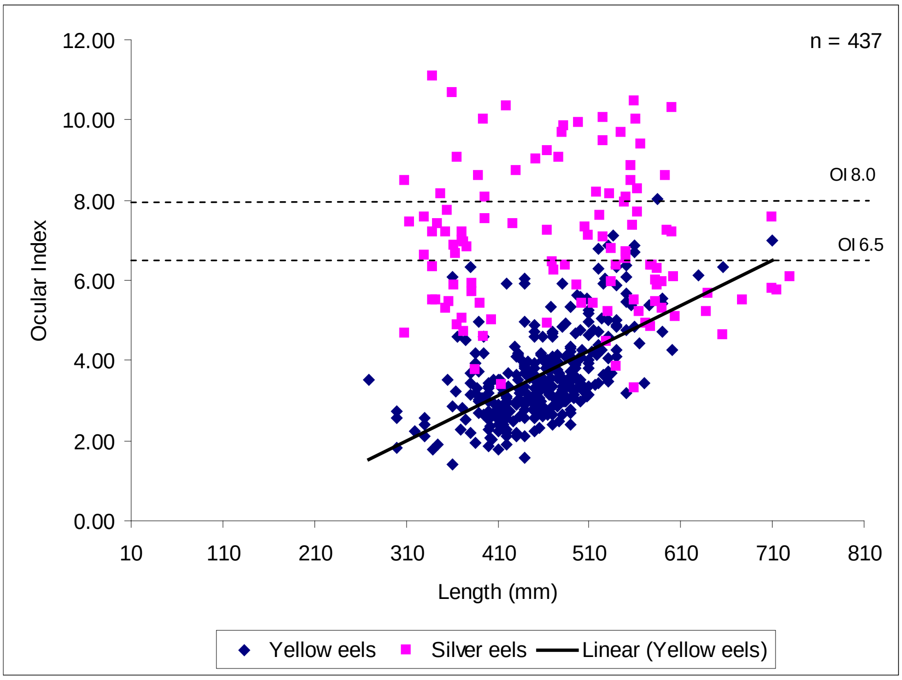


Figure 4.7. Relation between Ocular Index (OI) and total body length (cm) for yellow eels collected in summer 2009 (n = 326) and the silver eels collected in Autumn/Winter 2009 (n = 111).

Table 4.8. Stage classification (according to Acou *et al.*, 2005) of migrating silver eels in the Corrib catchment.

Life stage	Number of eels
Yellow	48
Pre-silver	55
Silver	8

The Galway silver eels were analysed using two methods of the Durif classification. The first classification uses length, weight, fin length and mean eye diameter. The second classification used length, weight and mean eye diameter. Excluding the fin length of the analysis caused an overestimation of small yellow females (which included some of the silver males) (Figure 4.8).

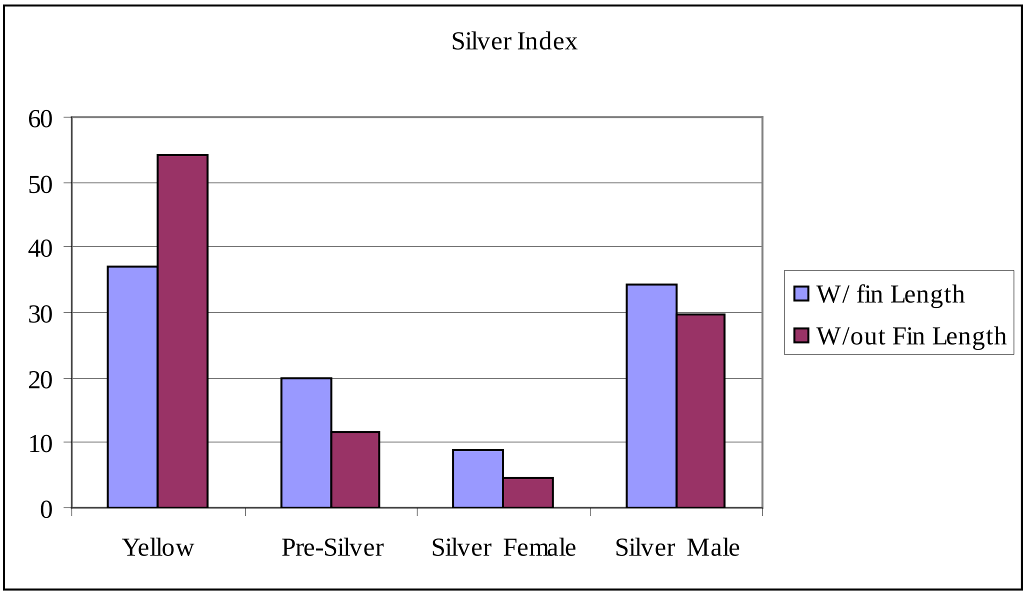


Figure 4.8. Stage classification (according to Durif *et al.*, 2009b) of migrating silver eels in the Corrib catchment with and without the length of the pectoral fin in the silver index.

4.4.3.2 Comparison between colour and eye index and the silver index

A comparison was made between the two life-stage criteria Colour and Eye Measurements (Acou *et al.*, 2005) and the Silver Index (with fin length; Durif, 2009b). The Colour & Eye Index underestimates the number of migrating eels when compared with the Silver Index, with 7% of eels classified as silver compared with 43% of eels under the Silver Index (Figure 4.9). The Colour & Eye Index appears to overestimate the pre silver eels with 50% of eels classified as pre-silver compared with 20% of eels under the Silver Index. However both classifications report similar numbers for the proportion of yellow eels in the silver eel catch 43% and 37% respectively.

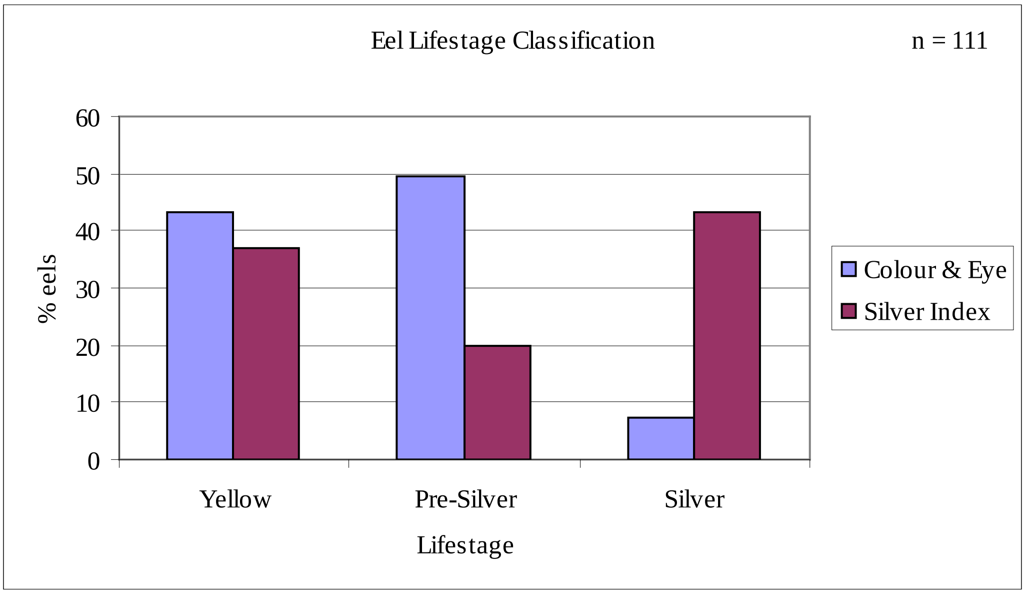


Figure 4.9. Comparison between Eye & Colour index (Acou *et al.*, 2005) and the Silver Index (Durif *et al.*, 2009b). All of these eels were downstream migrants.

4.4.3.3 Burrishoole mark–recapture case study to assess silver rate (Poole, 1994)

In the freshwater Burrishoole catchment (west Ireland), the fish trapping facilities at the outflow offer a unique opportunity to examine the total silver eel migrations emigrating from an unexploited catchment and count the number migrating that were previously marked as yellow eels in the catchment upstream.

In a comprehensive mark–recapture study using coded alcian blue panjet tattoos applied in 1987 and 1988, yellow eels captured in a summer fykenet survey were marked and released back into the capture location. The fykenet caught yellow eels ranged in length down to a minimum of approximately 30 cm and the minimum lengths of the trapped silver eels were also approximately 30 cm. Because of this similarity in length ranges, the fykenet catches can be taken to represent the overall population with the potential to become silver and to migrate. Reliable recaptures were made in 1987 and 1988 when the whole silver eel catch was examined individually.

Yellow eels were marked in two lakes, Bunaveela Lough at the headwaters of the catchment and Lough Feeagh just above the tidal limit (Table 4.9). Silvering rates of between 4.1% and 10% in Bunaveela and 2.0–2.1% in Lough Feeagh were observed with an overall average rate for the catchment of 2.5% to 3.7%. The higher rates observed in Bunaveela may reflect the relatively faster growth and higher relative distance from the sea.

Table 4.9. Number of eels marked as yellow eel and recaptured as silver eel in 1987 and 1988.

	Marked in 1987	No. recap in 1987	% Silver	Marked in 1988	No. recap in 1988	% Silver	Total marked in lake in 1987 and 1988 [1]	No. recap in 1988	% Silver
Bunaveela	80	8	10.0%	149	4	2.7%	221	9	4.1%
Feeagh	296	6	2.0%	477	10	2.1%	767	16	2.1%
Total	376	14	3.7%	626	14	2.2%	988	25	2.5%

[1] This is the number marked in 1987, less those that migrated as silvers, plus those marked in 1988.

4.4.3.4 Comparison of left and right eye measurements (A. Walker, unpublished data)

The list of biological measurements required to classify eels to their respective life stages are length, weight, horizontal and vertical eye diameters and fin length. The question was posed as whether it was necessary to measure both right and left eyes and pectoral fins or whether the measurements on one side of the body would be sufficient.

Silver eels from Avon-Hants were measured for the full suite of morphological parameters and a comparison was made between using an average for the parameters for the left and right side of the body with the measurements from the right side only and left side only. The Silver Eel Index (Durif *et al.*, 2009b) was applied to the data. There was no significant difference between the three methods with a small number of eels changing life-stage between the three methods mainly between female silvers and the pre silver classification (Figure 4.10).

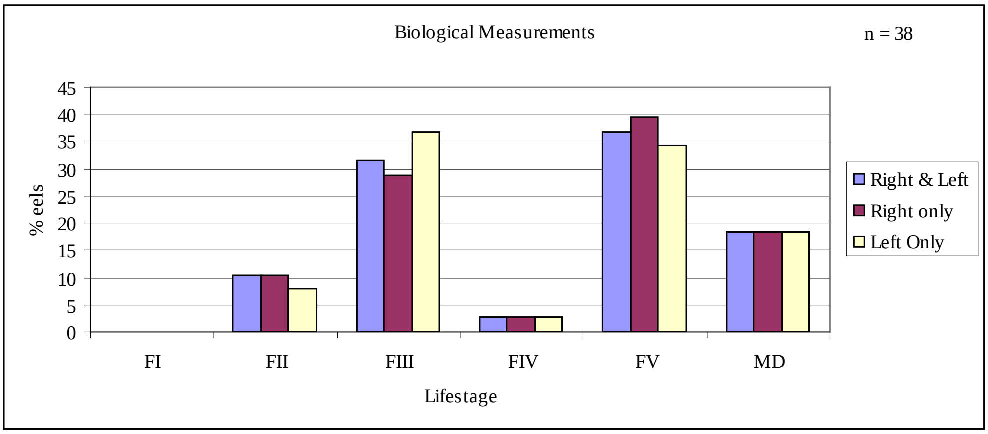


Figure 4.10. Comparison between left and right measurements, right only and left only measurements.

4.4.3.5 Using length distribution to predict silvering

A comparison was made between the predictions by the silvering model (Bevacqua *et al.*, 2006) and the number of silver eels as determined by the silver index (Durif *et al.*, 2009b). The dataset used for the validation was different from that used to develop the model. The test data consisted of lengths of 1102 eels (male and female at different stages) collected in France in different types of water habitats. The predicted number of silver eels was very close to what the silver index determined (Figure 4.11). In the dataset 13% of the eels at were the pre-silver stage and 35% at the silver stage; the model predicted that 41% of the eels were silver. This value is intermediate between the estimate of strictly silver eels and a broader estimate which would encompass pre-silver eels. Figure 4.12 shows that the model behaves well at 600 and up, length classes with less than 3% difference with the index estimations. The main difference occurs in the 500 mm length class (6% difference).

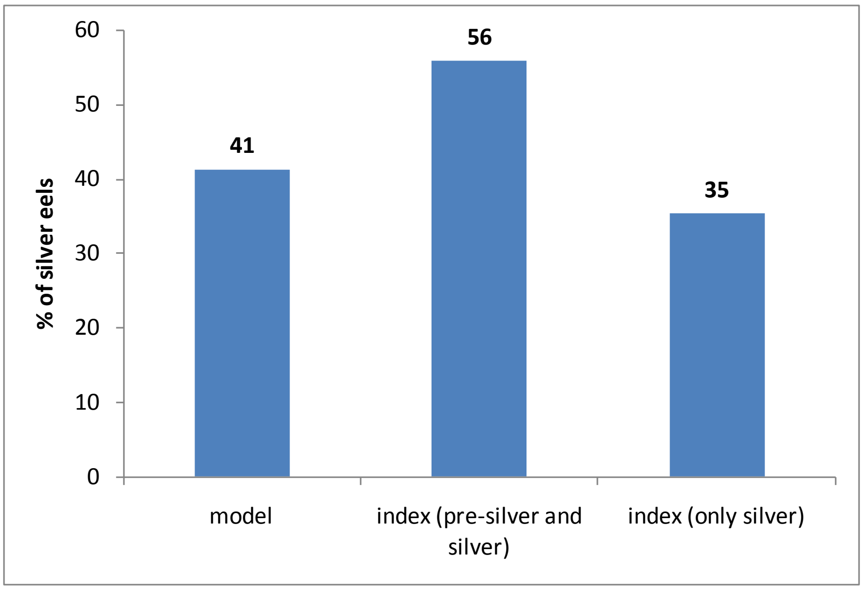


Figure 4.11. Percentages of silver eels (blue: as determined using the silver index; green: as predicted according to the silvering rate model) according to each size class.

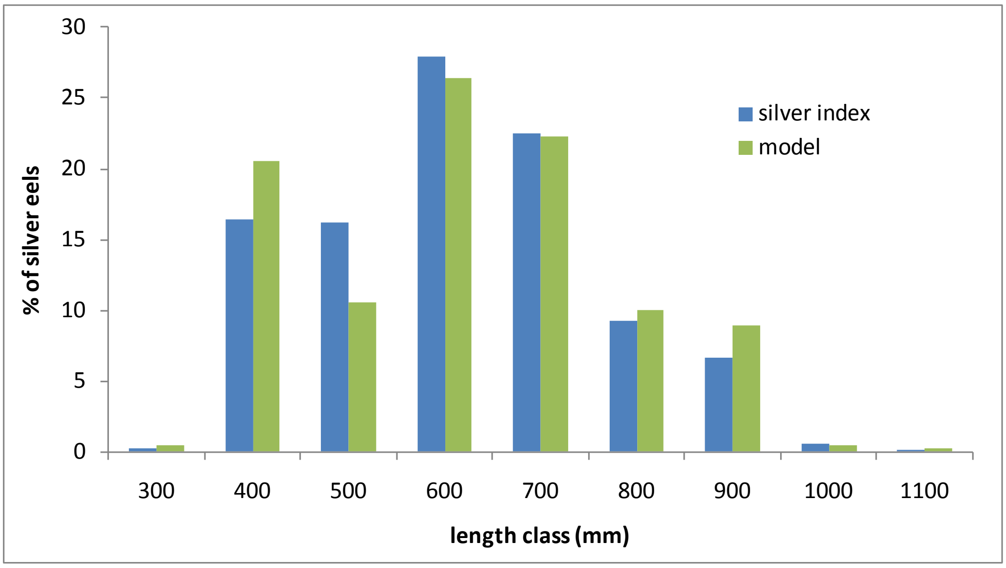


Figure 4.12. Percentages of silver eels (blue: as determined using the silver index; green: as predicted according to the silvering rate model) according to each size class.

4.4.4 Length distribution of silver eels

European eel demonstrate high inter-individual and interstock phenotypic variability (e.g. in body growth, silvering age and size, etc.). Inter-stock variability of age and size at silvering was well examined by Vøllestad (1992). In last 20 years, new data have been collected all around Europe (Figure 4.13) and some preliminary analyses were performed by the working group.

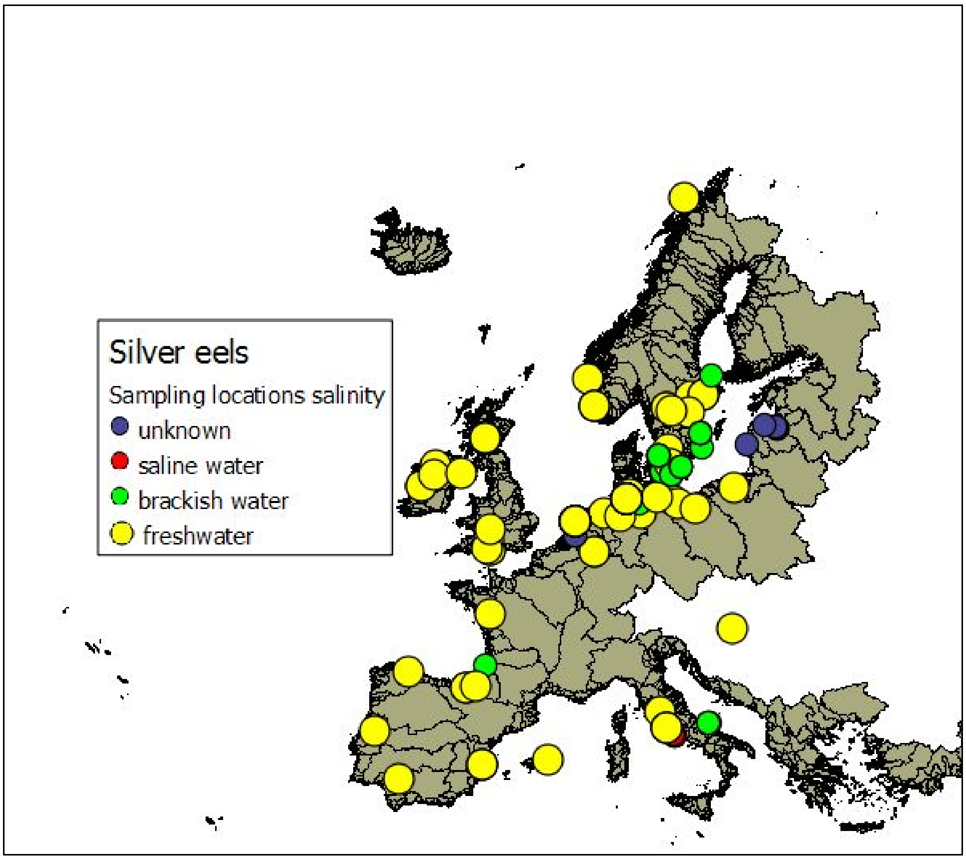


Figure 4.13. Location of silver eel samples.

Particularly, data on silvering size and age (where available) silver males and females were gathered from 66 eel stocks belonging to 12 Member States during the period 1936–2010.

Variability of silvering length with respect to latitude of sampling sites is shown in Figure 4.14. Mean length of females significantly increases with latitude ($p<0.01$), from 500 to 800 mm between 37–70 latitude, while there is no relationship between male sizes and latitude almost equal to 380–400 mm.

As regards age at silvering, it increases significantly ($p<0.01$) with latitude from 3 to 25 and 3 to 34 years for males and females, respectively (Figure 4.15).

As consequence of variability of age and size at silvering. Average growth rate (estimated as size/age) significantly ($p<0.01$) with latitude (Figure 4.16).

Finally, thanks to three long-term datasets from Ijsselmeer (NL), Burrishoole (IE) and Girnock Burn (UK), trends in silvering length with time in last 40 years were analysed in Figure 4.17. Length at silvering in males increased in IJsselmeer and Girnock Burn ($p <0.01$), but not in Burrishoole ($p = 0.66$). Silver females were not captured in Girnock Burn and those caught in Burrishoole and Ijsselmeer reveal a size increase in mean length in Burrishoole ($p <0.01$) yet not significantly in Ijsselmeer ($p= 0.07$). The differences between catchments may be attributable to the exploitation pressures, Burrishoole is not fished while Ijsselmeer has a heavy yellow eel fishery.

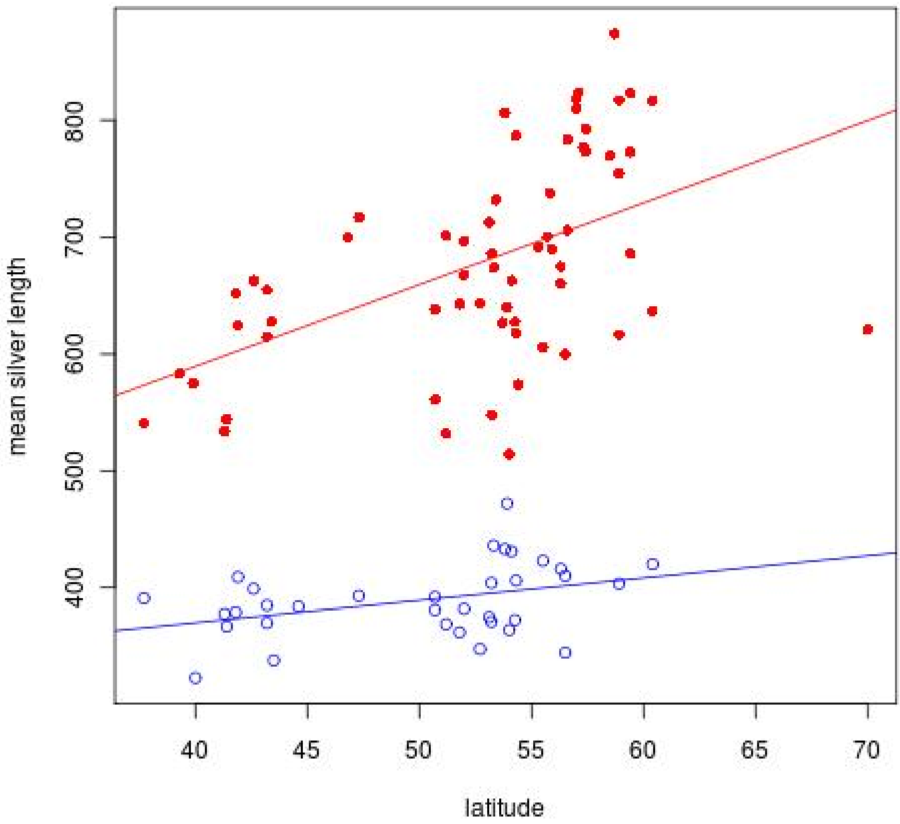


Figure 4.14. Mean silver eel length according to latitude from twelve different countries (66 different locations), blue: male; red: female).

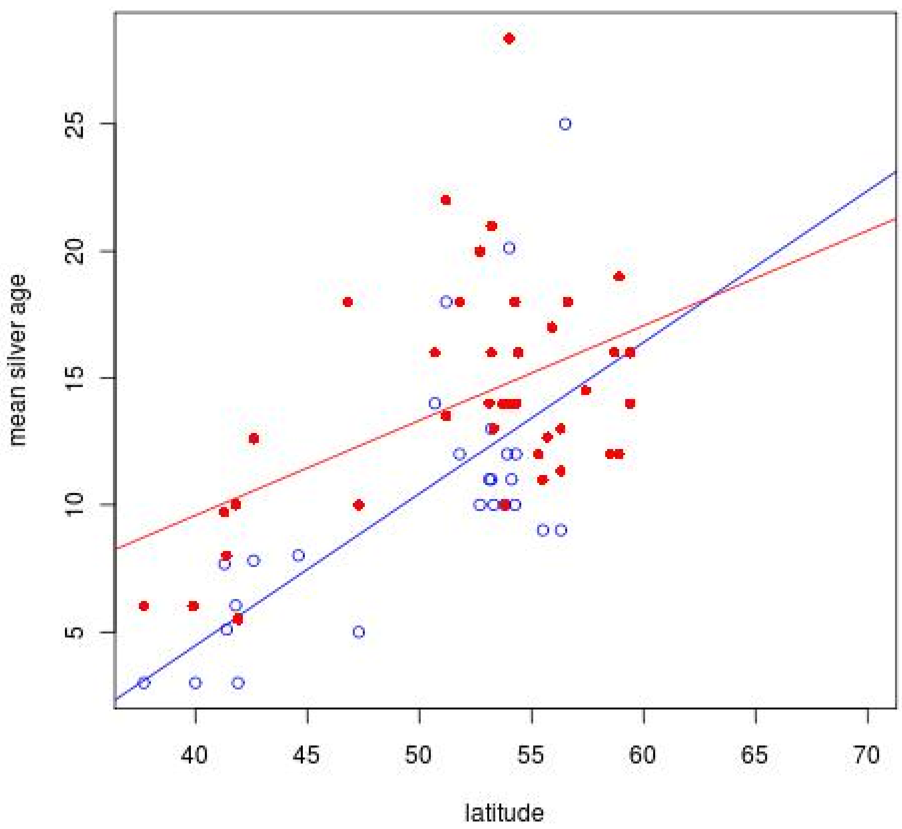


Figure 4.15. Mean silver eel age according to latitude from twelve different countries, blue: male; red: female.

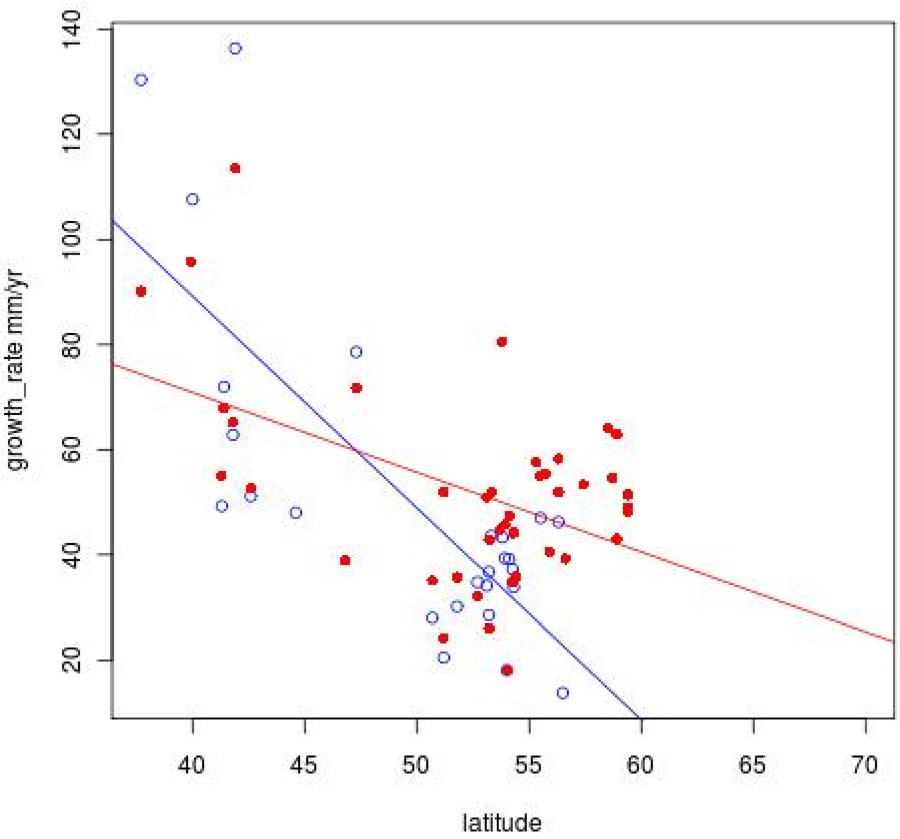


Figure 4.16. Growth rate (mm/year) of eels according to latitude from twelve different countries, blue: male; red: female.

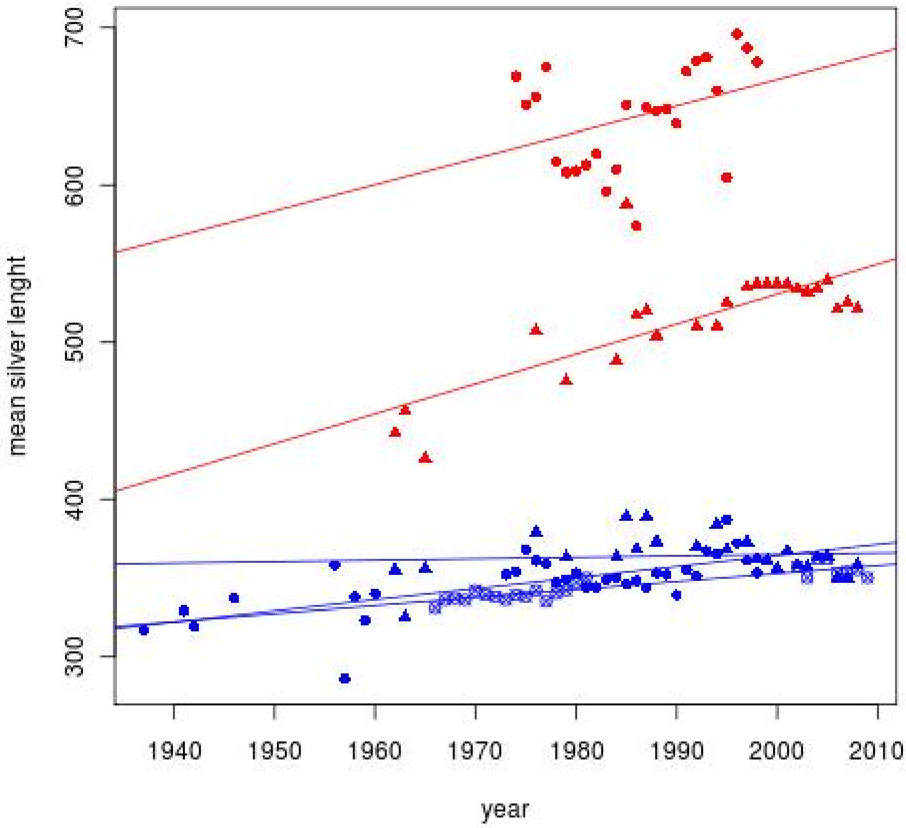


Figure 4.17. Mean silver eel length over the years of stocks from three different countries, Netherland (Ijsselmeer, circles), Ireland (Burrishoole, triangles) and Scotland (Girnock Burn, circle with cross), blue: male; red: female. Note trend lines for Ijsselmeer females and Burrishoole males were not significant.

4.4.5 Timing of silvering

A detailed investigation of the seasonal dynamics of silvering was carried out on eels from brackish water (van Ginneken *et al*., 2007a; van Ginneken *et al*., 2007b). Samples of eels were collected between April and November in Lake Grevelingen in the Netherlands. Morphological, metabolic and endocrine parameters were measured.

Results displayed a clear gradual increase in GSI and vitellogenin, but also in metabolites such as triglycerides, phospholipids, and cholesterol. Cortisol also demonstrated highest values in September prior to downstream migration. From our observations in this study it became clear that a role for cortisol may be in mobilization of energy stores, especially in the European eel which has to cover a distance of 6000 km to its spawning areas in the Sargasso Sea. August was clearly a cross-over month for silvering when silver eels (stage IV and stage V) appeared. A regular increase of 11-KT during silvering, with a maximum value in November during the migratory season was significant. The increased E2 profile in the period September–November suggests that in the period of gonad development the aromatizing enzymes are partially stimulated. Further analyses of body constituents and blood substrata revealed that cholesterol, phospholipids, triglycerids, and other fatty acids start to increase in August and up until migration season (October–November).

In conclusion it appears clearly that silvering begins during summer (August). In the Grevelingen, changes coincided with a decrease in photoperiod and temperature. Analyses of commercial silver eel fishery data from the Loire River demonstrated that the onset of downstream migration was linked to light level in terms of photoperiod and sunshine hours and migratory movements started earlier during years with low light level (Durif and Elie, 2008).

4.4.6 Sex ratio during migration season

Observed variability and underlying patterns within the timing, composition and intensity of silver eel downstream migrations may lead to ambiguity in the interpretation of localized escapement data. Therefore, an understanding in the dynamics therein is crucial in the design, implementation and analytical phases of escapement quantification and modelling (Durif and Elie, 2008). Additionally, considering the value of catch comparisons between individual RBDs, it is essential that localized variation is not only addressed, but noted in detail for future data collation. Such patterns and their possible influences are discussed.

Given the dimorphic characteristics of migrating silver eels, insight into the sex composition of a catch of silver eel can be gained from length frequency data. This technique is non-lethal and relatively fast, making it an available method for long-term, practical examination of sex-ratios of silver eel catches.

Data on total body length frequencies of silver eel catches were collated from country representatives present at WGEEL 2010 were available, and are displayed in Table 4.10. A number of these datasets are relatively small and reflect the quantity of data often available for analysis and may not have the required resolution to reveal patterns within. Therefore, two larger studies are also highlighted, one from Ireland, (Burrishoole, Poole, collected 2008–2009, Figure 4.18) and one from France,(Loire, Durif and Elie, 2008, Figure 4.19).

Table 4.10. Percentage of large eel (>450 mm) observed each month in annual silver eel catches.

Country	Site	Year	Month												Total Catch (n)
			Jan	Feb	Mar	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec	
Ireland	**Burrishoole**	**1988**							**50**	**56**	**43.8**	**61.4**	**70.2**	**86.3**	**3003**
Denmark	Gudena	2009									85.3	87.7	80.5		878
Scotland	Girnock	2002										0	0		37
		2003									0	4.1	0.9		159
		2004				0	0	0	0	12.5	0	0			115
		2005					0	0		0	0	1.8			143
		2006								0	0				50
		2007						0	5	11.1	0	0	0		107
		2008								0	0	0			89
		2009			0			0	0	0	0	0			98
England*	Avon, H	2009											89.4		38
	Avon, W	2009											100		42
	Piddle, D	2009											96		50
	Stour, D	2009											95.3		43
Ireland	Erne	2009								64		69.4		57	617
	Corrib	2009										18.6		22.9	503
	Burrishoole	2009								50		73		75	273
Spain	Basque	2009								22.2	34.2	36.8			189
Italy	Unknown	1997										100	100	100	13
		1998				100	100	100			50	60	25		29
		1999			88.8	100	100				100	73.4			81
		2000	100			80	100	80	100	50	66.6	50	91.2		56
		2001	100	50	100		100	100	100	100	78.9	82.4	0	83.3	131
	Tiber	2008					50	0	0	0	0	11.8			47
		2009					14.3	40	0		0	0	16.7		80

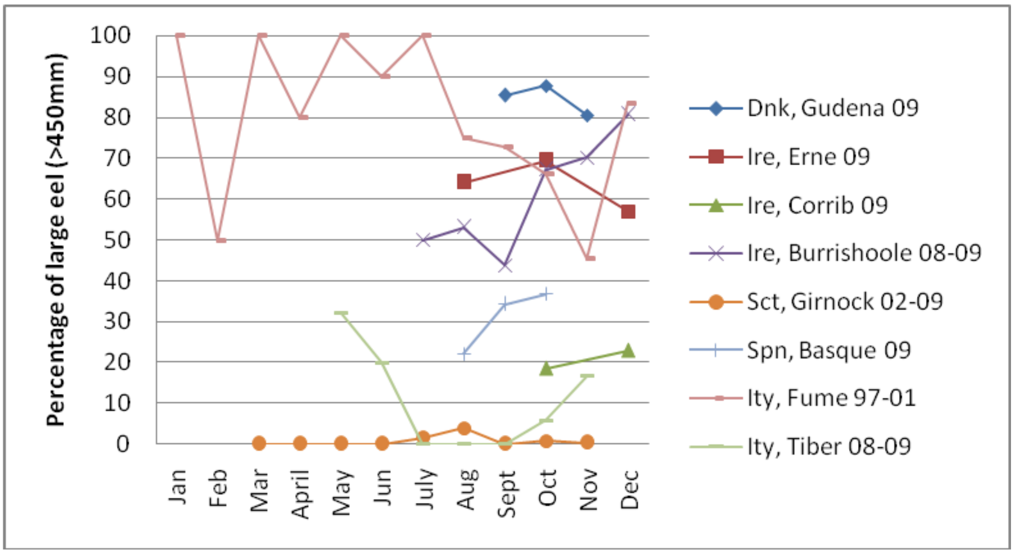


Figure 4.18. Percentage of large eels (L%) caught per month from various sites in Europe. Note: missing data for specific months are a result of no fishing, with exception to Scotland and Ireland (Burrishoole), where no eels were caught on months where data are omitted.

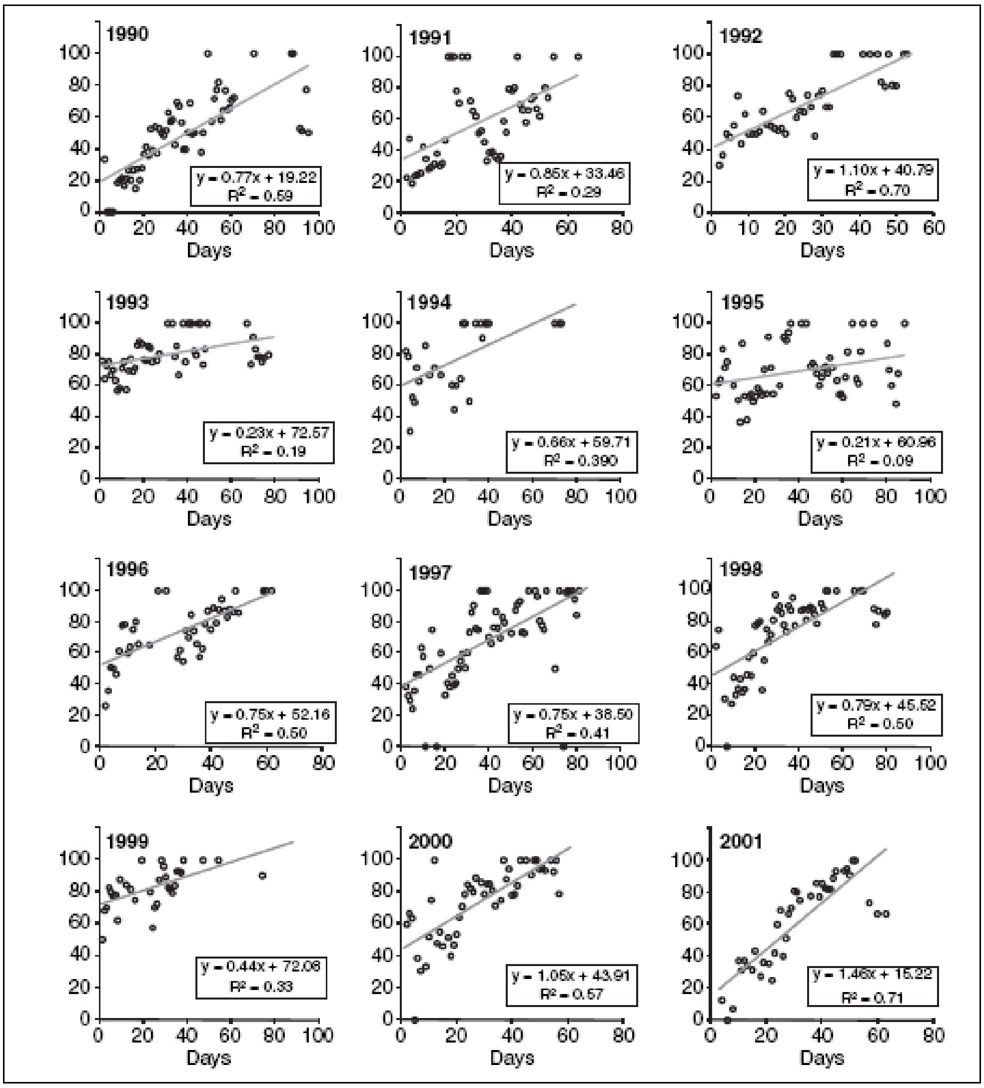


Figure 4.19. Percentage of large eels caught in one fishing night ($L_{\%}$) according to the number of days after 1 October between 1990 and 2001. Linear regression equations and correlation coefficients are indicated for each year (Durif and Elie, 2008).

It is well documented across the distribution (Tesch, 2003) that silver eel catches taken earlier in the season have a larger proportion of shorter (<450 mm) individuals which, as migration continues, gradually reverts to a larger proportion of longer eels (>450 mm) which are observed in late season catches. Research on silver eel swimming efficiency (EELREP, 2005) suggests that smaller eels (typically males) swim slower than larger eels (typically females). Therefore, in order to synchronize the arrival of a population at a hypothetical breeding ground and maximize reproductive success, small eels are observed to begin migration earlier than their larger counterparts and thus can be described as having sex-specific life-history strategies, (Davey and Jellyman, 2005).

4.4.7 Conclusions on methods for stage determination

Table 4.11 summarizes the different methods used for silver stage determination. The application of these different methods depends on for example the sample size, research question and management unit. From a practicality perspective, the use of qualitative criteria like colouring or presence of a colour contrast is favoured.

However, the usage of visual criteria can cause a misclassification of eel due to the subjectivity of the interpretation. In contrast, methods with less subjective bias are more time consuming. The most reliable methods for stage determination use several criteria. Body measurements are more time consuming than colour determination, but are significantly more accurate. Presence of black corpuscles and the dorso-ventral differentiation are indices that are easy to identify in the field (presence or absence); however the appearance of metallic coloration is a subjective criteria and depends on the field observer and apparently on variations between catchments/regions. When large numbers of observers are involved in the recording process then this will affect the outcome of the results.

Using a digital caliper considerably reduces data collection time, as well as reading errors. From these results it is the recommendation of the group that due to the time constraints involved in measuring biological measurements a decision by the relevant field officer be made between left and right side and measurements are taken from one only. If a large discrepancy occurs between a horizontal and vertical measurement, we recommend a repeat measurement be taken of the same eye.

Some criteria have still not been investigated such as the anal closure (due to regression of the digestive tract) which may be indicative of silvering (D. Evans, personal communication). The thickness of the skin is also related to silvering but there is no evident method to evaluate this.

All three classification methods (silver index, colour and eye index and silvering model) are demonstrating that a proportion of eels caught in the Silver Galway Fishery are actually classified as yellow and pre-silver eels. This is consistent with other field observations of yellow eels in silver eel catch (Ciara O'Leary, personal communication). Attempts at inducing sexual maturation of yellow eels using hormone treatments have been unsuccessful, so it is doubtful that these eels will migrate to the spawning grounds within the same year. We question whether these eels will continue their maturation process in transitional waters and migrate within the season or do they remain and migrate the following year.

It is the group's recommendation that at least five morphometric measurements of eels (length, weight, Right or Left Eye Horizontal and Vertical and corresponding fin length) are taken in order to classify between migrating silver eels and those eels moving downstream either to the transitional or coastal waters.

The silvering rate model based solely on length of eels caught between September and December is extremely promising to predict the percentage of silver eels in a given catchment. Knowledge of the sex ratio will increase the efficiency of the model.

Table 4.11. Summary and evaluation of different quantitative and qualitative criteria used to describe the eel development status.

Silvering criteria	Lethal/Non-lethal	Time demand	Accuracy	Subjectivity[3]
Colouring/presence of a colour contrast	NL	+	+	Yes
Colour measurements (Durif *et al*., 2009)	NL	+	?	Yes
Ocular index (Pankhurst, 1982)	NL	+	++ Over-estimation of migrants	No
Colour and ocular index (Acou *et al*., 2005)	NL	+++	++ Underestimating migrants	No
Silver index (Durif *et al*., 2005, 2009a)	NL	+++	+++	No
Fat content	NL	+	+	No
Gonadosomatic Index (GSI)	L	+++	+++	No
Gut Index (GI) [1]	L	+++	++	No
Macroscopic gonad status	L	++	++	Yes
Microscopic gonad status	L	+++	+++	No

Scale working intensity: +++ high intensive, ++ medium intensive, + low intensive. Scale accuracy: +++ accurate, ++ medium accurate, + less accurate.

4.5 Quantification of eel habitat: wetted area

Production of eel is defined in terms of the number or biomass of eel per unit area of eel habitat, or wetted area. However, there may be large variation in the types of waterbodies included in the estimation of wetted area, the methods used to determine area, and the scale on which the area is measured. Standardisation of methods would allow production estimates to be compared across Europe.

4.5.1 Current approaches to quantifying wetted area

Surveys of the 18 participants in WGEEL 2010 indicated that there is considerable variation in what waterbodies are included in habitat assessment. Twelve countries include transitional waterbodies, twelve include coastal waterbodies (to varying extents) and almost all include lakes and larger rivers. Eleven countries also include small streams (Table 4.12). Small offline lakes are included in the calculation of eel habitat in Ireland, but not in Denmark. While many regions present data on the extent of eel habitat, often, this area is not included in the assessment of current and pristine production (e.g. coastal and transitional waters of Ireland and Denmark) (Tables 4.13 and 4.14). The variation in waterbody inclusion for production estimates is a reflection of two issues:

- Availability of resources such as maps, GIS, aerial photographs. For example, some regions do not have access to appropriate GIS data, particularly for smaller rivers and streams;

- Knowledge of where the main eel production occurs. For example, some countries do not include fluvial habitat as it is not considered important for eel production. Similarly, many countries do not include coastal waterbodies in production estimation, either because it is felt that eels do not occur there, or because there is not enough data to quantify coastal eel production.

In general, where national or regional quantification of eel habitat has been carried out, map derived data in GIS format has been used to measure surface area of lacustrine, transitional and coastal waterbodies. All contributors to ICES / EIFAC use national or regional maps and GIS data rather than European scale data. The scale on which these measurements were available from maps ranges from 1:1250 (Scotland) to 1:250 000 (Italy). Variation in scale can have a large impact on the measured surface area of standing waters, and hence on eel production estimates measured in kg/ha. For example, the area of Lough Feeagh (Ireland), measured from the Ordnance Survey of Ireland Discovery series on a scale of 1:50 000 is 395 ha. The same lake has an area of 464 ha according to the CCM dataset (www.ccm.jrc.ec.europa.eu) which has a scale of 1:250 000 (Figure 4.20). Nevertheless, if high resolution maps are not available, resources such as the CCM dataset are highly valuable, especially for extrapolation at a European or international scale (Vogt *et al*., 2007).

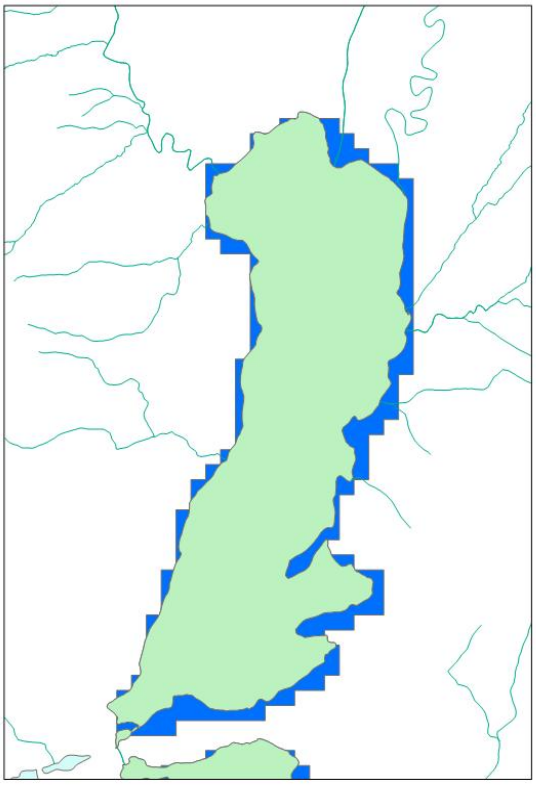


Figure 4.20. Area of Lough Feeagh (Ireland) as represented by the OSI discovery series (1:50 000) in green, and the CCM dataset (1:250 000) in blue. The difference in area is 69 ha.

Where high resolution maps are available, river lengths and widths were used in the estimation of eel habitat in the Eel Management Plans. At lower resolution (smaller scale), rivers are sometimes only represented as lines or vectors, in which case estimates of river width were determined using field surveys, photographic measurements or predictive models. For example, in Ireland, a predictive model which uses Shreve index (Shreve, 1974) and upstream catchment area to estimate river width, is used to convert all river segments to area in m^2. While this model underestimates river widths at larger sites (Figure 4.21), it is accurate for the vast majority of river reaches in Ireland (McGinnity *et al*., in prep.). In Scotland, below a certain channel width (defined as normal winter flow width) the digital network represents channels as a single dimensional line, which thus provides no data on the width of river channels. On 1:10 000 scale maps this occurs nominally on channels below 5 m in width; at the 1:1250 scale it is for channels below 1 m. To provide a reasonable measure of the true extent of water area represented by these lines, it was decided to allocate all non-determined widths of channels as 1 m. Similarly in Italy, a mean river width of five metres was used to extrapolate from river length to fluvial wetted area. Several countries (Denmark, Norway) use river widths measured during salmonid field surveys to estimate probable river width.

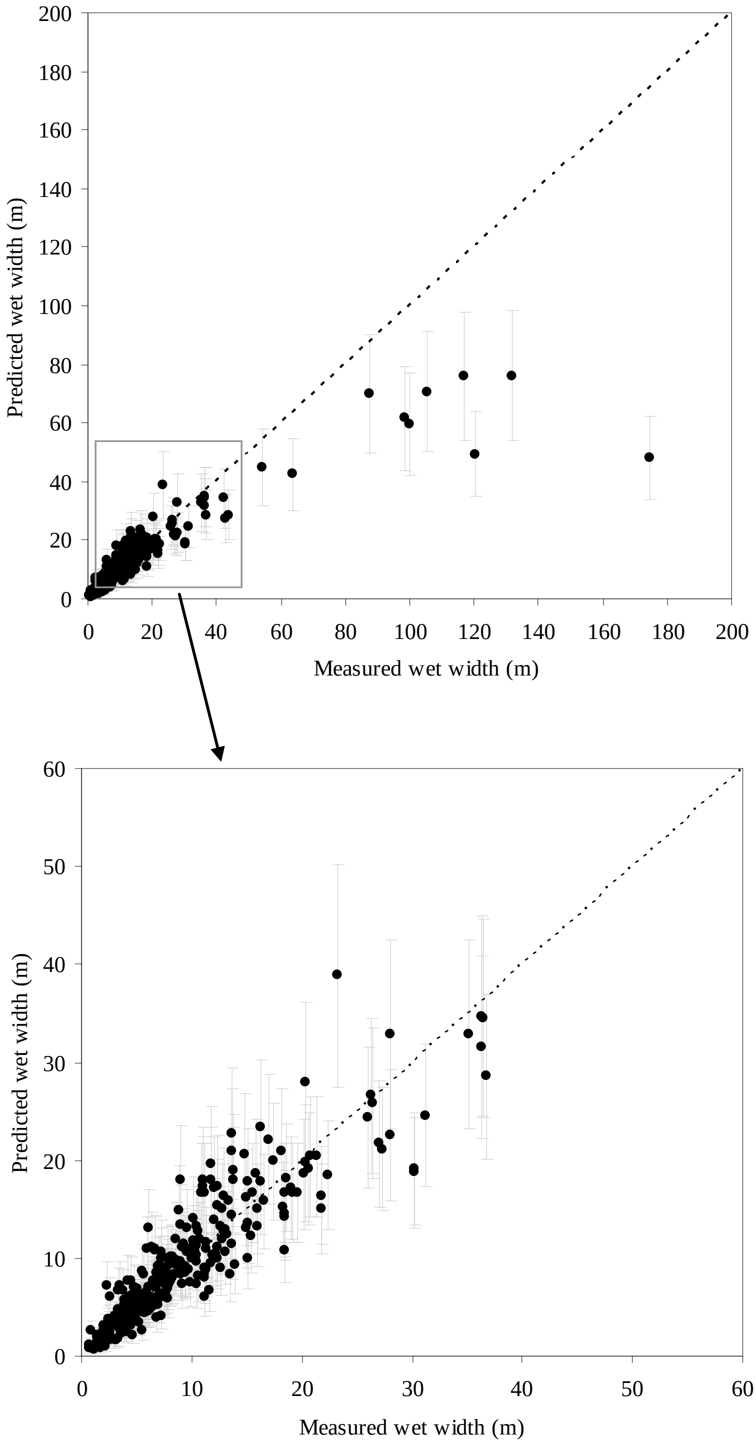


Figure 4.21. Measured and modelled wet widths for 340 river sites in Ireland. Wet widths were measured using tape measures, while modelled wet widths were calculated using the formula: $\log_{10}$ (Wet width + 1) = 0.22734+ 0.20045 ($\log_{10}$ catchment area) + 0.25939 ($\log_{10}$ Shreve index). Error bars indicate the standard error of the estimate, and the dashed line indicates a relationship with a Pearson product correlation coefficient of 1 (McGinnity *et al.*, in prep).

An assessment of wetted area above barriers is crucial when quantifying eel habitat. Two classes of barriers were considered (Table 4.12); natural impassable barriers above which wetted area was never available for pristine production of eel, and anthropogenic structures which have reduced the habitat area in comparison with the pristine situation, but needs to be considered when calculating current production. In several regions and countries, barriers are not considered a problem for eel migration (UK, Denmark), while in other countries barriers significantly reduce the area available for current production (Sweden, Norway, Spain, Portugal). If estimates of wetted area are based on map data collated after the building of dams, estimates of pristine habitat may be overestimated, as many rivers, once dammed, form lakes with relatively large surface areas. While this extra area may be insignificant in most cases, some countries have subtracted surface area of reservoirs from estimates of pristine eel habitat to account for this discrepancy.

While dams and other barriers have reduced the habitat available for eel habitat considerably, there are some cases where new wetted area has become available. For example, the cessation of coal mining in the Elbe catchment has led to lakes forming in open mines, which have been successfully stocked with eel (K. Wysujack, pers. comm.). Similarly, reservoirs behind dams may be ideal habitat for eel production. However, it should be noted that unless these **new** areas are accessible to migrating eel (upstream and downstream), it may not be appropriate to include it in the estimate of current eel production of that EMU. Wetted area upstream of hydropower stations is present in many EMU's, and there appears to be several ways in which this is dealt with. Some EMU's (Scotland, Spain and Portugal) consider that all wetted area above hydropower stations and other impassable weirs is not available eel production habitat, and it is therefore excluded when estimating current eel production, but is included in the estimate of pristine habitat. Some EMU's include such wetted area, but apply a turbine mortality factor to the eel production originating in the wetted area above the station (Poland, Sweden, France, Ireland, Northern Ireland and Germany) (Tables 4.13 and 4.14).

There is some regional variation in how eel habitat in lakes and coastal waters is determined. It is relatively unknown how much eel utilize deeper areas of these waterbodies, although some data suggests that eel move into deep, even anoxic water to feed (McCarthy *et al*., 1999; Yokouchi *et al*., 2009; R. Rosell and R. Poole, pers. comm.). Most countries include the total surface area of all lakes in the wetted area quantification, others (Italy) included only those >10 ha while others use a depth limit. For example, Sweden does not include lake area where the depth is greater than 20 metres. Similarly, Swedish wetted area does not include coastal waters of the Baltic sea that are greater than 20 metres, while Poland uses an 8 mile limit to quantify the eel habitat in coastal waters of the Baltic (Table 4.12).

Table 4.12. Attributes of wetted area quantification for each ICES/EIFAC country. Where quantification of wetted area has occurred does not necessarily mean it has been used for production estimates (see Table 4.13).

Country	Quantification of eel habitat	Transitional	Coastal	Lakes	Small streams	Rivers	Inaccesible/ accessible	Scale of map	Method used to estimate River width
Norway	In progress	n	n	y	y	y	y	?	Survey
Sweden	y	y	y Coast area <20 m	y Lakes area <20 m	n	y	y	1:100 000	n.a.
Finland	n	n	n	n	n	n	n	n.a.	n.a.
Estonia	?	?	y	?	?	?	?	?	?
Latvia	y	n	y	y	y	n	y	?	?
Lithuania	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Poland	y	y	Y 8 mile coastal limit	Y	n	n	y	?	n.a.
Germany	y	y	y	y	y	y	y	?	?
Denmark	y	y	y	y	y	y	All access.	?	survey
Netherlands	n	n	n	n	n	n	n	n	n.a.
Belgium	y	y	n	y	y	y	y	?	survey
England & Wales	y	y	y	y	some	y	All access.	1:50 000	Survey/model
N. Ireland	y	y	y	y	n	y	y	1:50 000	Survey/map
Scotland	y	n	n	y	y	y	y	1:1250	1 m width
Ireland	y	y	y	y	y	y	y	1:50 000	model
France	y (partial)	y	n	y	y	y	n	1:50 000	survey
Spain	y (partial)	y	y	y	y	y	y	?	?
Portugal	y	y	y	n.a.	y	y	y	?	estimate
Italy	y	y	y	y	y	y	?	1:250 000	5 m mean

n.a.= no information available.

Table 4.13. Wetted area (,000 ha) of eel habitat classified according to freshwater (fluvial and lacustrine) and saline (transitional and coastal) waterbodies. The area used for pristine and current production is the area referred to reporting production and escapement of eel in EMPs.

Country	Fluvial	Lacustrine	Freshwater	Transitional	Coastal	Total	Area used for pristine production	Area used for current production	Notes on production estimates
Norway	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	
Sweden			3276.3	1784.3		5060.6	5060.6	5060.6	*
Finland	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	
Estonia			200	1500		1700	n.a.	n.a.	
Latvia	n.a.	n.a.		n.a.		n.a.	n.a.	n.a.	
Lithuania									
Poland		329		78.5	990.6	1398.1	1398.1	1398.1	*
Germany			360.1	64.8	1080	1504.9	1504.9	1504.9	*
Denmark	15	45		1300		60	60	60	Only fw used. All area considered accessible
Netherlands			321.1	358.8		679.9	n.a.	n.a.	Wetted area not used in production estimates
Belgium			n.a	n.a	n.a	n.a.	n.a.	n.a.	
England & Wales			112.7	277.4	1637.1	2027.2	112.7	112.7	Only fw used. All area considered accessible
Scotland			186.7	n.a	n.a	186.7	153.739	111.1	Only fw used. Adjusted for barriers
N. Ireland			73.5	8.9	82.3	164.7	73.5	73.5	*
Ireland			153.8	79.3	1298.3	1531.4	153.8	153.8	* Only fw water used
France			316.2	152.7	3504	3972.9	3972.9	3972.9	*
Spain	134.9	38.0		24.5		362.4	n.a.	105.9	
Portugal			43.8	91.7		135.5	n.a.	135.5	Pristine production not based on wetted area.
Italy	79.3	160.5		108.3		348.1	348.1	348.1	

*** Current production adjusted by turbine mortality**

n.a.= no information available

Table 4.14. Wetted area (,000 ha) of eel habitat classified according to freshwater (fluvial and lacustrine) and saline (transitional and coastal) waterbodies. The area used for pristine and current production is the area referred to reporting production and escapement of eel in EMPs. For more details, see Table 4.13.

Country	EMU/RBD	Fresh water	Saline	Total	Area used for pristine production	Area used for current production
Norway	Total	n.a.	n.a.	n.a.	n.a.	n.a.
Sweden	Total	3276.3	1784.3	5060.6	5060.6	5060.6
Finland	Total	n.a.	n.a.	n.a.	n.a.	n.a.
Estonia	East-Estonian	200	n.a.	200	n.a.	n.a.
Estonia	West-Estonian		1500	1500	n.a.	n.a.
Latvia	Total		n.a.	n.a.	n.a.	n.a.
Poland	Oder	179	692.2	871.2	871.2	871.2
Poland	Vistula	150	376.9	526.9	526.9	526.9
Germany	Eider	7.9	460.9	468.8	468.8	468.8
Germany	Elbe	154.8	46.3	154.8	154.8	154.8
Germany	Ems	7.8	36.1	7.8	7.8	7.8
Germany	Maas	0.9	n.a.	0.9	0.9	0.9
Germany	Oder	51.9	28.5	80.4	80.4	80.4
Germany	Rhein	58.9	n.a.	58.9	58.9	58.9
Germany	Schlei/Trave	23	310.8	333.8	333.8	333.8
Germany	Warnow/Peene	34.8	310	344.8	344.8	344.8
Germany	Weser	20.1	34.6	54.7	54.7	54.7
Denmark	Total	60		60	60	60
Netherlands	Total	321.1	358.8	679.9	n.a.	n.a.
Belgium	Scheldt	n.a	n.a.	n.a.	n.a.	n.a.
Belgium	Meuse	n.a	n.a.	n.a.	n.a.	n.a.
England & Wales	Northumbria	6.7	73	79.7	6.7	6.7
England & Wales	Humber	14.4	66.6	81	14.4	14.4
England & Wales	Anglian	15.9	261.8	277.7	15.9	15.9
England & Wales	Thames	7.4	48	55.4	7.4	7.4
England & Wales	South East	2.4	216.7	219.1	2.4	2.4
England & Wales	South West	7.5	327.1	334.6	7.5	7.5
England & Wales	Severn	13	54.7	67.7	13	13
England & Wales	West Wales	8.7	446.6	455.3	8.7	8.7
England & Wales	Dee	2.2	10.9	13.1	2.2	2.2
England & Wales	North West	11.1	178.8	189.9	11.1	11.1

Country	EMU/RBD	Fresh water	Saline	Total	Area used for pristine production	Area used for current production
England & Wales	Solway-Tweed	23.4	230.3	253.7	23.4	23.4
Scotland	Total	186.7	n.a.	186.7	153.7	111.1
N.Ireland	North Eastern	0.5	15.9	16.4	0.5	0.5
N.Ireland	Neagh Bann	40	40	80	40	40
N.Ireland	North Western	33	35.3	68.3	33	33
Ireland	Eastern	7	38.2	45.2	7	7
Ireland	South-Eastern	4.2	111.4	115.6	4.2	4.2
Ireland	Shannon	45.3	147	192.3	45.3	45.3
Ireland	South-Western	10.7	374.2	384.9	10.7	10.7
Ireland	Western	49.9	470.7	520.6	49.9	49.9
Ireland	North-Western	36.7	236.1	272.8	36.7	36.7
France	Rhin	7.7	0	7.7	7.7	7.7
France	Meuse	3.7	0	3.7	3.7	3.7
France	Artois Picardie	24.5	15.1	39.6	39.6	39.6
France	Seine Normandie	88	220	308	308	308
France	Bretagne	16.4	21.5	37.9	37.9	37.9
France	Loire	94.4	3279.6	3374	3374	3374
France	Garonne Dordogne	54.3	120.1	174.4	174.4	174.4
France	Adour	27.2	0.4	27.6	27.6	27.6
France	Rhône-Méditerranée	n.a	n.a.	0	0	0
France	Corse	n.a	n.a.	0	0	0
Spain	Andalucía	35.3		186.8	186.8	61.3
Spain	Asturias	2.3		2.3	2.3	1.6
Spain	Cantabria	1.9		1.9	1.9	0.6
Spain	Castilla-La Mancha	0.6		0.6	0.6	0
Spain	Catalunya	40.3		40.3	40.3	1.7
Spain	Galicia	2.9	1.4	4.3	4.3	3.1
Spain	Illes Balears	4.3		4.3	4.3	4.3
Spain	Murcia	0.2		13.7	13.7	13.7
Spain	Páis Vasco	1.4		1.4	1.4	1.4
Spain	Rest of Spain	66.9	21.7	88.5	88.5	0
Spain	Valencia	16.8	1.5	18.2	18.2	18.2
Portugal	Minho&Lima	7.8	3.9	11.7	n.a.	11.7
Portugal	Cavado,Ave&Leca	1.7	0.7	2.5	n.a.	2.5
Portugal	Douro	2.3	0.8	3.1	n.a.	3.1
Portugal	Vouga,Mondego,Lis	4.2	13.8	18	n.a.	18
Portugal	Tejo	20.5	36.9	57.4	n.a.	57.4
Portugal	Sado&Mira	1.5	21.9	23.4	n.a.	23.4
Portugal	Guadiana	5.3	3.6	8.9	n.a.	8.9
Portugal	Algavere streams	0.5	10	10.5	n.a.	10.5
Italy	Total	239.7	108.3	348.1	348.1	348.1

n.a.= no information available

4.6 Conclusions to quantitative assessments of local eel populations

- Mark–recapture is a valuable tool for estimating silver eel escapement. It is important to ensure the right combination of experimental design and data analysis and to adopt the most appropriate methods for the local situation.
- M–R based estimation of silver eel escapement and/or production should be approached in one of two ways: Either driving assessments toward a single point M–R analysis, minimizing space and time between mark and recapture; or accepting that data are too wide ranging in space and time using data analysis techniques (survivor models) capable of functioning when the classical "closed population" M–R approach is inappropriate. Studies falling between these two routes may tend to have unacceptable high levels of uncertainty of the final output estimate.
- Some variables which could clearly have an impact on recapture rate are currently inadequately investigated. Examples include whether to release to flowing or static water, how far upstream to relocate before release back to a single point assessment site, which anaesthetic, how long to hold eels for recovery. There is a strong case for carrying out coordinated experimentation to improve protocols and produce guidance on protocols.
- The use of telemetric tagging/hydroacoustics (Didson) to determine behaviour patterns of small batches of individual eels can be very informative, and are needed to lend reassurance to assumptions over routes taken, for instance around or through a power station or fishery site.
- The eel is not a key indicator species for WFD sampling and therefore the collection of eel data through this programme is inconsistent between countries. The DCF has a specific requirement for the collection of eel data from marine and inland waters. As with the WFD, however, the eel data collection differs between countries. Furthermore, while the required data support classical fish stock assessment methods in those situations where fishing mortality is a significant impact, they are less appropriate to other scenarios.
- Most countries in fact will require scientific survey data in order to derive their estimates of Biomass and Anthropogenic mortality (A). Therefore, the most efficient and cost-effective way to collect robust eel data to support stock assessments is probably to coordinate WFD and DCF sampling programmes in relation to the collection of eel data. However, such coordination appears to be rare across the surveyed countries.
- The most reliable methods for silver stage determination use several criteria. Body measurements are more time consuming than colour determination but are significantly more accurate. The silvering index based on eye diameters (based on the mean between vertical and horizontal either on the right or left side of the eel), pectoral fin length, body length and body weight give an accurate description of the stages in a sample. The appropriate period for a survey predicting the potential number of migrants is in September, just before migratory movements. The silvering rate model, based solely on the length of eel caught between September and December, is extremely promising for predicting the percentage of silver eels in a given catchment. Knowledge of the sex ratio will increase the efficiency of the model.

- An update on silver eel length and age according to the latitude confirms the results of Vøllestad (1992). The summary of silver eel length over the years indicates an upward trend of size at silvering.
- An analysis of the type of waterbodies used to estimate wetted areas and silver eel production revealed a lack of consistency within and between countries. The types of habitats considered in these estimates (riverine, coastal, transitional and lakes) varied between EMU's and countries, despite being natural habitats for eels in many regions. The main habitats which are overlooked in certain regions are transitional and coastal waters and 1st order streams. Given the differences found in the areas included in the estimates of eel habitat and the implications this has for production estimates, stock assessment at the international level becomes inevitably associated with a much higher uncertainty. A consistent approach to including all types of natural eel habitat is necessary, and may require more data collection to inform this process.
- Methodologies used to estimate wetted area were fairly consistent across EMUS's (generally map data). However, variation in scale and measurement of river widths introduces error into the quantification. Consistency in this regard would be most beneficial, but will require additional resources (e.g. larger scale maps in some regions) and may not be possible. It is likely that the calculation of river width in each EMU may require different methodologies, depending on hydromorphological and climatic conditions and the occurrence of barriers. As it is difficult to standardize these methods, it is crucial to ensure that widths are ground-truthed and verified for each EMU to enable international comparisons.
- Some regions differentiate between natural and anthropogenic barriers, while some do not. In addition, some regions do not consider habitat above barriers for production estimates, while some use this habitat, but correct for turbine mortality. For the purpose of wetted area estimates it is necessary to consider as pristine distribution of eels the areas that are/were naturally colonized by eels. Natural inaccessible areas, such as above waterfalls or disconnected lakes should not be included in the pristine situation, in contrast to areas which have become artificially isolated from downriver stretches. Quantification of the pristine eel production area seems to vary between regions and countries, depending on whether areas that were traditionally stocked or naturally colonized by eels are included. Pristine production is the basis for determining how close current production is to target, and informs the measures that contribute to accomplishing the objectives set in Regulation 1100/2007. The variation in pristine eel habitat quantification is a cause for concern.
- In estimating current eel production, there is a discrepancy between regions which include areas above dams, and those that do not. In order to allow comparison between these two situations, reliable estimates of turbine mortality should be used in determining current eel production.
- Excluding areas of potential habitat on the basis of depth will require additional research to confirm whether it is appropriate.

4.7 Recommendations to local assessments

- Validated models for the analysis of mark–recapture data are needed where the time interval and distances between release and recapture site of marked silver eel can be long and the uncertainties over the fate of eel between tag and recapture are high, which can be addressed through survival models.
- There is a strong case for carrying out coordinated experimentation to improve protocols and produce guidance on protocols for mark–recapture studies.
- Electric fishing and fykenets are the methods most widely used to assess yellow eel populations, inter-calibration studies are needed to make the best use of these data at the population level.
- It is recommended to investigate to what extent (a) current WFD sampling can assist eel stock assessment by providing information on estimating eel standing stock (biomass) and mortality, and (b) if minor adaptations to national sampling protocols might enhance the quality and quantity of eel data.
- The DCF sampling requirements for eels should be reviewed, and if necessary revised, to ensure that the programme supports the data requirements for eel stock assessment methods, at both local and international levels, particularly in relation to reporting under the Regulation.
- Coordination at national/regional scale is encouraged between WFD and DCF sampling programmes to make best use of potential sources of eel assessment data from limited resources. Progress should be reported in the Country Reports to WGEEL.
- In order to classify between migrating silver eels and those eels moving downstream either to the transitional or coastal waters it is recommended that at least five morphometric measurements of eels (length, weight, Right or Left Eye Horizontal and Vertical and corresponding fin length).
- The silvering rate model based solely on length of eels caught between September and December is extremely promising to predict the percentage of silver eels in a given catchment, and further validation is required. Knowledge of the sex ratio will increase the efficiency of the model.

5 Assessment of the quality of eel stocks

Chapter 5 updates the European Eel Quality Database (EEQD) and discusses the importance of the inclusion of spawner quality parameters in stock management advice. Chapter 5 addresses the following Terms of reference:

d/ provide practical advice on 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;

e/ review and develop approaches to quantifying the effects of eel quality on stock dynamics and integrating these into stock assessments.

5.1 Introduction

In recent years WGEEL has discussed the risks of reduced biological quality of (silver) eels. The reduction of the fitness of potential spawners, as a consequence of (specific) contaminants and diseases, and the mobilization of high loads of reprotoxic chemicals during migration, might be key factors that decrease the probability of successful migration and normal reproduction. An increasing amount of evidence has been presented indicating that eel quality might be an important issue in understanding the reasons for the decline of the species. Previous WG reports have presented an overview and summaries of a variety of reports and data on eel quality. Hence, this chapter should be read in conjunction with the 'eel quality' chapters in WGEEL 2006, 2007, 2008 and 2009.

From the management point of view, and given the increasingly limited availability of glass eel for restocking, ICES (2009) recommended restocking should only occur in waters of good quality, thereby producing eels with a high capacity for successful reproduction. Many EU Member States have indicated that eel quality issues will be taken into account when planning future stocking as a management measure, especially with regard to infection by *Anguillicoloides crassus* and other pathogens. However, in most European countries monitoring programmes are mostly focused on *A. crassus* and not on other diseases. Likewise, monitoring of quality parameters at sites proposed for stocking seems to be inadequate and there are many proposals for stocking of habitats that are known to be highly polluted.

5.2 Information of eel quality provided by countries and update of database on eel quality related data: the European Eel Quality Database (EEQD)

The European Eel Quality Database (EEQD) was created by INBO (Belgium) in 2007 (ICES 2007). The database includes data of contaminants (polychlorine biphenyls, pesticides, heavy metals, brominated flame retardants, dioxins, PFOS), diseases and parasites (such as *Anguillicoloides crassus*, bacteria, and viruses such as EVEX and other lesions), and fitness (fat content).

Before and during this meeting (2010), the EEQD was updated with new data. These data were retrieved from recently published reports or scientific papers, and from the

Country Reports. Table 5.1 summarizes the amount of new data added to EEQD during the WGEEL 2010 session.

Table 5.1. Amount of new data records included during WGEEL 2010 session.

Contaminant group or pathogen	Number of new records
Polychlorinated biphenyls (PCBs)	475
Dioxins	120
Pesticides	44
Heavy metals	19
Anguillicoloides	175
Viruses, bacteria, and other diseases	20
Lipid content	508

The following sections give an overview of new information on contaminants or diseases that has become available to WGEEL since the drafting of the 2009 report. Although new information has been provided on eel quality in several countries, a comprehensive overview on the eel quality over its distribution area is far from complete. We recommend that MS measure eel quality in their river basins.

5.2.1 Contaminants

The review on literature on the impacts of contaminants on metabolic functions and on behaviour of the eel (see last year's Country Report), has now been published (Geeraerts and Belpaire, 2010). It includes a figure illustrating the variation in concentration of PCB 180 in eel over eleven European countries (Figure 5.1).

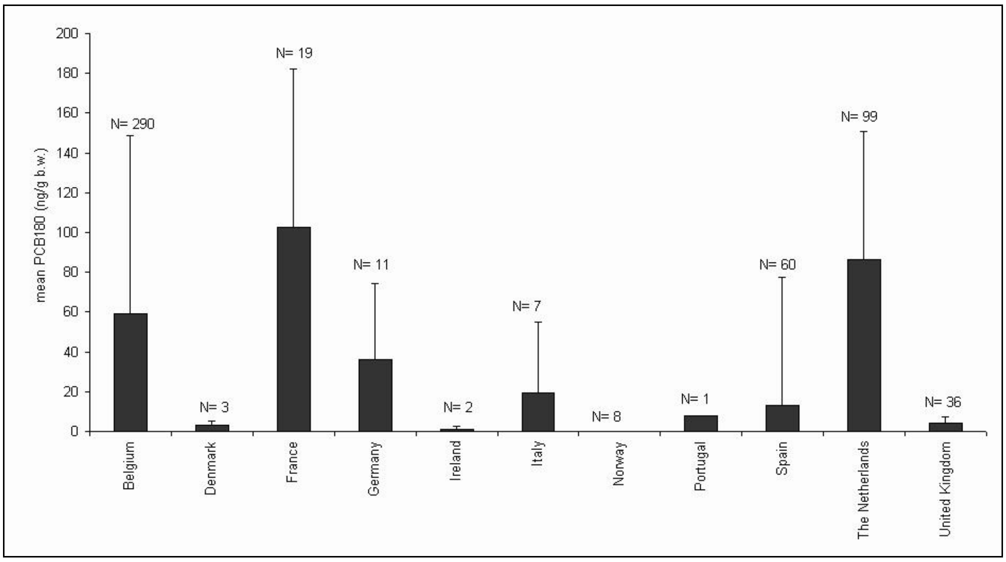


Figure 5.1. Mean concentration of PCB 180 (ng/g b.w.) in eleven countries in European eel muscle as reported recently. Extracted from Geeraerts and Belpaire, 2010.

The monitoring data described below give an insight into contamination levels of eels. However, it should be noted that the monitoring strategy is not uniform, giving rise to considerable variation between the data. In some countries individual eels are analysed, whereas other use pooled samples. In addition, different sizes of eels have been analysed also accounting for large variations. Nonetheless, the data below are informative and indicate that, at some locations, significant contamination takes place.

Sweden

During the production of HCl at an industrial plant adjacent to Helsingborg Harbour (SSW Sweden) chlorinated substances were unintentionally produced and subsequently entered the water and air. Hence, the Swedish authorities carried out analysis of POPs in flounder then in eel. The results revealed high levels of dioxins and PCBs in yellow eels and fishing for eels for sale in this harbour was banned in 2007. However, in 2009 the National Food Administration analysed two pooled samples of yellow eels from this area and, based on new analyses of samples from 2008 and 2009, this ban was lifted in July 2010.

Germany

Recent work (Nagel *et al.*, in prep.) investigated biliary polycyclic aromatic hydrocarbon (PAHs) metabolite concentrations in female yellow eels of twelve German rivers in 2009 (Figure 5.2).

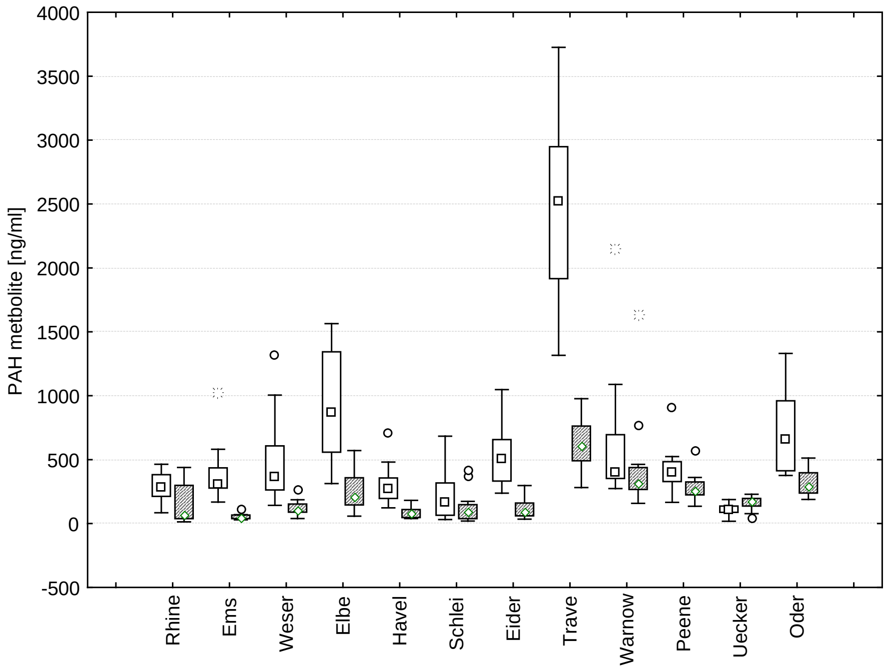


Figure 5.2. PAH-metabolites detected in the bile of female yellow eels from twelve German rivers. 1-hydroxypyrene (1-OH-Pyr) and 1-hydroxyphenantrene (1-OH-Phen, dashed blots) concentrations are shown [ng/ml]. Most of the individual results for 3-hydroxybenzo[a]pyrene (3-OH-BAP) in eel bile were found to be below the limit of quantification.

Another report describes data on temporal trends of PCDD, PCDF and PCB levels in muscle in eel from the western Baltic Sea (Karl *et al.*, 2010). The contaminant levels of 28 pooled eel samples varied considerably, between 1.35 and 16.75 ng WHO-TEQ.kg^{-1} wet weight.

Netherlands

In the previous Country Report (2009) some overviews were given for PCB contamination levels in eel in the Netherlands (see Hoek-van Nieuwenhuizen and

Kotterman (2007)); (Figure 5.3); Hoogenboom *et al*. (2007). The current eel monitoring has continued in 2009, and the last data have been added for a temporal trend analyses (see Subchapter 5.3). The situation has not changed over the years; waterways with input from the river Rhine or Meuse are more heavily polluted than waters with no input. Sedimentation areas (historically) of these rivers have the highest PCB concentrations. Of the analysed organic contaminants, PCBs are considered the most important contaminant, observed in the highest concentrations.

The Dutch Country Report and de Boer *et al*. (2010) also present temporal trends for some chemicals measured in eels (See Subchapter 5.3).

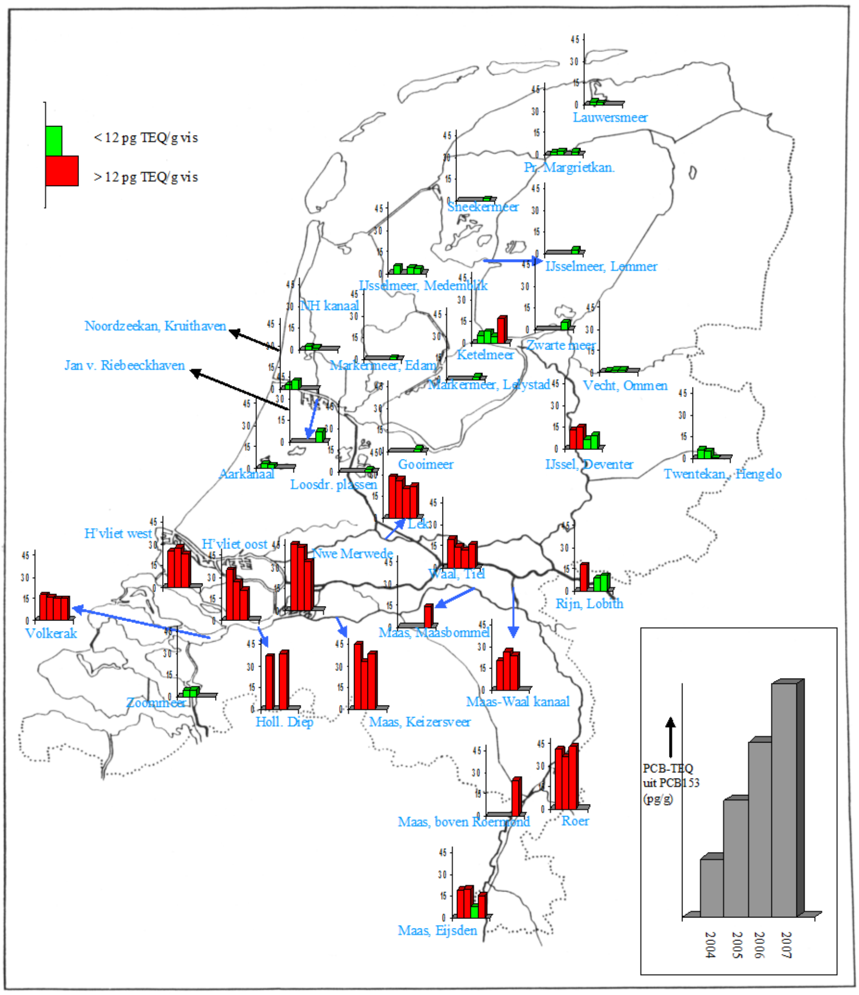


Figure 5.3. Temporal and spatial trend in PCBs in eel (from Hoek-van Nieuwenhuizen and Kotterman, 2007).

Belgium

In a new report, Belpaire *et al*. (Belpaire *et al*., under review) analysed 30 PCB congeners in pooled muscle tissue samples of eel collected from 48 sites in Flanders between 2000 and 2007. There was a large variation between individual sites (range 11–7752 ng/g wet weight (ww) for the sum of the ICES 7 PCBs), eels from the River Meuse basin (mean 1545 ng/g ww) being considerably more polluted than those from the River Scheldt (615) and IJzer (61) basins. PCB patterns varied between the monitored locations, indicating differential sources of pollution. Local and upstream sources linked to industrial activities seem to be the main cause for PCB presence in Flanders, rather than atmospheric fallout.

On average, five congeners contributed up to 53% of the total PCB load, but the relative abundance of individual congeners in the samples vary across Europe depending on the origin and country considered. Apparently, Flemish eels are characterized by a larger proportion of PCB 153 and PCB 180 compared with the other European countries (Figure 5.4). Considering the levels of the Sum 7 PCBs, eels are not compliant with the Belgian legal limits for consumption (75 ng/g ww) in 71% of the sites. Regular consumption of eels from the most polluted sites leads to consumers exceeding the WHO Acceptable Daily Intake values by a factor 375. Clearly, recommendations to fishers to avoid consumption of their own catch are not effective; an inquiry among 10 000 recreational fishers in 2008 indicated that annually 33.6 tons of eels are fished in Flemish waters and taken home for personal consumption (Vlietinck, 2010). The authors therefore recommended more stringent public health measures to prevent fishers and their families from consuming their catch.

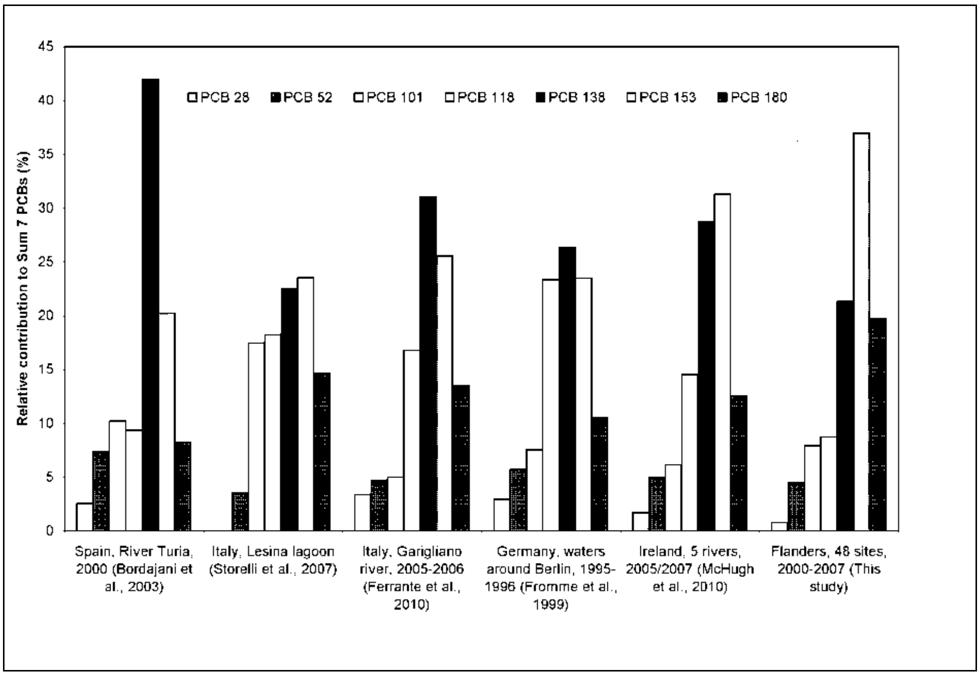


Figure 5.4. Weight % of the ICES 7 PCB congeners based on Sum 7 PCBs in eels from several European studies. In the case of the Lesina lagoon, PCB ratios were calculated on Sum 6 PCBs, as PCB 28 measurements were not available in this study (Storelli *et al.*, 2007) (From Belpaire *et al.*, under review).

The European maximum limit for the sum of dioxins and dioxin-like PCBs (WHO-PCDD/F-DL-PCB TEQ) in muscle of eel and products thereof is expressed in toxicity equivalents. It is set on 12 pg TEQ g^{-1} fresh weight. Dioxin concentrations in Flanders eel varied considerably between 38 sampling sites, ranging from 1.14 and 141.86 pg TEQ g^{-1} and exceeded the limit in 42% of sites (Geeraerts *et al.*, 2010). Half of the sampling sites reveal especially DL-PCB levels exceeding the European consumption level (with a factor 3 on average; Figure 5.5).

Once again, human consumption of eel, especially in these highly contaminated sites, seems unjustified with regard to these specific compounds. The highest human exposure risk is through the consumption of fish containing more contaminants than most other food products (Leonards *et al.*, 2005). Hence fish consumption can lead to an increase in (human) body burden, especially in those fishers and their families who consume eel from contaminated locations.

The majority of Flemish eel from this study had levels considered to be potentially detrimental for their reproduction. Palstra *et al.* (2006) reported disrupting effects in the embryonic development of eel, occurring at levels below 4 pg TEQ kg^{-1} gonad. Thus, the reproductive potential of most Flemish eel (66% >4 pg) may be impaired due to the presence of dioxins and dioxin-like PCBs.

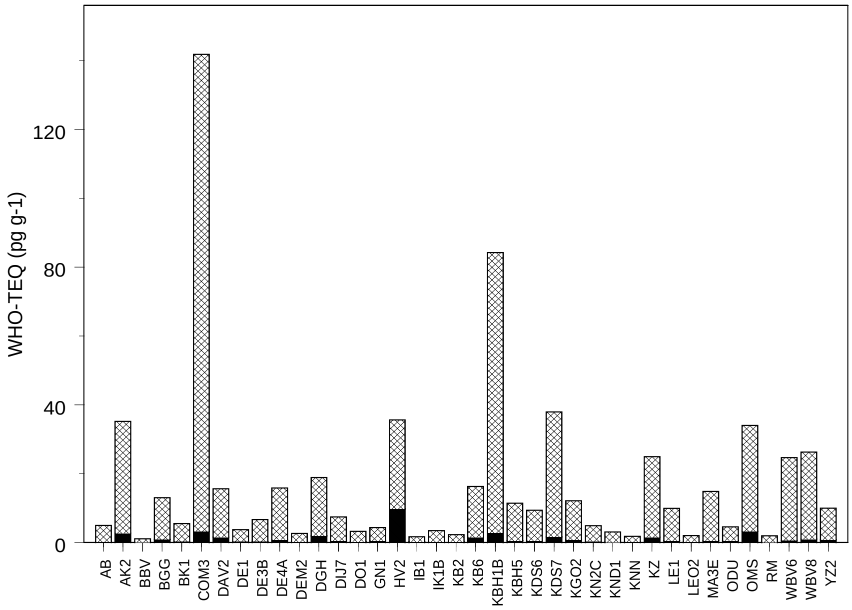


Figure 5.5. Concentrations of WHO-DL-PCB-TEQ (black) and WHO-PCDD/Fs-TEQ (white) in eel muscle tissue from pool samples in Flanders; (—) maximum level PCDD/Fs= 4 pg g^{-1} fresh weight, (- -) maximum level PCDD/Fs and DL-PCBs= 12 pg g^{-1} fresh weight (Geeraerts *et al.*, 2010).

Recent work (Reyns *et al.*, 2010) investigates the presence of 14 dyes in muscle of about 100 yellow eels captured in Flanders (Belgium) between 2000 and 2009. Preliminary results indicate contamination with malachite green, crystal violet and their respective leuco-metabolites, with dyes found in eels from about 35% of the sites. Concentrations ranged between 0.25 and 9.51 ng/g ww. None of the dyes are registered for use as veterinary drugs. Nevertheless, some of them are widely used illegally in fish-farming industry against protozoan, fungal and bacterial infections. These dyes could be of concern due to possible toxicological properties, but their effect on the eel is unclear. These preliminary findings on the presence of these chemicals warrant further investigation, including their potential effects on aquatic organisms and the dietary exposure by humans.

Scotland

SEPA have begun analysing eel samples for PCBs, DDTs, HCHs, HCBs and BDEs, and initial results have been published (Macgregor *et al.*, 2010). Up to five eels were sampled from 30 sites, minimum eel length was 23 cm, and 80% of eels were >30 cm in length. Sites were not randomly selected, being biased toward sites where high concentrations of pollutants were anticipated. DDT was present in nearly all samples despite having been banned for 30 years. However, comparison of data with previous contaminant analyses from 1986 and 1995 demonstrated considerable decreases in DDE and HCH concentrations. When compared with reported European and North American levels, PCBs levels (138–494 μg/kg) were generally low, while BDEs were broadly similar, while DDE levels (1–227 μg/kg) were rather high.

France

A campaign of PCB analysis in eel (among five other fish) was set up by the French Ministry of Agriculture in order to prioritize sectors of intervention to reduce risk for human food. In general, 290 sites in France were analysed. Results of the set of analyses were published recently (http://www.pollutions.eaufrance.fr/pcb/; http://www.pollutions.eaufrance.fr/pcb/resultats-xls.html http://pollutions.eaufrance.fr/Demo/Resultats_hydro.aspx.). PCB concentrations levels were so high in some locations that commercial fisheries have been closed in many parts in order to protect consumers. For detailed information about levels see Chapters 5.5 and 5.6.

Other information was also available in the scientific literature and has been included in the EEQD; see EEQD reference list.

5.2.2 Parasites and diseases

New information on parasites and diseases from the following countries is referred to below.

In **Sweden**, prevalence of *Anguillicoloides crassus* is consistently recorded in all DCF and related sampling in Swedish coastal waters. The observed prevalence is presented by year, life stage and ICES subdivision in Tables 11.2.1–2 in Appendix SE (see Swedish Country Report in Annex). As an average over years with sampling (2002–2009) there is a clear gradient from marine to brackish habitats in yellow eel, with a low prevalence (7%) in the most marine area on the Skagerrak coast to a much higher prevalence (60%) inside the Baltic Sea. The prevalence in silver eel is generally lower in all areas (30–40%), with no clear gradient from west to east (Figure 5.6).

All sampled eels handled at the Institute of Freshwater Research are analysed with respect to prevalence and intensity of the infestation of *Anguillicoloides crassus*. From 2009 and 2010, 118 eels, mainly yellow eels from Lake Mälaren were analysed. The prevalence was 46% and the corresponding intensity 4,2 ± 4,7 (SD).

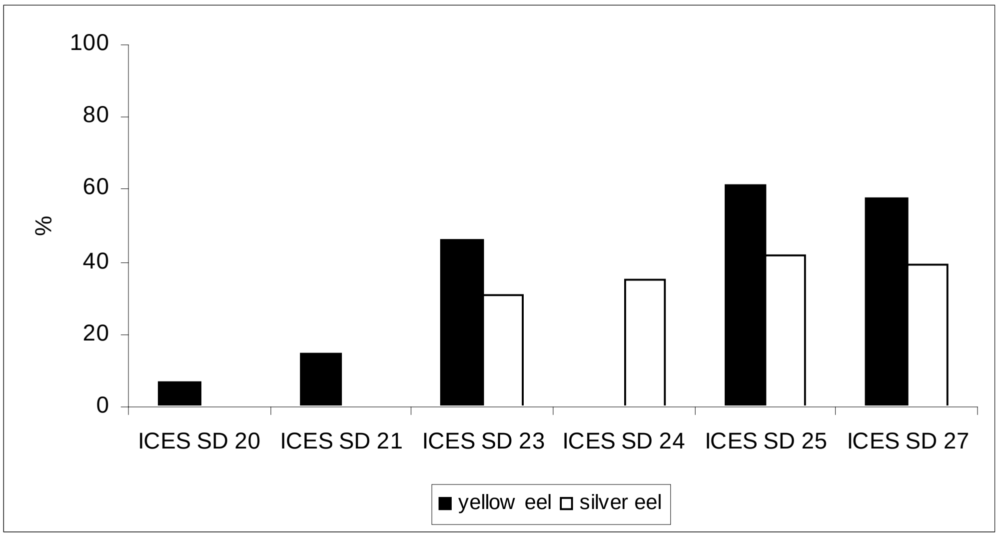


Figure 5.6. Prevalence of *Anguillicoloides crassus* in yellow eel and silver eel as an average of all samples collected from the Swedish coastal fishery in 2002–2009.

In **Finland,** the first record of *Anguillicoides* came from a sample of "natural" elvers collected in 2002 on the coast of the Bothnian Bay: one third of the elvers were infected (Tulonen, 2002).

Latvia reports a standard sampling procedure for the presence or absence of *A. crassus*, but provided no details.

Germany. In the German RBDs, *A. crassus* was detected in all eel samples from 16 rivers with prevalence ranging from 56% (Schlei) to 93.7% (Uecker) (Figure 5.7).

The abundance of nematodes was higher in silver eels (6.3 in females, 4.7 in males) compared with yellow eels (3.2, sexes pooled) (Figure 5.8). In line with high abundances of nematodes, apparent swimbladder damage was higher in female silver (2.8) than yellow eels (2.1), with intermediate values for male silver eels (values after Hartmann, 1994; Figures 5.8d–f).

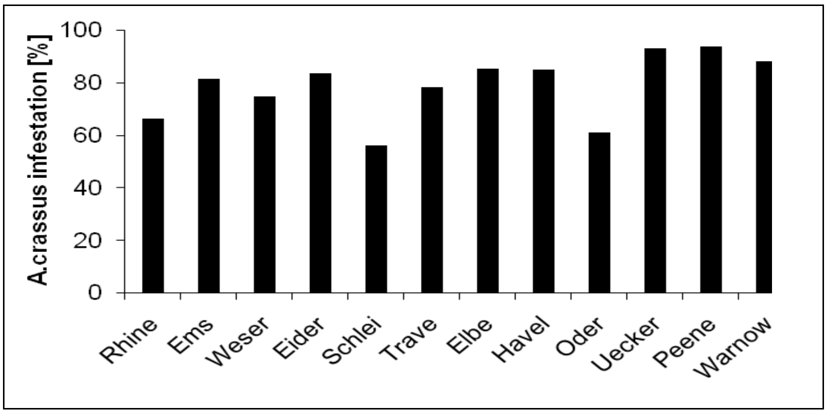


Figure 5.7. Infestation [%] of eel swimbladder with *Anguillccloides crassus* (including larvae) in 2009. Pooled samples of male and female yellow and silver eels for each river (n ≥ 60 per river) (Nagel, Annex Country Report Germany 2010).

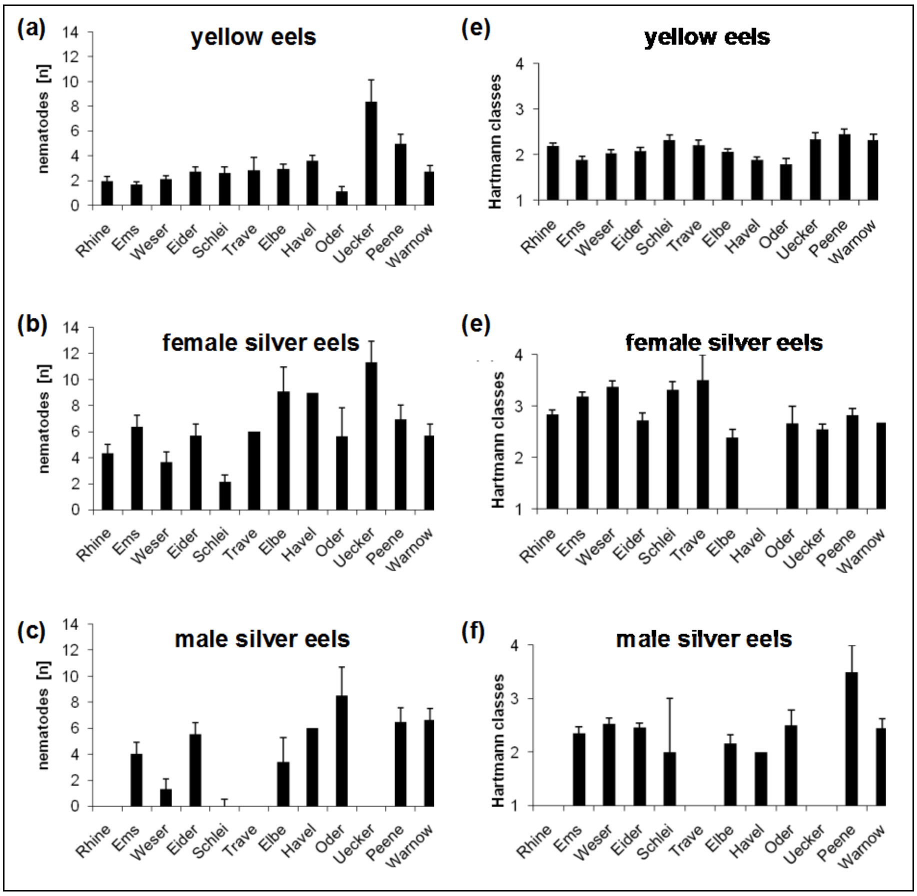


Figure 5.8a–c. Abundances of *Anguilliccloides crassus* infection of the swimbladder in yellow eels (a), female silver eels (b) and male silver eels (c). d–f: Degree of swimbladder damage by *A crassus* in yellow eels (d), female silver eels (e) and male silver eels (f), expressed in Hartmann classes. (Note that numbers of females silver eels were limited for the river Trave, Havel and Oder (n = 1–3). The sample size of female silver eels for all other rivers was n ≥ 28. Note that males were not available for the rivers Rhine, Trave and Uecker and were limited in numbers for the river Schlei, Havel, Peene and Oder (n = 2–4). The samples size of males for other rivers was n ≥ 26.9 (Nagel, Country Report Germany 2010).

Denmark stated *A. crassus* is widely distributed throughout both brackish and freshwaters all over the country. Monitoring of *Anguillicoloides* parasites takes place on a yearly basis at three locations starting in 1987 or 1988. The number of *Anguillicoloides* infected eels (prevalence) in 2009 ranged from 40 to 73% (Table 5.2).

Table 5.2. ***Anguilliccloides* monitoring data in Denmark for 2009.**

Location	Salinity ppt	Coordinates	Year	Total	Infected	Prevalence	Intensity
				N	n	%	n
Arresø	0	55.59N;11.57E	2009	65	40	61.5	3.4
Isefjord	18	55.50N;11.50E	2009	97	39	40	4.5
Ringk. Fj	5–10	55.55N;08.20E	2009	100	73	73	5.1

In the **Netherlands**, the market sampling for Lake IJsselmeer collects information on the percentage of eels revealing *Anguillicoides* infection (Figure 5.9, based on visual inspection of the swimbladder). Following the initial infestation in the late 1980s, infection rates stabilized between 50 and 70% between 1989 and 2006, but have slightly decreasing in recent years. As part of the extended market sampling programme in 2009, data on *Anguillicoides* infection rates were collected in two other areas (Friesland and Rivers). In both areas the infection rate was similar to the levels observed in Lake IJsselmeer over the past years.

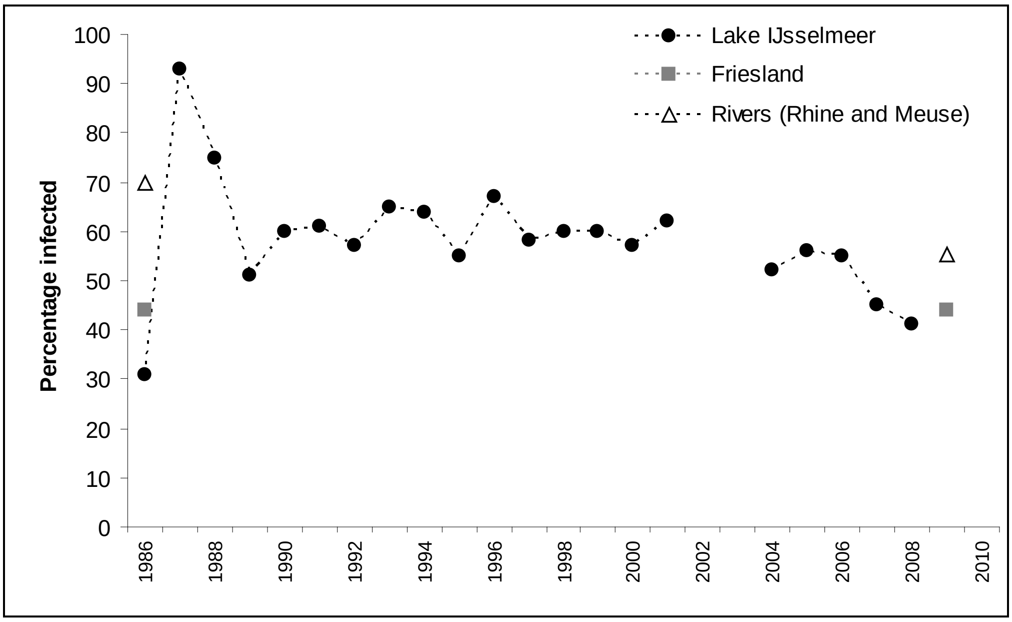


Figure 5.9. Trend in *Anguilliccloides* infections in Lake IJsselmeer eel, Friesland and rivers (Rhine and Meuse). Based on visual inspection by the naked eye (reported in The Netherlands Country Report).

Throughout **England and Wales** *A. crassus* is considered ubiquitous, although there is no routine sampling or monitoring of parasites or pathogens (Nigel Hewlett, Environment Agency National Fisheries Laboratory, pers. comm.). Those applying for a licence to move or stock eels in England and Wales must submit a health check of a sample of the fish being stocked, which includes a check on parasites and pathogens, but currently there are few such applications.

In **Northern Ireland**, no introduced parasites or pathogens have been recorded from eels examined in North Eastern RBD. *A. crassus* was first recorded in the Erne system, North Western International RBD, in July 1998. In Neagh-Bann RBD, *A. crassus* was found in Lough Neagh for the first time in 2003, and its spread has been monitored via the analysis of a total of 2093 yellow and 600 silver eels from 2003 to 2009. In 2008 the prevalence of *A. crassus* in both yellow and silver eels was recorded as 67.3% and 86%, respectively, while in 2009 it had fallen to 53,6 and 81%, respectively.

In **Scotland**, prior to 2008, there was only a single reported instance of *A. crassus* (Lyndon and Pieters, 2005), and, while recognizing the absence of any coordinated survey, it was tentatively thought that *A. crassus* was not widespread in Scotland. A survey of *A. crassus* infection in 2008 and 2009 has revealed the presence of adult *A. crassus* in the swimbladders of eels from three more catchments: Forth, Leven, and Monikie Burn. In these sites prevalence (based on very small samples) ranged from 25–40%. All four of the catchments are concentrated in a relatively small part of the east coast of Scotland.

Spain provided new data to the EQDD on *A. crassus*, in Spanish Mediterranean ecosystems and Asturias (see Table 18 of Spanish Country Report).

The prevalence of bacterial infections has been reported for the Albufera lake in El Palmar (C. Valenciana) and in the Mar Menor Lagoon (Alcaide and Esteve, 2010; Esteve and Alcaide, 2010; Muñoz *et al*., 2009) (Table 5.3). Edwardsiellosis was previously reported along 2003–2005 with a prevalence of 8.2% on the wild eel population from Albufera Lake (Esteve and Alcaide, 2009). A new study investigates *Edwardsiella tarda* reservoirs in Albufera Lake, as well as Edwardsiellosis distribution in eels in regard of water physico-chemical parameters. In 2008, 27 water samples as well as 131 wild eel individuals were analysed monthly. The results demonstrate that the Edwardsiellosis disease is present in the wild eel population from Albufera Lake, and its present prevalence (12,21%) was slightly higher than that previously reported (8,2%) (Esteve and Alcaide, 2009; 2010). In accordance with previous results prevalence of the disease among younger eel (25–48 cm) was (13,2%) significantly higher than in silver (57–74 cm) ones (0%).

One hundred and seventeen of the Albufera Lake eels of 2008 were also examined in for HVA via PCR. Of these, 63 have been confirmed positive (53.9%) (Bandin, pers. comm. 2010).

Table 5.3. Prevalence of infectious diseases in eel from Albufera Lake and Mar Menor.

River/Lake	Year	N eels	Eel size (cm)	Max	Min	Eel Stage	*Edwardsiella septicaemia* (%)	*Vibriosis septicaemia* (%)	*Aeromonas septicaemia* (%)	Skin injury caused by bacteria or fungi (%)
Albufera lake	'03/'04/'05	45	25.0	34.0	29.6	Y	6.7	35.6	8.9	2.2%
Albufera lake	'03/'04/'05	46	35.0	46.0	39.7	Y	10.9	6.5	10.9	17.4%
Albufera lake	'03/'04/'05	31	49.0	75.0	56.7	S	3.2	12.9	22.6	22.6%
Albufera lake	2008	121	25	48	34.3	Y	13.20	7.40	19.80	12.4%
Albufera lake	2008	10	57	74	61.2	S	0	10	10	20.0%
Albufera lake	2009	60	74.04				9,3	1.1.	1.85	No data
Mar Menor	2009	109	23.79				5.5	7.5	0	No data

Portugal: In Portugal, *A. crassus* is probably widespread. Figure 5.10 shows the locations where this parasite has been reported so far. In one location (Obidos Lagoon) only one eel (n=110) was infected with four parasites, which has probably migrated from a freshwater stream draining into the lagoon. Infection rate seems to be lower in areas with higher salinities.

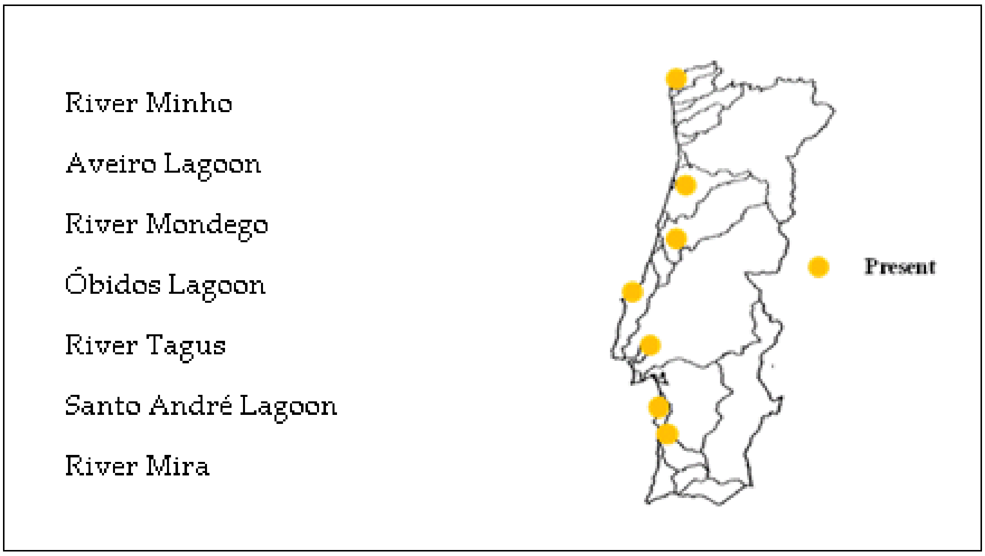


Figure 5.10. Reports of *Anguilliccloides crassus* in seven locations of Portugal (Antunes, 1990; Domingos, 2003; Neto *et al.*, 2010).

5.3 Trends in contaminants and diseases

Trend analysis (Maes *et al.*, 2008) of contaminants in yellow eel in Belgium over the period 1994–2005 indicated significant decreases in the average wet weight concentration of all PCB congeners, nearly all pesticides and four metals. PCBs were restricted in use and banned by the EU in 1985. Sediment core analyses have revealed that in various places in Europe the TEQ levels were dropping through the 1970s in some parts of Europe. Several time-series have indicated decreasing levels of contamination since the late 1970s/early 1980s demonstrating that the concerns and reductions were already visible in eel. Also concentrations of most pesticides have 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 its accumulation in the 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. Also, for some heavy metals, especially lead, arsenic, nickel and chromium, concentrations decreased in the eel. Cadmium and mercury, however, did not demonstrate decreasing trends and remain common environmental pollutants in the industrialized region of Flanders (Maes *et al.*, 2008) although in the Rhine estuary cadmium levels have dropped to about one percent of the levels in the early seventies (Anderberg and Stigliani, 1994).

In the Netherlands, de Boer *et al.* (2010) monitored PCBs, organochlorine pesticides (OCPs) and tetrabrominated diphenylether (tetra-BDE) in the rivers Rhine and Meuse and other Dutch canals, rivers and lakes over a period of 30 years. Temporal trends demonstrated a slow decrease of PCB concentrations since 1977, and decreases in OCP and tetra-BDE concentrations. Eels from the rivers Rhine and Meuse still exceed present European maximum residue limits for dioxin-like PCBs.

The Dutch Country Report presented data of temporal trends in chemicals in The Netherlands. Trends differ substantially between sampling locations, but an overall decline is apparent. This is illustrated in Figure 5.11 that shows the trend in PCB 153 in eels derived from Lake IJsselmeer and several places in the main rivers.

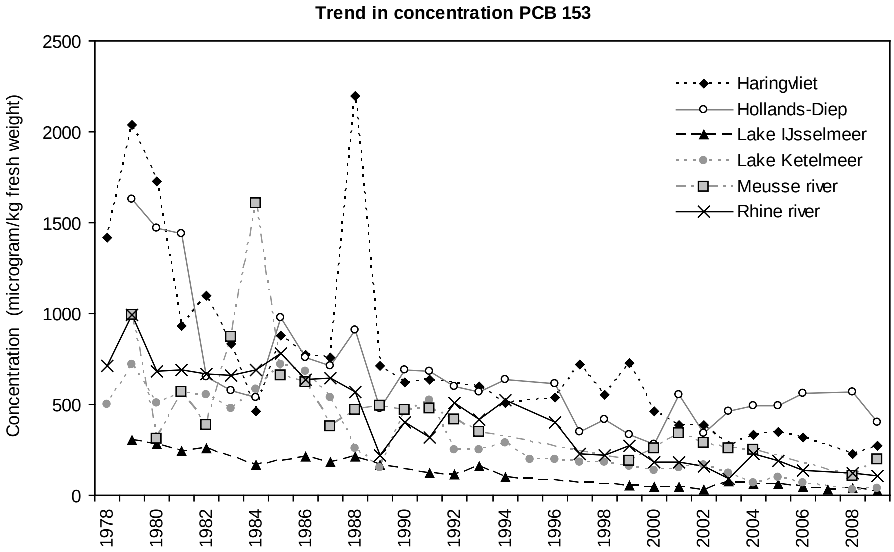


Figure 5.11. Temporal trend in PCB 153 in eel (data from IMARES and RIKILT).

It is clear that a substantial decrease in PCB concentrations was achieved in the eighties and nineties, but the decline has all but ceased. Compared with industrial contaminants like hexachlorobenzene (HCB) and hexachlorbutadiene (HCBD), both regulated in the Water Framework Directive (WFD), the extent of decrease in PCBs is low. HCB and HCBD have declined from levels comparable with PCB153 around 1980, to levels as low as 10–20 μg/kg fresh weight in the more polluted areas of the Dutch rivers in 2000. This is a residual concentration of only 0.1%. None of these compounds are being used anymore, but PCBs are clearly most persistent. This could be due to the higher amount produced, their lower volatility and/or their higher affinity to particles (organic matter), which results in a slower release to the environment where it can be taken up in the food chain, whereas other chemicals like HCB are washed out more quickly.

From the new information provided we may conclude that *Anguillicoloides* continues its spread across Europe. Infection levels are less in brackish water systems. Overall, the levels tend to decrease slightly. Figure 5.12 gives an overview of the colonization trend of the parasite after its introduction over Europe.

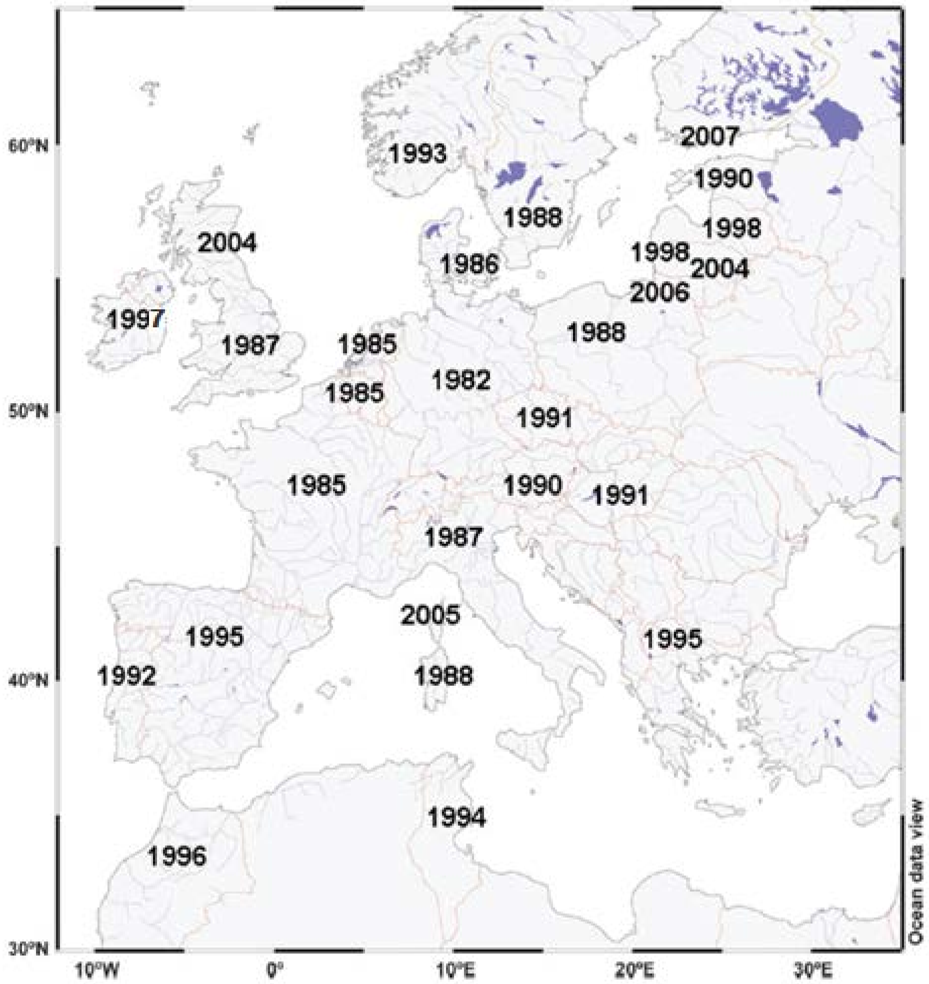


Figure 5.12. Dates of first reported records of *Anguilliccloides crassus* from the European eel (from Jacob *et al.*, 2009; Map source, Ocean Data View; Schlitzer, 2007).

Some reports mention that also climate change may induce changes in the abundance of diseases or parasites. In Spain, percentages of *E. tarda*-positive fish (40–84%) during the warm period (water temperature >20^{0}C) were significantly high in comparison with those detected during the cold period (<7,4%) (Esteve and Alcaide, 2010).

Considering diseases it is worth noting that eel viral diseases are of growing importance for eel farming as fish viruses can cause disease or even mortality when fish are under stressful conditions. The main viruses occurring in eel farms are the rhabdoviruses EVEX (Eel-Virus-European-X), and EVA (Eel-Virus-America), the birnaviridae EVE (Eel Virus European), and the herpes virus HVA (*Herpesvirus anguillae*) (van Ginneken *et al.*, 2005; Dipnet, 2007 for review). Among the viruses HVA particularly is widely distributed in eels (van Nieuwstadt *et al.*, 2001; van Ginneken *et al.*, 2005). The disease is characterized by ecchymoses in the pectoral fins, operculae and head, ulcerative skin, and congested gill epithelium (Haenen *et al.*, 2002). This virus can be isolated from many intensive production units although clinical signs are not obvious (van Nieuwstadt *et al.*, 2001). Morbidity is reported as usually high and mortality ranges from 0.5 to 10% (Haenen *et al.*, 2002). Percentages of up to 50% have been reported in conditions causing stress in fish. It can be severe in native populations and recurrent outbreaks in populations continue to be a serious source of economic loss due to depressed appetite and mortality.

Glass eels have been exposed to experimental autogenous vaccines with some success. Current practice is to expose juveniles to the latent infection of the resident population early in the growing phase. This induces disease in the glass eels, and a mortality which can vary between 2 and up to 25%. Survivors gain some protection from further infection with HVA (EFSA, 2008). As well as often causing significant mortalities, this process causes a significant drop in food intake and growth rate but is considered cost-effective by the industry at present in the absence of an approved commercial vaccine.

5.4 Scientific advances in understanding processes related to the impact of contaminants and diseases on the eel

Due to the international concern about the stock decline many studies have recently been undertaken to study the degree and the effects of pollution on the eel, resulting in an increasing quantity of information that demonstrates the negative impact of pollution on eel. However many gaps in our knowledge remain.

These advances in the science of the effects of contaminants on the eel have been reviewed recently by Geeraerts *et al.*, 2010 and by Elie and Gerard, 2009, and by WGEEL 2009 (ICES 2009). For example, there were reports of a weak negative correlation between TEQ levels in females and survival time in embryos (Palstra *et al.* (2006); a negative effect of cadmium on sexual maturation of female silver eels and on spawning migration by altering the lipid accumulation process (Pierron *et al.* (2008)); and on the alteration of transoceanic spawning migration through PCBs (van Ginneken *et al.* (2009)). But this information has been thoroughly reviewed during last year's session. Hence, we refer to WG Eel 2009 for a full review.

A new report available (Gravato *et al.*, 2010) compares the effects of pollution on glass and yellow eels from the estuaries of Minho, Lima and Douro Rivers (NW Portugal). The health status of eels with different types and levels of pollution was compared in relation to morphometric parameters, Fulton condition index (F index) and several biomarkers. Several of these parameters and biomarkers were demonstrated to be different between eels with different levels of pollution. Overall, this study indicates that eels from polluted estuaries may have a poorer health status compared with those from a reference estuary, and that adverse effects become more pronounced after spending several years in polluted estuaries.

At present it is difficult to attribute a direct cause and effect relationship between contaminants, or pathogens, and the sudden and rapid decline in recruitment in the early 1980s. It is possible that there has been a change in reproductive success of the eel since the early 1980s, contributed to by contaminants, and that this has continued through to the present. This would also feed into depensatory mechanisms, as discussed in previous reports (ICES 2005).

At the current low recruitment, and presumably spawning stock, the levels of contaminants (albeit somewhat lowered compared with the sixties and seventies) and the present high levels of swimbladder parasite infections may have an even larger negative effect on reproduction than before and may seriously inhibit the stock in its ability to recover.

5.5 Assessment of the quality of local eel stocks

For management purposes it is essential to understand the quality of eels present in European RBDs in order to evaluate the reproductive potential of the silver eels leaving those systems and to compare eel quality between systems. However, there are many uncertainties and comparing the effects of different 'quality' pressures might not be appropriate. Given the need to obtain this estimate of overall quality, WGEEL 2010 began the development of an Eel Quality Index. In our approach we used only a set of the apparently most important pressure parameters, and where sufficient data were available in the EEQD.

Quality classes with boundaries were available in literature for about 30 contaminants (Belpaire and Goemans, 2007). We selected Sum ICES 7 PCBs, Sum DDTs and Cadmium as important parameters (as suggested from the review by Geeraerts and Belpaire, 2010; Pierron *et al.*, 2008; van Ginneken *et al.*, 2009). With respect to diseases, *Anguillicoloides* and viruses seem also to have an impact (Palstra *et al.*, 2007; van Ginnekin *et al.*, 2005).

The quality classes for contaminants were developed based on the quantitative distribution of the data (means per location) for PCBs, OCPs and heavy metals in a large set of data. Reference values were fixed for each chemical as the 5 percentile value of the means of all sites. A common procedure was used to distinguish four quality classes as a measure of deviation from the reference value, and class boundary values were set. Class limits and reference values for each contaminant are listed in Table 5.4. Class boundary calculations were based on the distribution of the relationship between the recorded values and the reference value. Four stars represent unpolluted or low polluted eel. Eel with a slight to moderate pollution level are classified as two star eel. The more polluted sites are assigned as 2 (polluted) or 1 (strongly polluted) star eel. This classification system is not based on ecotoxicological data from dose effect studies, but from environmental concentrations in the field. Nevertheless, they may provide a practical tool for classifying the intensity of contaminants in eel.

This approach could be developed further in future to include other quality factors such as condition index, fat content, other diseases and a broader range of contaminants. Future research unravelling actual toxic effect levels of the various contaminants and eel sensitivity to threshold levels would greatly improve this classification.

EQI values might be presented as an average value for all pressure parameters available; or for one or a selection of parameters dependent of the availability of results.

As an example, the EQI values have been calculated in eels on the basis of their Sum 7 PCBs using recent data from case studies in Scotland, France, The Netherlands and Belgium. It should be stated that in most of the cases (Scotland, France, The Netherlands) sample sites may not be representative of the quality of eel across the whole country. Furthermore, the sampling strategy was not standardized (e.g. length classes) and this could give rise to additional variation in contaminant levels. Figure 5.13 is an illustration of a 'traffic light' system that could be applied in future to classify eel quality, based on standardized sampling programmes.

Table 5.4. Boundary values of the quality classes for a series of selected contaminants (as from Belpaire and Goemans, 2007) and diseases.

Class EQI value	Not impacted 4	Slightly impacted 3	Impacted 2	Strongly impacted 1
Cadmium (ng/g BW)	<5	5–<12,6	12,6–<31,7	≥31,7
Sum PCBs (ng/g BW)	<73	73–<183	183–<460	≥460
Sum DDTs (ng/g BW)	<40	40–<101	101–<254	≥254
Anguillicoloides	not infected	/	/	infected
EVEX	not present	/	/	present
HERPES Virus	not present	/	/	present

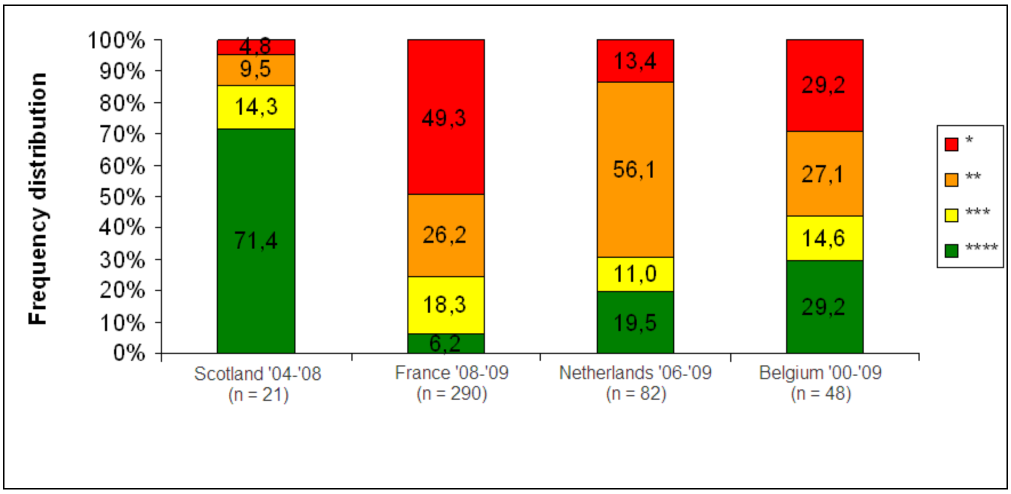


Figure 5.13. Demonstration of the Eel Quality Index (EQI) based on ICES 7PCBs from recent data provided in the EEQD from case studies in Scotland (MacGregor *et al.*, 2010; N=21 sites), France (ASSFA, 2009; N=290), The Netherlands (Data IMARES/RIKILT; N=82) and Flanders (Belpaire *et al.*, under review; N=48). Four stars (green) represent unpolluted or low polluted eel. Eel with a slight to moderate pollution level are classified as three (yellow) or two (orange) star eel. The more polluted sites are assigned as 2 (polluted) or 1 (strongly polluted) star eel (red). This classification system is not based on ecotoxicological data from dose effect studies, but from environmental concentrations in the field.

During WGEEL 2009, preliminary work was presented in order to estimate the effects of certain chemicals on the stock (ICES 2009). In the absence of clear relationships between body burden in muscular and ovarian eel tissue, we used the field concentrations measured in eel muscles and compared that with benchmarks derived from dose effect studies in whiting. We are aware that threshold and impact levels in eel may be very different from those in other fish species, that this is not strictly comparable and may only be treated as indicative and these comparisons must be treated with caution.

Von Westernhagen *et al.* (1989) compared tissue burden and hatching success in whiting indicate that chlorinated hydrocarbons accumulated in ovaries of North Sea whiting were related to significant negative effects on embryonic development and production of normal larvae at relatively low tissue concentrations. To enable determination of the toxic effect of each major contaminant, toxicity factors based on acute toxicity test towards adult fish were used. Through this approach, it could be determined that for the major contaminants SUMDDT (sum of p,p' DDT, p,p' DDD, p,p' DDE), dieldrin and SUMPCB (being the sum of CB 118/149, 153, 138, 180) a combined threshold value higher than 20, 10 and 200 μg kg^{-1} ovary wet wt. respectively impeded reproduction considerably (viable hatch below 10%).

From the data and figures presented in ICES 2009 it was clear that, overall, the body burden of PCBs, DDTs and dieldrin in eel over Europe is so high that in many eel we may expect negative effect on normal reproduction, although large variations between catchments or countries are noticeable.

Other studies on other fish species have become available since 2009 and we summarize these here for comparison with eel.

Vuorinen *et al*. (1997) analysed a large number of contaminants in Baltic salmon and observed both a positive correlation between mortality of young larvae and hexachlorobenzene, flame retardant PBDE and oxychlordane (concentrations around 10–30 μg/kg fresh weight), as well as a correlation between embryonic mortality on the one side and PCB and DDT on the other side. Significant embryonic mortality was observed when SUMPCBs and SUM DDTs were in the range of 200–300 μg/kg fresh weight.

Giesy *et al*. (2002) studied the effects of chronic dietary exposure to environmentally relevant concentrations to TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin) on reproduction in female rainbow trout (*Oncorhynchus mykiss*). This study has demonstrated adverse effects of TCDD to both adults and fry at concentrations comparable with current environmental concentrations. A body burden of 2 ng TEQ/kg fresh weight reduced the survival of young trout larvae strongly.

Foekema *et al*. (2008) observed, after eggs of sole (*Solea solea*) were exposed to the dioxine like PCB-126, that 50% of the larvae died prematurely at an internal dose of 100–200 ng TEQ/kg fresh weight (LC50=1000 pg/g fat weight).

Walker and Peterson (1994) demonstrated that the toxic effect of dioxins, either by maternal transfer or by injection into the egg, were similar. They also observed an LC50 at a TEQ level of 200 ng/kg egg fresh weight.

It is important to mention that under field situations, effects are induced by a mixture of compounds present. The effect of these mixtures on sole larvae survival is currently being investigated in The Netherlands.

Steevens *et al*. (2005) suggest a methodology to use and apply tissue residue-based toxicity benchmarks distributions rather than single-point estimates. Benchmark distributions allow the user to select a tissue concentration that is associated with the protection of a specific percentage of organisms, rather than linked to a species. The approach is demonstrated for 2,3,7,8-TCDD in early life stage fish. The calculated tissue residue benchmarks for 2,3,7,8-TCDD toxic equivalency (TEQ) derived from the resulting distribution could range from 0.057- to 0.699-ng TCDD/g lipid depending on the level of protection needed; the lower estimate is protective of 99% of fish species whereas the higher end is protective of 90% of fish species. Such an approach may be a useful to apply for species where dose effect studies are difficult to carry out, such as the eel.

Using this approach, these sensitivity levels relate to a TEQ in silver eel of 17 to 210 ng/kg wet weight (30% fat). Taking the lower end and applying a factor of 0.85 to correct for weight loss during migration (50% loss of lipid), silver eels are not likely to be negatively affected with a TEQ below 14 ng/kg wet weight, unless they are in the 1% high sensitivity group.

The request for additional eel quality data has paid dividends, highlighting further contamination. From the new data and reports presented at WG Eel 2010 (Subchapter 5.2), the high levels of contamination which were present in eel in some countries (e.g. Belgium) have also been found in other countries.

Figure 5.14 shows PCB body burden in eel (from individual sites and country means) from eight countries according to new data incorporated in the EEQD during the WGEEL 2010.

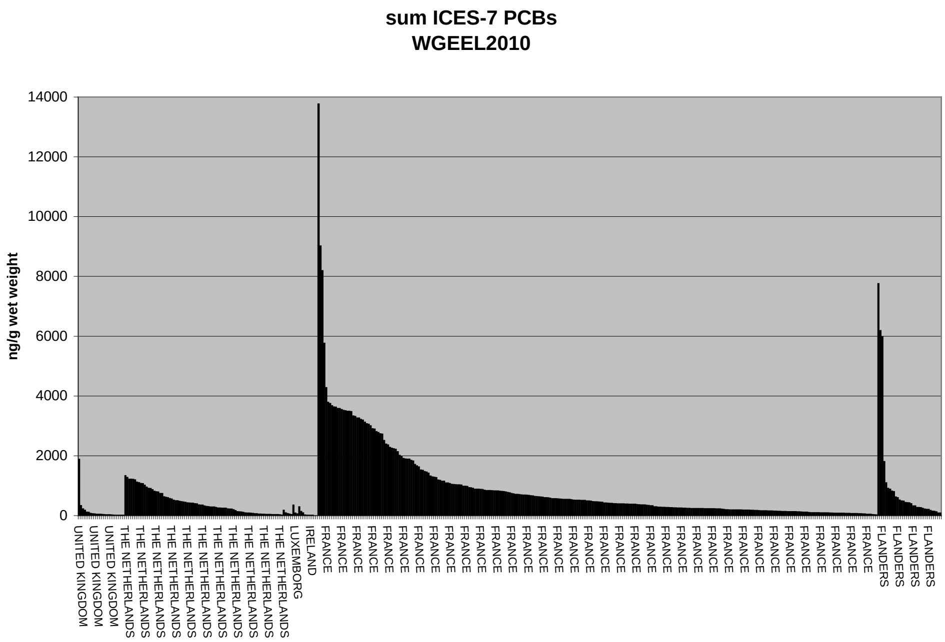
Compared with the whiting benchmark discussed in 2009 (ICES 2009) 63% of the new records exceed the whiting benchmark, 81% exceed the Belgian limit of consumption.

New dioxin levels were available but time constraints precluded the inclusion of all new dioxin data in the EEQD. Figure 5.15 shows dioxine levels in the Baltic Sea and in The Netherlands. As with PCBs, there is considerable spatial variation between sites. Levels in many eels are exceeding the benchmark for normal eel reproduction as suggested by Palstra *et al*. (2006).

Recent monitoring of *A. crassus* reveals no new trends of infection in Europe. Figure 5.16 provides new data from Germany, Ireland, Portugal and the Netherlands.

Over Europe the average prevalence in brackish waters ranges around 40%, but around 70% (up to 100%) in freshwater.

Average prevalence and infection intensities in some countries are shown in Figure 5.17. The highest values have been recorded in Germany and the Netherlands.



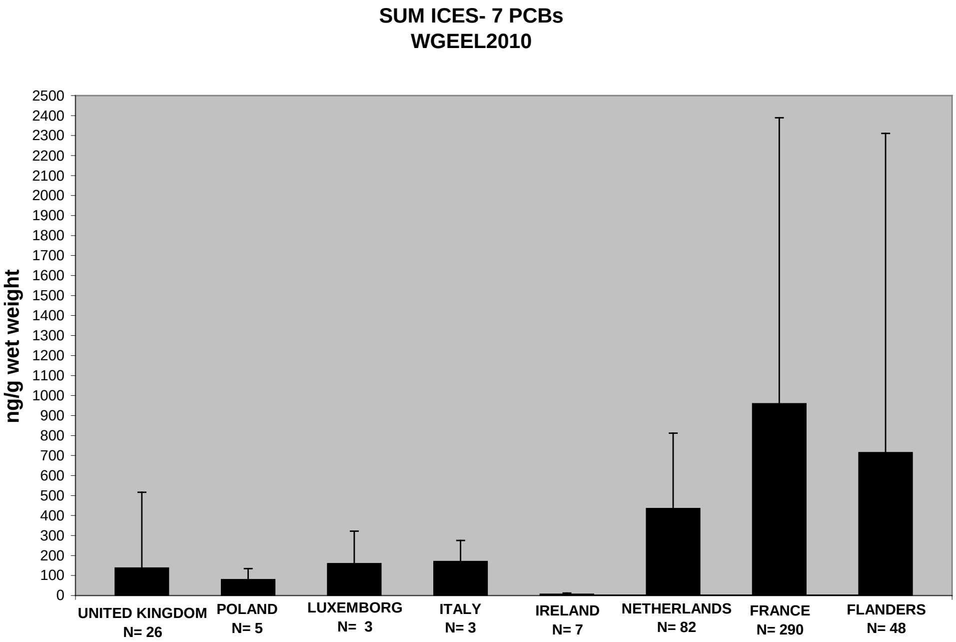


Figure 5.14. Sum of seven PCBs in eel from various countries according to new data incorporated in the EEQD during WG Eel. Data from U.K are from Scotland. Upper figure: distribution of individual records. Lower figure: means and standard deviation per country.

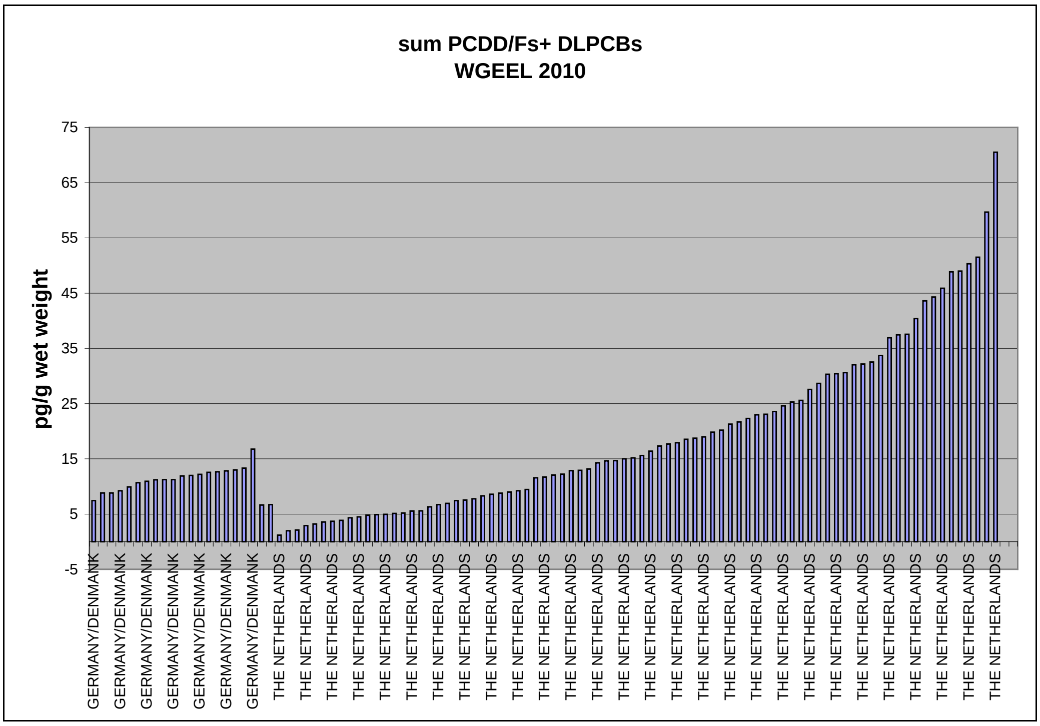


Figure 5.15. Dioxin levels in the Baltic Sea, and the Netherlands (EEQD, data provided in 2010).

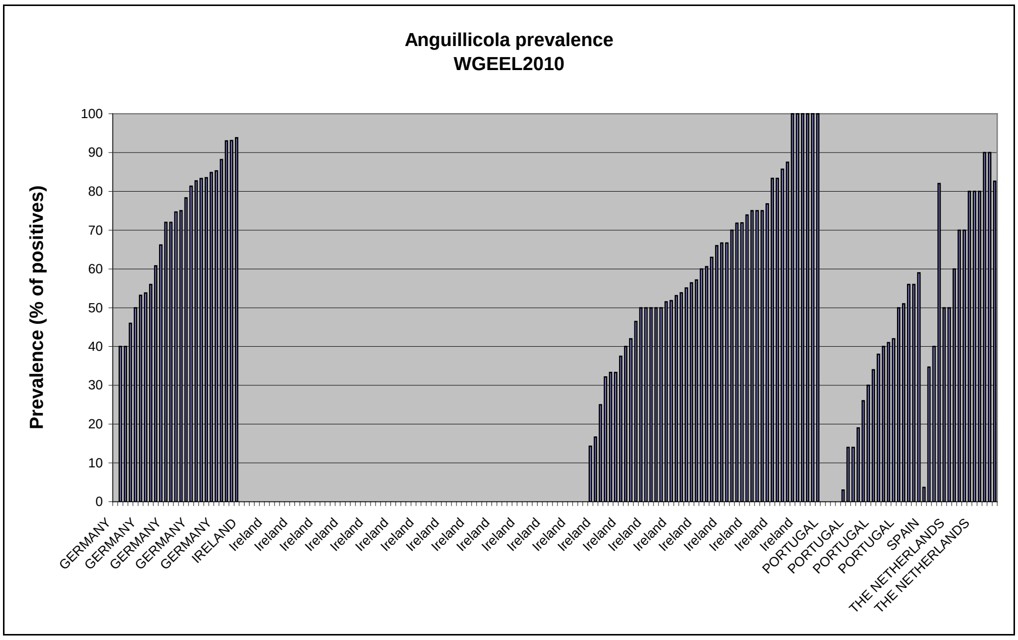


Figure 5.16. Prevalence of *A. crassus* in European eel from Germany, Ireland, Portugal, Spain, and the Netherlands (in 2010 delivered new data from EEQD).

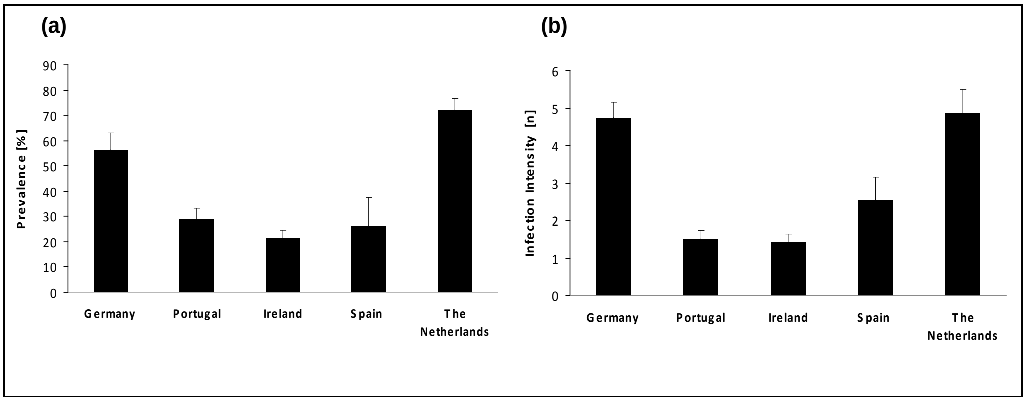


Figure 5.17. (a) Prevalence and (b) infection intensity of *A. crassus* in European eel from Germany, Portugal, Ireland, Spain, and the Netherlands. (Data are given as average ± standard error of the mean).

5.6 Fisheries closure as a human health measure due to contamination

As a consequence of the increased effort in monitoring the contamination in eel over its distribution area, and as the concentrations of contaminants in eel at a considerable number of sites/rivers/RBDs have attained levels which warrant immediate action to protect human health, fisheries have recently been closed in a number of rivers.

Fisheries have been closed for human health reasons in

- the Walloon region (Belgium):
  - Walloon part of the Meuse RBD
  - Walloon part of the Scheldt RBD
- France (closure since 2008)
  - RBD Seine-Normandy
    - River Orge
    - River Therouanne
    - River Esches
  - RBD Loire-Bretagne
    - River Ondaine
    - River Furan
  - RBD Rhône-Méditerranée-Corse:
    - River Gland
    - River Azergues
    - River Gier
    - River Cadière
    - River Huveaune

There is a prohibition of trading eels in Germany, Lower Rhein and main channel in Northrein-Westfalian.

In some other countries (i.e. France, Flanders) it is highly recommended by the local authorities not to consume eels sourced in these regions.

The Working Group recommends that it would be useful to evaluate the direct impact of these measures on silver eel escapement and stock restoration, i.e. what is the quantity and quality of eels 'saved' by these measures, and to what extent do they contribute to the stock considering their probable low quality?

5.7 Eel quality monitoring and Water Framework Directive

The Water Framework Directive aims to prevent further deterioration, and to protect and enhance the status of the aquatic ecosystems. The Directive selected a number of priority substances to monitor within the evaluation of the chemical status of our waterbodies. The monitoring strategy for chemicals, and especially for lipophilic substances, should integrate biotic measurements. The European eel in its yellow phase represents a good biomonitor model as it is widespread, sedentary, and accumulates many lipophilic substances in its muscle tissue. For important lipophilic contaminants such as PCBs and DDTs, many water-phase measurements are below detection levels even in places where these chemicals are omnipresent in aquatic biota. This is shown in Figure 5.18, where the percentage of samples higher than the detection limit is demonstrated for analysis in water compared with sediment and eel. From these figures it is obvious that a monitoring strategy with the aim to achieve good chemical status by analysing the water compartment only, will not represent the actual levels of contamination in the sediment and fish, and does not necessarily highlight the need for measures to diminish pollution levels in fish.

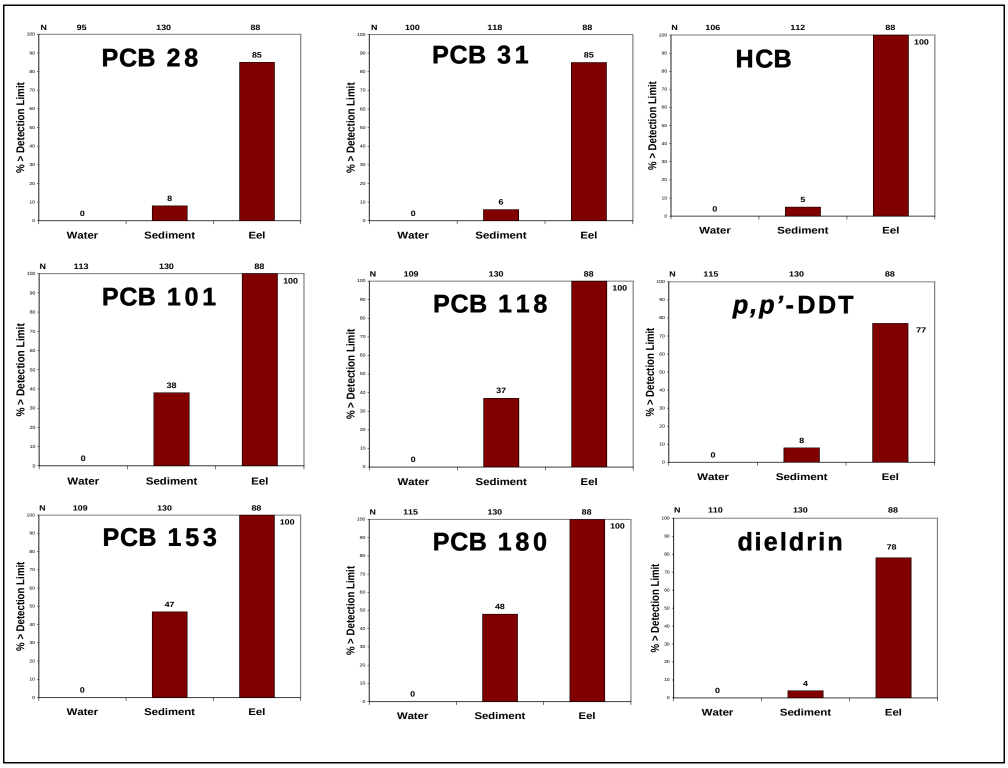


Figure 5.18. Percentage of measured concentrations of lipophilic substances in river water, sediment, and eels from the Grote Nete and Kleine Nete basins above the detection limit (%.DL; N is indicated (after Belpaire *et al.*, 2008).

5.8 Eel quality issues and future work-monitoring and research

In order to assess to what extent member countries will take account of quality issues in eel for their monitoring and research programmes in the near future, a questionnaire on eel quality (contaminants and diseases), was developed and distributed to all countries participating in the WGEEL meeting. Fourteen countries were represented in the survey.

In more than half of the countries (eight countries, 57%), there will be analyses of contaminants in eel in 2011. In four countries (29%) there will be no analyses of contaminants in 2011, whereas for the remaining two countries it is uncertain whether analyses will be carried out or not.

In ten countries (71%), there will be analyses of diseases in eel in 2011. In two countries (14%) there will be no analyses of diseases in 2011, whereas in one country analyses will only be performed if "there is a problem". At least eight countries (57%) will monitor infestations of the parasite *Anguillicoloides crassus*.

The monitoring of contaminants and diseases is carried out in the framework of EMPs in four of the countries surveyed, through the DCF in three countries, through the WFD in two countries, and human health programmes in two countries. Results of the monitoring of contaminants and diseases will be reported in the evaluations of the EMPs in 2012 in ten of the surveyed countries (71%).

Eel quality is taken into account in restocking measures in nine countries (64% of the countries performing restocking, two countries are not performing restocking), whereas eel quality is not taken into account in two countries. Quality of the receiving waterbody is taken into account in ten countries (83% of the surveyed countries performing restocking).

Research concerning the effects of eel quality is planned in at least seven countries (50%), whereas there are no plans in four countries. Research plans are uncertain for three countries (dependent on funding, etc.).

5.9 Conclusions to assessment of the quality of eel stocks

- A considerable amount of contaminant data in eel have been collected in several countries. The request for additional eel quality data has paid dividends, highlighting further contamination. The high levels of contamination in eel previously reported in some countries (e.g. Belgium), are now reported from other countries (e.g. France, The Netherlands, Germany). In some cases, levels were so high that immediate actions had to be taken and fisheries were closed as a human health measure.
- From the new data available, the WGEEL is concerned that contamination levels of the eels leaving some parts of Europe are high and therefore the quality of these eels is low, although considerable spatial variation and data gaps exist across Europe.
- Though interspecific comparisons should be viewed with caution, threshold values of toxic compounds in other fish species suggest that the body burden of pollutants in eels from many parts of Europe are so high that effects at the population level could occur.
- From the analyses presented in this chapter, it is clear that stock assessments should take into account the quality status of the eel. Estimation of an effective spawner biomass requires the quantification of

the adverse effects of contaminants, parasites, viruses and bacteria, and low fat levels on the capacity of eel to migrate and spawn successfully. The development of an EQI (Eel Quality Index) is an essential tool for this stock assessment.

- With respect to diseases, the *Anguillicoloides* parasite has been monitored in a considerable number of countries. The parasite continues its spread over Europe, but eel in some parts of Scotland and Ireland are not infected. Infection levels are less in brackish water systems. Overall, the intensity levels in waterbodies where the parasite is well established tend to decrease slightly compared with previous years.
- The update of the EEQD is a challenging and time consuming process, difficult to achieve during annual Working Group sessions, and hindered by the lack of standard sampling procedures and data reporting of contaminants and diseases.

5.10 Recommendations

The Working Group recommends that:

- the Eel Quality Index should be further developed in order to better assess the overall status of eel quality over river basins, and methodologies to incorporate Eel Quality Assessments in the quantitative assessments impact of levels of contaminants on effective spawner escapement in the EMUs should be developed. This will require monitoring and reporting.
- the direct impact of fisheries closure for human health’s sake on stock restoration should be evaluated, i.e. what is the quantity and quality of eels affected by these measures, and to what extent do they contribute to the stock, considering their low quality?
- the further development and management of the EEQD is supported at the international level.
- Research resulting in a better understanding of the eel’s sensitivity towards parasites, diseases, and contaminants under field conditions, with respect to reproduction, should be supported. When the effects of stress-factors can be quantified a better, clear decision about the importance of "eel-quality" in eel management can be made.

Examples given

- Maternal transfer (higher of lower contaminant load in eggs);
- Effect of contaminant loads in mother eel, eggs on hatching and larval survival;
- Effect of contaminants during continual growing phase on fertility and energy levels.

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6 Advances in eel science

Chapter 6 reviews any significant new research findings, particularly in relation to advances in artificial reproduction and oceanic factors. Reference is made to other Anguillid species. Chapter 6 addresses Terms of Reference g.

g) report on improvements to the scientific basis for advice on the management of European and American eel;

and has links to:

c/ 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 (in conjunction with SGAESAW 2);

e/ review and develop approaches to quantifying the effects of eel quality on stock dynamics and integrating these into stock assessments;

An extensive range of scientific papers have been published in the peer reviewed literature since the WGEEL 2009 meeting, a bibliography of which is presented at the end of Chapter 6. However, given the Terms of Reference for Chapter 6 and the current focus of WGEEL towards stock recovery it was decided to review only those scientific advances with direct relevance to stock management.

6.1 Recent genetic findings

Pujolar *et al.* (2009) examined glass eels arriving at two Mediterranean and two Atlantic sites which were tested for differences in genetic composition between regions using a total of 23 microsatellite loci developed from an expressed sequence tag (EST) library. Hierarchical analysis of molecular variance indicated a non-significant difference between regions (Mediterranean *v.* Atlantic), which contrasted to the significant differences observed between samples within regions. It is believed that the existence of a single spawning site for all *A. anguilla* individuals and extensive migration loop with great opportunity for mixing of individuals might explain the homogeneity in genetic composition found between the various regions. The observation of a (small-scale) pattern of genetic patchiness among intra-annual samples (arrival waves) within geographic regions did not conflict with the lack of (large-scale) geographic substructuring found between the Mediterranean and Atlantic regions, but was most likely a consequence of the strong dependence of *A. anguilla* on oceanic conditions in the Sargasso Sea which may result in a limited parental contribution to each spawning event. As a result, the comparison of Atlantic and Mediterranean *A. anguilla* glass eel recruits based on EST-linked microsatellite loci provides additional evidence supporting the hypothesis of panmixia of *A. anguilla* across Europe discussed previously in WGEEL 2009.

6.2 Artificial reproduction

6.2.1 *Anguilla anguilla*

While yellow eel and silver eels are fished and purchased for human consumption, aquaculture and stocking rely exclusively upon their supply of seed stock from glass eels caught in nature. The development of a self sustaining aquaculture industry has prompted investigations into the reproduction of the European eel in captivity (Pederson, 2003; Palstra *et al.*, 2005). Such investigations may ultimately relieve pressure on the requirement of glass eel seed stock and thus leave a greater proportion of wild glass eels which could be used in stocking programmes as per eel management plan requirements. This EU research project continues under the project "Reproduction of European Eel; towards a self-sustained aquaculture" (PROEEL). The production of glass eel from artificial propagation has apparently not advanced from what was previously reported in the 2009 WGEEL.

6.2.2 *Anguilla japonica*

It is now understood that in recent years Japanese researchers almost completely rely on using *A. japonica* broodstock which have been matured in the laboratories following the feminization of glass eel via the administration of -17β for 12–56 (Okamura *et al*., 2009). The reason for using feminized-laboratory matured broodstock is to offer the growing females a modified diet containing the optimal ratio of n-3 to n-6 fatty acids necessary for successful reproduction as well as growth of eel broodstock. Higher ratio of n-6 to n-3 fatty acids has been demonstrated to negatively affect embryogenesis (Furuita *et al*., 2007). Such research and development comes at significant cost with Japanese researchers commenting that the first glass eels produced are known as "the million Yen glass eel" ($10 000 per larva) and can regularly produce fertilized eggs every Friday. The Fisheries Research Agency in Yokohama have reported on their first successful breeding of second-generation cultivated eels by using sperm and eggs collected from those artificially raised from the eggs (Kurogi, H. 2010. Eel culture fully achieved. FRA News Vol. 23, pp 4–21). Details on this first complete cultivation of an Anguillid eel species have not (yet) been published.

The first ecologically based studies on the early life-history stages of anguillids were published in 2009, which were made possible due to artificial culture techniques making eggs, larvae, metamorphosing larvae, and glass eels of the Japanese eel all available at the same time. Two papers out of the IRAGO Institute were published using artificially cultured larvae, one demonstrating the ontogenetic changes in buoyancy of the eggs and larval stages (Tsukamoto *et al*., 2009) and one measuring the relative degree of negative phototaxis behaviour of leptocephali, metamorphosing larvae, and glass eels (Yamada *et al*., 2009).

6.2.3 Other anguillid species

Collaboration between teams from Mahurangi Technical Institute (MTI)/ New Zealand and Leiden University Institute of Biology, Leiden, Netherlands, has followed the protocol developed for the production of NZ shortfin eel larvae. As a result of this work, several batches of hybrids between *Anguilla anguilla* and *A. australis* have survived for up to 12 days post-hatching (in press). A hybrid between the European and the Japanese eels had previously been produced (Okamura *et.al*,, 2004). The above work is still ongoing while a new collaboration between the same NZ team and a German team has already started to develop a breeding protocol for the European eel based on results to date.

6.3 Advances in Japanese eel (*Anguilla japonica*) science

While European and American scientists are making progress in uncovering the offshore spawning migration and reproductive biology of the Atlantic eels *Anguilla anguilla* and *Anguilla rostrata*, Japanese researchers have had recent successes with the discovery of spawners of the Japanese eel (*Anguilla japonica*) at their spawning grounds west of the Mariana Islands (Chow *et al*., 2009), caught pre-leptocephali

(Tsukamoto, 2006) and artificially closed their reproductive cycle (Tanaka *et al*., 2001). More recently they have succeeded in collecting eggs at the southern end of the seamount chain of the West Mariana Ridge for the first time (Scientific American). Because egg development in eels lasts for only two days, these findings can be regarded as historical in the search for eel spawning grounds worldwide. Adults as well as newly hatched larvae have been captured at about 150 to 200 m depths in deep-water areas around the time of a new moon, corroborating the "New Moon Hypothesis" of Tsukamoto *et al.* (2003).

6.4 Eel quality

6.4.1 *Anguillicoloides crassus*

Infections by the parasitic nematode *Anguillicoloides crassus* was reported for several new European locations in scientific publications in 2010 (e.g. Costa-Dias *et al*., 2010; Kangur *et al*., 2010; Neto *et al*., 2010). The first record of *A. crassus* has also been done in American eels *Anguilla rostrata* in Canada (Rockwell *et al*., 2010) Sjöberg *et al*. (2009) hypothesized that parasite-induced damage to the swimbladder inhibited vertical migrations, and that infected *A. anguilla* tended to migrate in shallower coastal waters, relatively close to the shore, based on the distribution of recaptures.

6.4.2 Contaminants

Eel quality might be an important issue in understanding the reasons of the decline of the eel. Many studies have recently been undertaken to study the degree and the effects of pollution, diseases and parasites on the eel, resulting in an increasing quantity of information that demonstrates the negative impacts on eel. Eels are more vulnerable to pollution than other fish as they accumulate contaminants to a much higher degree than other species. A comprehensive literature review on the impacts of contaminants on metabolic functions and behaviour of the eel has recently been published (Geeraerts and Belpaire, 2010). Further, several authors have in recent years described the requirements of energy for spawners to migrate and reproduce, in terms of percentage of lipids in muscle wet weight, or on body weight basis (reviewed by Belpaire *et al*., 2009).

Several scientific publications have recently reported levels of a range of contaminants and muscle lipid levels in different European locations (Belgium: Roosens *et al*., 2010; Ireland: McHugh *et al*., 2010; Italy: Ferrante *et al*., 2010; Netherlands: de Boer *et al*., 2010; Kwadijk *et al*., 2010; Poland: Szlinder-Richert *et al*., 2010; Portugal: Gravato *et al*., 2010; Scotland: Macgregor *et al*., 2010).

In Belgium, comparison with previous studies reveals that PBDE and HBCD levels in Flemish eels have decreased rapidly between 2000 and 2006 at particular sites, but alarming concentrations are still found at industrialized hot spots. This is reflected in the human exposure to PBDEs and HBCDs through eel consumption. Intakes by recreational fishers were higher than average consumers and were above reference doses described in literature which may induce adverse effects (Roosens *et al*., 2010).

In Irish waters sampled, POP levels in general were determined to be low compared with those in other countries, with the exception of higher substituted dioxins (especially OCDD), in three samples collected from one catchment (Burrishoole) in the West of Ireland (McHugh *et al*., 2010). In the Italian River Garigliano, concentrations of DDTs and PCBs were determined (Ferrante *et al*., 2010). As regards toxicological risk for human health, in general OCPs residual levels were below the limits established for fish and aquatic products. Conversely, the concentrations of PCBs exceeded the limit set by the EU for terrestrial foods.

In the Netherlands, time-trend monitoring of polychlorinated biphenyls (PCBs), organochlorine pesticides (OCPs) and tetrabrominated diphenylether (tetra-BDE) over a thirty-year period revealed a slow decrease of PCB concentrations since 1977 (de Boer *et al*., 2010). Eels from the rivers Rhine and Meuse still exceed present European maximum residue limits for dioxin-like PCBs. Apart from some exceptions, OCP and tetra-BDE concentrations have also decreased, and more than those of PCBs. Fat contents of eel have decreased from an average of 21% to ca. 13% (de Boer *et al*., 2010). A 30 year time-series for perfluorooctanesulfonate (PFOS) revealed concentrations increasing by a factor of 2–4 until the mid-1990s, followed by a return to the initial levels (Kwadijk *et al*., 2010).

In Poland, the levels of OCPs, and PCDD/F/dl-PCBs in the muscle tissues of eels captured in the Vistula and Szczecin lagoons were compliant with European regulations (Szlinder-Richert *et al*., 2010).

On the Portuguese coast, the health status of eels developing in three estuaries with different types and levels of pollution was compared in relation to morphometric parameters, Fulton condition index and several biomarkers (Gravato *et al*., 2010). Eels from polluted estuaries displayed a poorer health status than those from a reference estuary, and adverse effects became more pronounced after spending several years in polluted estuaries.

In Scotland, when comparing 1986 and 1995 data, the results revealed considerable decreases in p,p'-DDE concentrations (Macgregor *et al*., 2010). More drastic reductions were evident for gamma-HCH, reflecting the tightening restrictions on pesticide use imposed over the previous decades.

6.5 Stocking

There is no new information on the outcome of previous stocking exercises in terms of survival of stocked material and through to eventual production of silver eel though some projects are due to deliver answers soon. WGEEL recommends that all stocking activity from now on be designed to include traceability of eel into later life stages by using permanent marking of bone structures. The best means of ensuring such traceability would be by batch or other marking methods. Oxytetracycline (OTC), alizarin and strontium have all been used successfully to mark otoliths in glass eel; PIT, CDTs, and other tags for larger stages.

6.6 Hydropower

Obstacles to migration in river systems are one of several factors causing the dramatic decline in the eel population. Barriers impede eels from colonizing large parts of catchments, thus reducing upstream density and additional production of large fecund spawners (Durif, *et al*., 2006). Power plants represent clear obstructions for downstream movement and cause a risk for the survival of silver eel. Mortalities, sublethal effects and the behaviour of downstream migrants have previously been examined by WGEEL in 2007 (Chapter 5).

New publications over the last two years are limited but include a study of silver eel migration at a Swedish power station (Calles *et al.*, 2010), and an experimental laboratory study examining the behavioural response of downstream migrating eel at bar racks (Russon *et al.*, 2010). In the Swedish river, downstream migrating silver eels could either enter the water intake of the power station, or they could use the former river channel via the spill gates. The overall passage success for radio-tagged eels released upstream of the power station was 30%, including both routes. The mortality for silver eels that entered the power station intake was (74%), and mortality was caused both by impingement on the bar racks in front of the turbine and injury caused by the turbine itself (Calles *et al.,* 2010). This mortality-risk increased with increasing body length. Bar racks are frequently installed in water intakes in front of turbines, and can cause mortality in eel when impinged on the rack. However, bar racks can under certain conditions be used to guide eel towards a bypass if the bypass is connected to openings in the rack. Increased rack efficiency (greater bypass passage and reduced impingement) was found when vertical bar racks (12 mm bar spacing) were angled relative to the flow instead of using horizontally inclined racks placed perpendicular to the flow (Russon *et al.,* 2010).

A new sensor has been developed in the Netherlands which can be guided through a power station to record pressures, accelerations and turbulences a fish can be exposed to as it passes through turbines. This sensor has the added advantage of being able to provide such provide information without the need for using real fish in the studies. However, there is a need for calibrations of what the data recorded by the sensor really means in terms of eel injuries and eel mortality.

6.7 Oceanic phase

6.7.1 Adult migration

European eels are believed to undertake a ca. 5000 km spawning migration from Europe to the Sargasso Sea, during which time they develop to sexual maturity. The conditions eels experience, and the types of behaviours that they exhibit, are therefore of direct interest to biologists and aquaculturists alike. However, the methodological and logistical difficulties related to tracking eels in the Atlantic Ocean have prevented empirical studies on the subject. Satellite tag technology offers a solution to these difficulties but, until recently, the sizes of available tags had precluded tracking animals as small as European eels. The EU EELIAD project was designed to examine the migratory behaviour of female European eels during their spawning migration, based on data collected with miniaturized pop-up satellite archival transmitters (PSAT) deployed in 2006 and 2008, and with archival tags deployed in 2008 and 2009.

The project was able to track eels for up to five months and >2000 km from release sites. Eels migrated towards the Sargasso Sea at a range of speeds consistent with previous acoustic tracking research (5 km d- 1 to 25 km d-1). During their oceanic migration, the eels adopted a diel vertical migration pattern, ascending rapidly into shallow water (~200 m) at dusk and returning rapidly into deep water (up to 1200 m) at dawn. Due to the large depth change at dawn and dusk, eels experienced a temperature gradient of up to 5°C twice daily and a pressure change of up to 100 bar. Across the sampled population, migration was observed between 1.5°C and 12°C.

Similar results have been found in studies into the oceanic migrations of silver phase New Zealand longfin eels (*Anguilla dieffenbachii*) which exhibited diel vertical migration pattern ranging from close to the surface to 980 m deep (Jellyman and Tsukamoto, 2005), while Japanese eel (*Anguilla japonica*) were reported to migrate in diurnal cycles from depths between < 400 to 600 m (Tsukamoto, 2009).

6.7.2 Spawning grounds

Previously, small recently hatched larvae of Atlantic eels had been observed south of distinct temperature fronts located in the Subtropical Convergence Zone of the Sargasso Sea (Kleckner and McCleave, 1988). The recent investigation by Munk *et al*. (2010) has provided new insights into the physiochemical properties surrounding these proposed spawning grounds and help to refine the search for their exact location. In addition the composition of plankton communities in this area, (specifically the presence of gelatinous species) is suggested as being an essential factor in the survival of leptocephali (Riemann *et al*., 2010).

6.7.3 Juvenile migration

In the review by Bonhommeau *et al*. (2010) into the duration of migration of Atlantic *Anguilla* larvae, it was found that larval migration estimates varied between seven months and more than two years in both species. They reviewed the different methods used to estimate the duration of larval migration and critically described their possible sources of misinterpretation. They evaluated the consistency of these methods against the current knowledge of the ecology and physiology of eel larvae and the physical oceanography. While a moderate discrepancy in migration duration was found between methods for the American eel, the discrepancy was large in the European eel. In this species, otolith microstructure studies indicated migration durations between seven and nine months, while other methods pointed to durations of about two years. They concluded that estimates in favour of a long migration duration seemed more robust to methodological caveats than methods estimating short durations of migration.

6.7.4 Climate change

The impact of climate change must be taken into account, as its interactions with other anthropogenic factors, has the potential to compound impacts at various stages of eel biology, (Collins *et al*., 2007; IPCC, 2007).

Climate change continues to modify environmental conditions and each species must adapt accordingly, either by remaining in current habitats and adapting phenotypically or by migrating to more suitable sites. Very few studies concerning the influence of climate change on eels have been carried out but the effects of climate change have been noted in other fish species (FSBI Fish and Climate Change Conference, Belfast 2010).

Models have been established on a larger scale which explain the suitability of European drainage basins for the 28 European diadromous fish species (Béguer *et al*., 2007; Lassalle, 2008; Lassalle *et al*., 2008; 2009a; Lassalle *et al*., 2009b; Lassalle and Rochard, 2009). They predict the potential future distribution according to several climate change scenarios. Some species have the possibilities of expanding their current area but for the majority of species, the area of distribution will diminish and they will be forced to move. Eel has a particular status because it is a panmitic species and is exposed to climate change during its marine phase and continental migration to inland waters; North and East, towards the black sea.

In its 2008 report, WGEEL reviewed the role that oceanic factors play in regulating recruitment to the continent. The historical record demonstrated strong evidence that the abundance and size of glass eel recruiting to the continent have the same periodicity as the natural climate oscillations. However, the steep decline in recruitment between 1980 and 1983 and the failure for this to recovery in the following years cannot be easily explained by oceanic factors alone and is out of phase with the NAO. Continual climate and ocean warming in the last decades has probably overridden the effect of the NAO (WGEEL 2008; Table 6.1).

Table 6.1. Oceanic parameters and their putative effects on eels, (source Report WG Eel 2008 updated for 2010).

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 progressive northerly position of the Gulf Stream. Impacts larval migration.	Dekker, 2004, Durif *et al.*, 2010
Sargasso Sea Sea Surface Temperatures (SS-SST), average 0-100 m deep	Marine production increases with sea surface temperature in the cooler waters from the North Atlantic but decreases in warmer waters. This effect is due to a reduced vertical mixing. Impacts larval feeding.	Bonhommeau *et al.*, 2008 Durif *et al.*, 2010
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. Impacts larval migration.	Friedland *et al.*, 2007
Mean Temperature of the northern hemisphere (NHT)	Would reflect climate change and extrapolate primary production. Impacts larval feeding.	Knights and Bonhommeau, unpublished
Gulf Stream Index (GSI)	Latitude of the Gulf Stream, from monthly charts of the north wall. Impacts larval migration	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. Impacts larval migration	Bonhommeau, 2008
PP (Bermuda biological station, North of spawning area)	Primary production. Considered as a good proxy for leptocephali food. Impacts larval feeding.	Bonhommeau, 2008 Riemann *et al.*, 2010
Sea surface temperatures anomalies (SSTA)	Food availability expected to be reduced during warm high SSTA periods due to reduced spring mixing, nutrient recirculation and productivity. Impacts larval feeding	Knights, 2003

Oceanic factor	Mechanism of influence	Author
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 eel 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. Impacts larval migration.	Friedland *et al*., 2007 Munk *et al*., 2010

6.8 Conclusions and recommendations

Most elements of the natural reproduction of *A. anguilla* and *A. rostrata,* including their migration routes and spawning grounds, still remain unknown, although investigations into their artificial reproduction are yielding some useful information.

Mitigation measures against the impact of hydropower on silver eel migration remain insufficiently studied and need to be coordinated.

Although new information has been provided on contaminant and infection levels of diseases and parasites in several countries, data are still missing from large parts of the distribution area and on converting from pollutant levels to eel sensitivity and impact of different levels on the viability of eel.

It is recommended that there is continuing research into the reproductive process, with particular emphasis on the effects and threshold levels that repro-toxins may have on spawner quality and continued research into improving early larval survival in culture.

All stocking activity from now on be designed to include traceability of eel into later life stages (i.e. batch marking of otoliths).

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7 Research needs

- Due to the urgent need for EU Member States of gathering data for imminent reporting under the EU Eel regulation, some experimental programmes for yellow eel stock assessment and Silver Eel escapement estimation have been begun without time taken to test for the best methods. Coordinated testing of methods associated with M–R and inter-comparison between practitioners could is required to provide advice on which methods are best suited to particular situations.
- Further research is required into mitigation methods to reduce eel mortality and facilitate migration at hydropower facilities.
- Until much more is known of the spawning location and biology of European eels, there will remain a need to conduct research on the Marine phase including searches for spawning eels. Recent advances on *A. japonica* in the pacific, migration tracking, such as in EU EELIAD, and laraval surveys should be built upon to target further marine phase investigations.
- The proportion of eels which never enter freshwater, or spend much of their lives in marine and coastal waters, is still not known in many regions. This requires surveys and documentation with a view to quantifying the contribution of marine and coastal eel to spawner production.
- A proposal for a project (study group or workshop) on Sustainable (eel) Fisheries is given in Annex 7.

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Annex 2: Agenda

Thurs 9th September

9.00	Get organized
9.30–10.00	Welcome RP
	Local Welcome & Information: Wysujack
10.00–10.30	Intro to Working Group, ToR, etc. RP
10.30	Coffee
10.45–11.15	Data Group – introduced by Briand
11.15–11.45	Report from SGIPEE – led by Beaulaton
11.45–12.30	Round table discussion on International Assessment & post-eval.
12.30–13.30	Lunch
13.30–15.00	Local Eel Assessments, inc. Saline Waters methods – led by Aprahamian
	DGMARE POSE – Alan Walker (20 min)
	Mark–recapture experiments, (2 x 10 min) - Dekker/Rosell
	Yellow to silver overview - Durif, (15 min)
15.00–15.30	Round table discussion on Local Eel Assessments, & methods
15.30	Coffee
16.00–16.30	Eel Quality database and process update - Belpaire
16.30–16.45	Advances in Science - Evans
16.45–17.00	EELIAD - Walker
17.00–18.00	Breakout to get organized, subgroups, rapporteurs, approaches, etc.

Friday-Sub-groups breakout

17.00 barbeque hosted by Klaus' Institute, and informal discussion on Eel Management Plans

Saturday-Sub-groups breakout

16.30–18.00 Plenary

Sunday-morning; subgroups breakout

(Subgroup leaders meeting on Advice during the morning)

14.00–15.30 Plenary (optional depending on progress)

Sunday-afternoon; Draft conclusions and recommendations draft 1

15.30–18.00 Producing draft report [**DEADLINE 18:00**]

Monday

9.00–13.00 Circulate draft advice & report for comment

14.00–18.00 Discuss and agree Conclusions, and agree technical advice

Tuesday

9.00–14.00 Discuss report, and Recommendations. **Conclude at 16.00.**

Annex 3: WGEEL Terms of Reference for the next meeting

2010/2/ACOM18 The **Joint EIFAC/ICES Working Group on Eels** [WGEEL] (Chaired by Cedric Briand*, France and XX (to be confirmed by EIFAC as well)), will meet in Lisbon, Portugal, 5–9 September 2011, to:

1) assess the trends in recruitment and stock, for international stock assessment, in light of the implementation of the Eel Management Plans; examine criteria for defining a recovery;
2) develop and test methods to post-evaluate effects of management actions at the stock-wide level (in conjunction with SGIPEE), including quality assurance checking of Eel Management Unit biomass estimates;
3) 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; test data scenarios at the local level;
4) provide practical advice on the establishment of international databases on eel stock, fisheries and other anthropogenic impacts, as well as habitat and eel quality related data, and review data quality issues and develop recommendations on their inclusion, including the impact of the implementation of the eel recovery plan on time-series data and on stock assessment methods;
5) review and develop approaches to quantifying the effects of eel quality on stock dynamics and integrating these into stock assessments; develop references points for evaluating impacts on eel;
6) respond to specific requests in support of the eel stock recovery Regulation, as necessary; and
7) report on improvements to the scientific basis for advice on the management of European and American eel.

Material and data for the meeting must be available to the Group no later than 14 days prior to the starting date.

WGEEL will report by date 21st September 2011 for the attention of WGRECORDS, SGEF, ACOM and EIFAC.

Annex 4: Tables from Chapter 2

Table 2.1. Series information for recruitment time-series.

Name	area	country	Short name	Begin	End	Duration	Missing	Number of	sampling_type	stage	Country code	unit
Ijzer Nieuwpoort scientific estimate	North sea	Belgium	Yser	1960	2009	50	0	50	scientific estimate	glass eel	BE	Index
Vidaa Højer sluice commercial catch	North sea	Denmark	Vida	1966	2009	44	3	41	commercial catch	glass eel	DK	Kg
Adour Estuary (CPUE) commercial CPUE	Atlantic Ocean	France	AdCP	1975	1989	15	0	15	commercial CPUE	glass eel	FR	Index
Adour Estuary (catch) commercial catch	Atlantic Ocean	France	AdTC	1981	2009	29	0	29	commercial catch	glass eel	FR	Index
Gironde Estuary (CPUE) commercial CPUE	Atlantic Ocean	France	GiCP	1938	2010	73	1	72	commercial CPUE	glass eel	FR	Kg
Gironde scientific estimate	Atlantic Ocean	France	GiSc	1969	2009	41	2	39	scientific estimate	glass eel	FR	Kg
Gironde Estuary (catch) commercial catch	Atlantic Ocean	France	GiTC	1977	2009	33	3	30	commercial catch	glass eel	FR	Kg
Loire Estuary commercial catch	Atlantic Ocean	France	Loi	1953	2010	58	0	58	commercial catch	glass eel	FR	t
Sèvres Niortaise Estuary commercial CPUE	Atlantic Ocean	France	SevN	1980	2009	30	0	30	commercial CPUE	glass eel	FR	Kg
Vilaine Arzal trapping all	Atlantic Ocean	France	Vil	1982	2010	29	5	24	trapping all	glass eel	FR	Kg
Ems Herbrum commercial catch	North sea	Germany	Ems	1971	1990	20	0	20	commercial catch	glass eel	DE	Kg
Erne Ballyshannon trapping all	British Isle	Ireland	Erne	1946	2001	56	0	56	trapping all	glass eel	IE	Kg
River Feale	Atlantic Ocean	Ireland	Feal	1976	2009	34	0	34	trapping all	glass eel	IE	Kg
River Inagh	Atlantic Ocean	Ireland	Inag	1962	2008	47	25	22	trapping all	glass eel	IE	Index
River Maigue	Atlantic Ocean	Ireland	Maig	1949	2010	62	5	57	trapping all	glass eel	IE	cpue
Shannon Ardnacrusha trapping all	British Isle	Ireland	ShaA	1967	2010	44	1	43	trapping all	glass eel	IE	Kg
Tiber Fiumara Grande commercial catch	Mediterannean Sea	Italy	Tibe	1992	2009	18	1	17	commercial catch	glass eel	I	Kg
Katwijk scientific estimate	North sea	Netherlands	Katw	1961	2008	48	1	47	scientific estimate	glass eel	NL	Kg
Lauwersoog scientific estimate	North sea	Netherlands	Lauw	1928	2008	81	40	41	scientific estimate	glass eel	NL	cpue
Rhine DenOever scientific estimate	North sea	Netherlands	RhDO	1960	2009	50	0	50	scientific estimate	glass eel	NL	Kg
Rhine Ijmuiden scientific estimate	North sea	Netherlands	RhIj	1992	2009	18	0	18	scientific estimate	glass eel	NL	Kg
Stellendam scientific estimate	North sea	Netherlands	Stel	1991	2010	20	0	20	scientific estimate	glass eel	NL	Kg
Bann Coleraine trapping partial	British Isle	Northern Ireland	Bann	1959	2010	52	2	50	trapping partial	glass eel	NI	Kg
Minho portugese part commercial catch	Atlantic Ocean	Portugal	MiPo	1975	2010	36	0	36	commercial catch	glass eel	PT	t
Nalon Estuary commercial catch	Atlantic Ocean	Spain	Nalo	1942	2009	68	0	68	commercial catch	glass eel	ES	Kg
Minho spanish part commercial catch	Atlantic Ocean	Spain	MiSp	1975	2006	32	0	32	commercial catch	glass eel	ES	cpue
Ebro delta lagoons	Mediterannean Sea	Spain	Ebro	1979	2006	28	2	26	commercial catch	glass eel	ES	Kg
Albufera de Valencia commercial catch	Mediterannean Sea	Spain	Albu	1971	2009	39	0	39	commercial catch	glass eel	ES	Kg
Albufera de Valencia commercial CPUE	Mediterannean Sea	Spain	AlCP	1960	2010	51	0	51	commercial CPUE	glass eel	ES	Kg
Ringhals scientific survey	North sea	Sweden	Ring	1946	2009	64	9	55	scientific estimate	glass eel	SE	cpue
Viskan Sluices trapping partial	North sea	Sweden	Visk	1985	2009	25	14	11	trapping partial	glass eel	SE	Kg
IYFS scientific estimate	North sea	Sweden	YFS1	1994	2005	12	3	9	scientific estimate	glass eel	SE	Kg
IYFS2 scientific estimate	North sea	Sweden	YFS2	1996	2008	13	3	10	scientific estimate	glass eel	SE	Kg
Severn EA commercial catch reports	British Isle	United Kingdom	SeEA	1900	2009	110	12	98	commercial catch	glass eel	GB	Number
Severn HMRC nett trade export	British Isle	United Kingdom	SeHM	1985	2009	25	0	25	commercial catch	glass eel	GB	Kg
Meuse Lixhe dam trapping partial	North sea	Belgium	Meus	1975	2010	36	0	36	trapping partial	yellow eel	BE	Index
Guden Å Tange trapping all	North sea	Denmark	Gude	1964	2010	47	1	46	trapping all	yellow eel	DK	Index
Harte trapping all	Baltic	Denmark	Hart	1971	2010	40	0	40	trapping all	yellow eel	DK	Index
Shannon Parteen trapping partial	British Isle	Ireland	ShaP	1992	2007	16	3	13	trapping partial	yellow eel	IE	Kg
Den Burg fyke net (CPUE)	North sea	Netherlands	DenB	1972	2010	39	2	37	scientific estimate	yellow eel	NL	Kg
Imsa Near Sandnes trapping all	North sea	Norway	Imsa	1924	2008	85	6	79	trapping all	yellow eel	NO	Index
Dalälven trapping all	Baltic	Sweden	Dala	1977	2010	34	0	34	trapping all	yellow eel	SE	Kg
Göta Älv trapping all	North sea	Sweden	Gota	1971	2009	39	0	39	trapping all	yellow eel	SE	Index
Kävlingeån trapping all	Baltic	Sweden	Kavl	1923	2008	86	28	58	trapping all	yellow eel	SE	Kg
Lagan trapping all	North sea	Sweden	Laga	1986	2008	23	0	23	trapping all	yellow eel	SE	Kg
Mörrumsån trapping all	Baltic	Sweden	Morr	1975	2009	35	0	35	trapping all	yellow eel	SE	Kg
Motala Ström trapping all	Baltic	Sweden	Mota	1951	2009	59	3	56	trapping all	yellow eel	SE	Kg
Rönne Å trapping all	North sea	Sweden	Ronn	1925	2009	85	0	85	trapping all	yellow eel	SE	t

Table 2.2. Recruitment raw data. These data remain the property of the Country of origin and should not be used without the permission of the data provider.

North sea	North sea	Atlantic Ocea	Atlantic Ocea	Atlantic Ocea	Atlantic Ocea	Atlantic Ocea	Atlantic Ocea	Atlantic Ocea	Atlantic Ocea	North sea	British Isle
Belgium	Denmark	France	France	France	France	France	France	France	France	Germany	Ireland
Kg	Kg	Kg	cpue	Kg	t	Index	cpue	t	cpue	Kg	Kg
North sea	North sea	Atlantic Oce	Atlantic Oce	Atlantic Oce	Atlantic Oce	Atlantic Oce	Atlantic Oce	Atlantic Oce	Atlantic Oce	North sea	British Isle
Ijzer Nieuwpoort scientific estimate	Vidaa Højer sluice commercial catch	Vilaine Arzal trapping all	Sèvres Niortaise Estuary commercial CPUE	Loire Estuary commercial catch	Gironde Estuary (catch) commercial catch	Gironde scientific estimate	Gironde Estuary (CPUE) commercial CPUE	Adour Estuary (catch) commercial catch	Adour Estuary (CPUE) commercial CPUE	Ems Herbrum commercial catch	Erne Ballyshannon trapping all
Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Glass eel

Atlantic Ocea	Atlantic Ocea	Atlantic Ocea	British Isle	editerannean S	North sea	North sea	North sea	North sea	North sea	British Isle	Atlantic Ocea
Ireland	Ireland	Ireland	Ireland	Italy	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	lorthern Irelan	Portugal
Kg	Kg	Kg	Kg	t	Index	Index	Index	Index	Index	Kg	Kg
Atlantic Oce	Atlantic Oce	Atlantic Oce	British Isle	Mediterranea	North sea	North sea	North sea	North sea	North sea	British Isle	Atlantic Oce
River Feale	River Inagh	River Maigue	Shannon Ardnacrusha trapping all	Tiber Fiumara Grande commercial catch	Katwijk scientific estimate	Lauwersoog scientific estimate	Rhine DenOever scientific estimate	Rhine Ijmuiden scientific estimate	Stellendam scientific estimate	Bann Coleraine trapping partial	Minho portugese part commercial catch
Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Glass eel

Atlantic Ocea	Atlantic Ocea	editerannean S	editerannean S	editerannean S	North sea	North sea	North sea	North sea	British Isle	British Isle	North sea
Spain	Spain	Spain	Spain	Spain	Sweden	Sweden	Sweden	Sweden	UK	UK	Belgium
Kg	Kg	Kg	Kg	cpue	Kg	Kg	Index	Index	Kg	Kg	Kg
Atlantic Oce	Atlantic Oce	Mediterranea	Mediterranea	Mediterranea	North sea	#N/A	North sea	North sea	British Isle	British Isle	North sea
Nalon Estuary commercial catch	Minho spanish part commercial catch	Ebro delta lagoons	Albufera de Valencia commercial catch	Albufera de Valencia commercial CPUE	Ringhals scientific survey	Viskan Sluices trapping all	IYFS scientific estimate	IYFS2 scientific estimate	Severn EA commercial catch reports	Severn HMRC nett trade export	Meuse Lixhe dam trapping partial
Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Glass eel	Yellow eel

North sea	North sea	British Isle	North sea	North sea	Baltic	North sea	Baltic	North sea	Baltic	Baltic	North sea
Denmark	Denmark	Ireland	Netherlands	Norway	Sweden	Sweden	Sweden	Sweden	Sweden	Sweden	Sweden
Kg	Kg	Kg	Index	Number	Kg	Kg	Kg	Kg	Kg	Kg	Kg
North sea	Baltic	British Isle	North sea	North sea	Baltic	North sea	Baltic	North sea	Baltic	Baltic	North sea
Guden Å Tange trapping all	Harte trapping all	Shannon Parteen trapping partial	Den Burg fyke net (CPUE)	Imsa Near Sandnes trapping all	Dalälven trapping all	Göta Älv trapping all	Kävlingeån trapping all	Lagan trapping all	Mörrumsån trapping all	Motala Ström trapping all	Rönne Å trapping all
Yellow eel	Yellow eel	Yellow eel	Yellow eel	Yellow eel	Yellow eel	Yellow eel	Yellow eel	Yellow eel	Yellow eel	Yellow eel	Yellow eel

*** Data resides with the WG/ICES and can be requested from ICES or a Working Group member.**

Contact the Country Report Author for permission before using for analysis.

Table 2.3. GLM predictions for selected years according to the area in percentage of mean [1960–1979].

	Glass eel		Yellow eel
	Elsewhere Europe	North sea	Europe
1950	0.58	0.26	1.68
1951	0.49	0.28	2.10
1952	0.35	1.07	2.12
1953	0.49	0.90	3.42
1954	0.67	1.45	1.66
1955	0.44	1.38	2.53
1956	0.48	1.06	1.22
1957	0.59	0.58	1.35
1958	0.44	1.00	1.38
1959	0.68	1.36	2.86
1960	1.26	1.67	1.40
1961	1.08	1.04	1.61
1962	1.40	1.83	1.46
1963	1.71	2.47	1.19
1964	0.90	1.04	0.57
1965	1.24	0.80	0.99
1966	0.77	0.78	1.37
1967	0.79	0.90	0.94
1968	1.32	1.09	1.94
1969	0.57	0.76	1.57
1970	0.97	0.94	0.65
1971	0.55	0.56	0.55
1972	0.54	0.84	0.90
1973	0.60	0.45	1.10
1974	0.91	1.10	0.53
1975	0.69	0.52	0.98
1976	1.12	0.89	0.37
1977	1.03	0.87	0.66
1978	1.14	0.68	0.64
1979	1.40	0.77	0.56
1980	1.18	0.59	0.86
1981	0.91	0.47	0.48
1982	1.02	0.30	0.53
1983	0.50	0.26	0.43
1984	0.58	0.09	0.35
1985	0.53	0.11	0.57
1986	0.36	0.10	0.38
1987	0.65	0.12	0.39
1988	0.66	0.09	0.47
1989	0.47	0.05	0.27
1990	0.39	0.15	0.22
1991	0.18	0.03	0.31
1992	0.25	0.06	0.15
1993	0.29	0.06	0.09
1994	0.30	0.08	0.43
1995	0.33	0.06	0.09
1996	0.29	0.05	0.08
1997	0.35	0.05	0.15
1998	0.21	0.03	0.11
1999	0.24	0.05	0.16
2000	0.20	0.05	0.12
2001	0.10	0.009	0.12
2002	0.15	0.027	0.29
2003	0.12	0.026	0.15
2004	0.08	0.007	0.16
2005	0.10	0.016	0.05
2006	0.07	0.005	0.09
2007	0.07	0.014	0.17
2008	0.06	0.006	0.05
2009	0.04	0.010	0.06
2010	0.06	0.012	0.02
2005–2009	**0.07**	**0.01**	**0.09**

Table 2.4. Total landings (all life stages) from 2009 Country Reports, except note Finland, Latvia, Lithuania, Netherlands, Portugal, Spain, France and UK (see Table notes at bottom of table).

	NO	SE	FI □	EE	LV □	LT □	PL	DE	DK	NL ●	BE	GB √	IE	FR Δ	ES ●	PT #	I
1945	102	1664							4169	2668							
1946	167	1512			1				4269	3492							
1947	268	1910			10	8			4784	4502							
1948	293	1862			10	14			4386	4799							
1949	214	1899			11	21			4492	3873							
1950	282	2188			14	29			4500	4152					90		
1951	312	1929			13	32			4400	3661					102		
1952	178	1598			14	39			3900	3978					80		
1953	371	2378			30	80			4300	3157					98		
1954	327	2106			24	147	609		3800	2085					103		
1955	451	2651			47	163	732		4800	1651					106		
1956	293	1533			26	131	656		3700	1817					80		
1957	430	2225			25	168	616		3600	2509					115		
1958	437	1751			27	149	635		3300	2674					100		
1959	409	2789			30	155	566	84	4000	3413					98		
1960	430	1646			44	165	733	51	4723	2999					95		
1961	449	2066			50	139	640	48	3875	2452					91		
1962	356	1908			46	155	663	67	3907	1443					95		
1963	503	2071			64	260	762	55	3928	1618					92		
1964	440	2288			43	225	884	56	3282	2068					76		
1965	523	1802			41	125	682	56	3197	2268		566			79		
1966	510	1969			43	238	804	68	3690	2339		618			80		
1967	491	1617			46	153	906	92	3436	2524		570			66		
1968	569	1808			34	165	943	103	4218	2209		587			57		
1969	522	1675			43	134	935	302	3624	2389		607			0		2469
1970	422	1309			29	118	847	238	3309	1111		754			43		2300
1971	415	1391			29	124	722	255	3195	853		844			44		2113
1972	422	1204			25	126	696	239	3229	857		634			44		1997
1973	409	1212			27	120	636	257	3455	823		725			33		588 *
1974	368	1034			20	86	796	224	2814	840		767			25		2122
1975	407	1399			19	114	793	226	3225	1000		764			17		2886
1976	386	935	28		24	88	803	205	2876	1172		627			14		2596
1977	352	989	63		16	68	903	214	2323	783		692			0		2390
1978	347	1076	77		18	70	946	163	2335	719		825			0		2172
1979	374	956	77		21	57	912	158	1826	530		1206			0		2354
1980	387	1112	79		9	45	1221	140	2141	664		1110			11		2198
1981	369	887	39		10	27	1018	131	2087	722		1139			19		2270
1982	385	1161	38		12	28	1033	166	2378	842		1189			16		2025
1983	324	1173	38		9	23	822	155	2003	937		1136			14		2013
1984	310	1073	28		12	27	831	114	1745	691		1257			11		2050
1985	352	1140	28		18	29	1010	477	1519	679		1035			14		2135
1986	272	943	28		19	32	982	405	1552	721		926		2462	12		2134
1987	282	897	19		25	20	872	359	1189	538		1006		2720	15		2265
1988	513	1162			15	23	923	364	1759	425		1110		2816	10		2027
1989	313	952			13	21	752	379	1582	526		1172		2266	0	14	1243
1990	336	942			13	19	697	374	1568	472		1014		2170	4	13	1088
1991	323	1084			14	16	580	335	1366	573		1058		1925	0	23	1097
1992	372	1180			17	12	584	322	1342	548		915		1585	5	30	1084
1993	340	1210		59	19	10	495	250	1023	293		857		1736	5	34	782
1994	472	1553		47	19	12	531	246	1140	330		1077		1694	4	27	771
1995	454	1205		45	38	9	507	242	840	354		1312		1832	4	24	1047
1996	353	1134		55	24	9	499	220	718	300		1246		1562	6	26	953
1997	467	1382		59	25	11	384	263	758	285		1190		1537	23	25	727
1998	331	645		44	30	17	397	28	557	323		943		1345	43	23	666
1999	447	734		65	26	18	406	38	687	332		963		1253	45	23	634
2000	281	561		67	17	11	305	36	600	363		702		1200	90	22	588
2001	304	543		65	15	12	296	141	671	371		742	98	1103	106	15	520
2002	311	633	0	50	19	13	236	130	582	353		650	123		80	27	415
2003	240	565	1	49	11	12	204	125	625	279		574	111		70	11	446
2004	237	551	0	39	11	16	148	117	531	245		634	136		71	9	379
2005	249	628	0	36	11	22	284	108	520	234		545	101		74	7	75 *
2006	293	670	1	33	8		257	87	581	230		408	133		39	10	56 *
2007	194	568		31	10		244	317	526	130		427	114	698		11	58*
2008	211	495		30	13		227	398	457	122		397	125	657	66	7	56*
2009	69	388			5		156	446	467	275		458	0		45	7	

□ From 2008 CR, Country not present in 2009

● Partial, for area (Neth) or life stage (Spain)

*** Only freshwater**

√ From 2008 CR, data source unknown

Δ Partial, discontinued

#Coastal yellow eel landings only (Portugal).

Table 2.5. Landings of European eel in Europe (tons). Source: FAO.

Table 2.5: Landings of European Eel in Europe (tons). Source: FAO.

	NO	SE	FI ?	EE	LV	LT	PL	DE	DK	NL	BE	GB
	Norway	Sweden	Finland	Estonia	Latvia	Lithuania	Poland	Germany	Denmark	Netherlands	Belgium	United Kingdom
1950	300	2200	0	0	0	0	700	400	4500	4200	.	100
1951	300	1900	0	0	0	0	700	400	4400	3700	.	100
1952	200	1600	0	0	0	0	900	400	3900	4000	.	100
1953	400	2400	0	0	0	0	900	500	4300	3100	.	200
1954	300	2100	0	0	0	0	800	300	3800	2100	.	400
1955	500	2600	0	0	0	0	1000	500	4800	1700	.	800
1956	300	1500	0	0	0	0	900	400	3700	1800	.	600
1957	400	2200	0	0	0	0	800	400	3600	2500	.	600
1958	400	1800	0	0	0	0	1200	400	3300	2800	.	500
1959	400	2800	0	0	0	0	700	500	4000	3400	.	700
1960	400	1600	0	0	0	0	1000	400	4700	3000	.	800
1961	500	2100	0	0	0	0	900	500	3900	2500	.	800
1962	400	1900	0	0	0	0	1000	400	3900	1600	.	700
1963	500	1900	0	0	0	0	1000	2100	4000	1900	.	700
1964	400	2368	0	0	0	0	1100	1900	3300	2500	.	600
1965	500	1868	0	0	0	0	900	1500	3200	2600	.	800
1966	500	2070	0	0	0	0	1000	1700	3700	2800	.	1000
1967	500	1667	0	0	0	0	1100	1900	3500	3100	.	600
1968	600	1872	0	0	0	0	1100	1800	4300	2700	.	600
1969	500	1773	0	0	0	0	1100	1600	3700	2800	.	600
1970	400	1270	0	0	0	0	1000	1600	3400	1500	-	800
1971	400	1469	0	0	0	0	900	1300	3200	1200	-	800
1972	400	1274	0	0	0	0	900	1300	3300	1100	-	700
1973	409	1213	0	0	0	0	825	1282	3554	1105	-	800
1974	368	1030	0	0	0	0	891	1285	2870	1029	-	817
1975	407	1492	0	0	0	0	917	1398	3293	1213	-	833
1976	386	1023	27	0	0	0	674	1322	2926	1353	-	694
1977	352	1084	63	0	0	0	996	1317	2381	961	-	742
1978	347	1162	77	0	0	0	941	1162	2379	891	-	877
1979	374	1038	77	0	0	0	1007	1164	1860	729	-	879
1980	387	1205	64	0	0	0	910	1051	2254	877	-	1053
1981	369	976	31	0	0	0	752	1033	2229	898	-	858
1982	385	1250	30	0	0	0	895	1027	2538	1153	-	1032
1983	324	1302	30	0	0	0	1103	1029	2120	1288	-	1113
1984	310	1161	24	0	0	0	1698	911	1855	723	-	957
1985	352	1211	23	0	0	0	1337	866	1601	688	48	781
1986	272	922	25	0	0	0	1134	887	1643	685	48	997
1987	282	703	1	0	0	0	962	731	1273	359	48	939
1988	513	965	1	11	4	94	1087	746	1784	433	48	715
1989	313	952	1	32	8	81	1109	678	1696	332	48	1075
1990	336	941	0	74	0	120	913	978	1674	209	30	1039
1991	323	1085	0	3	0	16	1097	1010	1464	160	30	822
1992	372	1180	0	9	19	12	1095	1026	1448	89	30	782
1993	340	1144	0	59	18	10	1116	1027	1081	419	30	752
1994	472	1298	0	54	39	12	1090	585	1200	358	30	873

*** Data resides with the WG/ICES and can be requested from ICES or a Working Group member.**

Table 2.6. Stocking of glass eel. Numbers of glass eels (in millions) stocked in Sweden (SE), Finland (FI), Estonia (EE), Latvia (LV), Lithuania (LT), Poland (PL), Germany (DE), the Netherlands (NL), Belgium (BE), Northern Ireland (NI), France (FR) and Spain (ES).

	SE	FI	EE	LV	LT	PL	DE	NL	BE	N.Irl.	FR	ES	Total
1927				0.3									
1928					0.1								
1929					0.2								
1930													
1931				0.4	0.2								
1932					0.2								
1933				0.3	0.2								
1934					0.3								
1935				0.2	0.6								
1936					0.3								
1937				0.3	0.3								
1938					0.4								
1939				0.2	0.1								
1940													
1941													
1942													
1943													
1944													
1945													0
1946								7.3					7.3
1947								7.6					7.6
1948								1.9					1.9
1949								10.5					10.5
1950								5.1					5.1
1951								10.2					10.2
1952						17.6		16.9					34.5
1953						25.5	2.2	21.9					49.6
1954						26.6	0	10.5					37.1
1955						30.8	10.2	16.5					57.5
1956			0.2		0.3	21	4.8	23.1					49.4
1957						24.7	1.1	19					44.8
1958						35	5.7	16.9					57.6
1959						52.5	10.7	20.1					83.3
1960			0.6	3.2	2.3	64.4	13.7	21.1					105.3
1961						65.1	7.6	21					93.7
1962			0.9	1.9	2	61.6	14.1	19.8					100.3
1963				1.5	1	41.7	20.4	23.2					87.8
1964			0.2	0.9	2.4	39.2	11.7	20					74.4
1965			0.7	0.4	2.1	39.8	27.8	22.5					93.3
1966		1.1			0.7	69	21.9	8.9					101.6
1967		3.9		1	0.5	74.2	22.8	6.9					109.3
1968		2.8	1.4	3.7	3	16.6	25.2	17					69.7
1969					0	2	19.2	2.7					23.9
1970			1	1.8	2.8	23.5	27.5	19					75.6
1971					1.6	17.4	24.3	17					60.3
1972			0.1	1.6	0.3	21.5	31.5	16.1					71.1

Table 2.6. Continued.

	SE	FI	EE	LV	LT	PL	DE	NL	BE	N.Irl.	FR	ES	Total
1973					1.4	62	19	14					96
1974			2		1.8	71	24	24					122.7
1975					2.2	70	19	14					105.2
1976			3	0.6	1	68	32	18					121.7
1977			2	0.5	1.4	77	38	26					145.2
1978		3.7	3		2.7	73	39	28					148.8
1979					0.8	74	39	31					144.65
1980			1		1.8	53	40	25					120.5
1981			3	1.8	3	61	26	22					116.4
1982			3		4.6	64	31	17					119.4
1983			3	1.5	3.7	25	25	14					72.1
1984			2			49	32	17		4			103.1
1985			2	1.5	1.6	36	6	12		10.9			70.52
1986			3		2.6	54	24	11		17.8			111.61
1987			3	0.3		57	26	7.9		13.8			107.55
1988				2.2		16	27	8.4		6.32			59.42
1989						5.9	14	6.8					27
1990	0.7	0.1				8.6	17	6.1					32.2
1991	0.3	0.1	2			1.7	3.2	1.9					9.2
1992	0.3	0.1	3			14	6.5	3.5		2.36			29.06
1993	0.6	0.1				11	8.6	3.8	1				24.5
1994	1.7	0.1	2		0.1	12	9.5	6.2	1	2.32			34.52
1995	1.5	0.2		0.6	1	24	6.6	4.8	1	2.06			40.96
1996	2.4	0.1	1		0.4	2.8	0.8	1.8	1	0.1		0.1	10.37
1997	2.5	0.1	1			5.1	1	2.3	0	0.21		0.1	12.58
1998	2.1	0.1	1		0.1	2.5	0.4	2.5		0.05		0.1	8.36
1999	2.3	0.1	2	0.3		4	0.6	2.9	1	3.6		0.2	17.02
2000	1.4	0.1	1			3.1	0.3	2.8		0.45		0.1	9.23
2001	0.8	0.1				0.7	0.3	0.9	0			0	3
2002	1.7	0.1		0.2			0.3	1.6		3.02		0	6.94
2003	0.8				0.4	0.5	0.1	1.6	0	4.1		0.1	7.89
2004	1.3	0.1				2.3	0.2	0.3		1.28		0.1	5.5
2005	1	0.1		0.1			0.6	0.1		2.16			4.05
2006	1.1	0.1		0				0.6	0	0.99			3.08
2007	1	0.1		0			1.6	0.2	0	3		0	5.98
2008	1.4	0.2							0	1.28			3.17
2009	0.8	0.1					0.1	0.3	0	0.65			2.27
2010	1.9	0.2						2.7	0	3	1		9.05

Table 2.7. Stocking of young yellow eel. Numbers of young yellow eels (in millions) stocked in Sweden (SE), Finland (FI), Estonia (EE), Latvia (LV), Lithuania (LT), Poland (PL), Germany (DE), Denmark (DK) the Netherlands (NL), Belgium (BE), and Spain (ES).

	SE	FI	EE	LV	LT	PL	DE	DK	NL	BE	ES	Total
1927												
1928												
1929												
1930												
1931												
1932												
1933												
1934												
1935												
1936												
1937												
1938												
1939												
1940												
1941												
1942												
1943												
1944												
1945												
1946												
1947									1.6			1.6
1948									2			2
1949									1.4			1.4
1950							0.9		1.6			2.5
1951							0.9		1.3			2.2
1952							0.6		1.2			1.8
1953							1.5		0.8			2.3
1954							1.1		0.7			1.8
1955							1.2		0.9			2.1
1956							1.3		0.7			2
1957							1.3		0.8			2.1
1958							1.9		0.8			2.7
1959							1.9		0.7			2.6
1960							0.8		0.4			1.2
1961		0		1			1.8		0.6			3.5
1962		0		0.7			0.8		0.4			2
1963				0.4			0.7		0.1			1.2
1964		0		0.4			0.8		0.3			1.6
1965		0		0.3			1		0.5			1.9
1966		0					1.3		1.1			2.5
1967				0.8			0.9		1.2			2.9
1968							1.4		1			2.4
1969							1.4					1.4
1970				0.4			0.7		0.2			1.3
1971							0.6		0.3			0.9
1972							1.9		0.4			2.3

Table 2.7. Continued.

	SE	FI	EE	LV	LT	PL	DE	DK	NL	BE	ES	Total
1973						0	2.7		0.5			3.4
1974							2.4		0.5			2.9
1975							2.9		0.5			3.4
1976				0.3			2.4		0.5			3.2
1977						0	2.7		0.6			3.4
1978							3.3		0.8			4.1
1979		0					1.5		0.8			2.4
1980							1		1			2
1981							2.7		0.7			3.4
1982				0.3		0	2.3		0.7			3.4
1983				0.4		2	2.3		0.7			5.7
1984						0	1.7		0.7			2.7
1985						1	1.1		0.8			2.4
1986						0	0.4		0.7			1.3
1987							0.3	1.6	0.4			2.28
1988			0.2	0.8		0	0.2	0.8	0.3			2.35
1989						1	0.2	0.4	0.1		0.1	1.48
1990	0.8					1	0.4	3.5			0	5.7
1991	0.9					0	0.5	3.1			0.1	4.62
1992	1.1					0	0.4	3.9			0.1	5.52
1993	1						0.7	4	0.2	0.2	0.2	6.23
1994	1				0	0	0.8	7.4		0.1	0.1	9.62
1995	0.9		0.2				0.8	8.4		0.1	0.2	10.66
1996	1.1					1	1.1	4.6	0.2	0.1	0.1	7.7
1997	1.1					1	2.2	2.5	0.4	0.1	0.1	7.57
1998	0.9				0	1	1.7	3	0.6	0.1	0.1	7.07
1999	1				0	1	2.4	4.1	1.2	0	0	9.4
2000	0.7					1	3.3	3.8	1		0.1	9.65
2001	0.4		0.4			1	2.4	1.7	0.1		0.1	5.74
2002	0.3		0.4	0.2		1	2.4	2.4	0.1	0	0	6.4
2003	0.3		0.5			1	2.6	2.2	0.1	0	0.1	6.32
2004	0.2		0.4		0	1	2.2	0.8	0.1	0	0.1	4.34
2005	0.1		0.4			1	2.1	0.3		0	0.1	3.67
2006			0.4			1	5.5	1.6				8.58
2007			0.3			1	9.1	0.8			0	11.18
2008			0.2			1		0.75	0.2		0	1.46
2009			0.4			1	6	0.8	0.3		0	8.95
2010								1.6	0.1		0	1.66

Table 2.8. Aquaculture production of European eel in Europe from 1996 to 2009.

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Denmark	2718	2674	2000	1880	2050	1500	1700	1900	1617	1740	1707
Estonia		5	7	15	18	26	19	27	52		
Germany	400	422	347	381	372	328	329	567	740	749	
Netherlands	3500	3800	4000	4000	4200	4500	4500	4200	4000	3700	3200
Portugal	3	4	7	4		2	1		1	?	?
Sweden	222	273	200	167	170	158	222	191	175	172	na
Total	6843	7178	6561	6447	6810	6514	6771	6885	7068		

Annex 5: Eel Management Plan reporting to the EU, 2012; data requirements

Following an informal request from the EU to the Chair, the Working Group compiled the following document.

Introduction

Under Article 9 of the EU Council Regulation (EC No. 1100/2007), each Member State shall report to the Commission, initially every third year, with the first report to be presented by 30th June 2012.

"*Reports shall outline monitoring, effectiveness and outcome, and in particular shall provide the best available estimates of:*

for each Member State, the proportion of the silver eel biomass that escapes to the sea to spawn, or the proportion of the silver eel biomass leaving the territory of that Member State as part of a seaward migration to spawn, relative to the target level of escapement set out in Article 2(4);

> *the level of fishing effort ~~that~~ and catches of eel each year, and the reduction effected in accordance with Articles 4(2) and 5(4);*
>
> *the level of mortality factors outside the fishery, and the reduction effected in accordance with Article 2(10);*
>
> *the amount of eel less than 12 cm in length caught and the proportions of this utilised for different purposes."*

NOTE: The wording in the Regulation for (b) is "the effort that catches eel each year" but this should be amended to include the catches and the effort; one is no good without the other.

Article 2 (4)

4. The objective of each Eel Management Plan shall be to 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. The Eel Management Plan shall be prepared with the purpose of achieving this objective in the long term.

Article 4 (2)

2. A Member State which has not submitted an Eel Management Plan to the Commission for approval by 31 December 2008 shall either reduce fishing effort by at least 50 % relative to the average effort deployed from 2004 to 2006 or reduce fishing effort to ensure a reduction in eel catches by at least 50 % relative to the average catch from 2004 to 2006, either by shortening the fishing season for eel or by other means. This reduction shall be implemented from 1 January 2009.

Article 5 (4)

4. A Member State which has submitted an Eel Management Plan to the Commission for approval not later than 31 December 2008, which cannot be approved by the Commission in accordance with paragraph 1, shall either reduce fishing effort by at least 50 % relative to the average effort deployed from 2004 to 2006 or reduce fishing effort to ensure a reduction in eel catches by at least 50 % relative to the average catch from 2004 to 2006, either by shortening the fishing season for eel or by other means. This reduction shall be implemented within three months of the decision not to approve the plan.

Article 2 (10)

10. In the Eel Management Plan, each Member State shall implement appropriate measures as soon as possible to reduce the eel mortality caused by factors outside the fishery, including hydroelectric turbines, pumps or predators, unless this is not necessary to attain the objective of the plan.

Post-evaluation

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

The Eel Regulation sets a limit reference for biomass as a percentage (40%) of the pristine biomass and requires the Member States to determine actual reference points for the part of the stock within their territory. Depending on the type of reference point chosen, either the current state or the target is hard to quantify. The SGIPEE/WGEEL present indicators for both biomass and mortality and demonstrate a suitable presentation format below. Due to the panmixia of the eel (i.e. local silver eel production contributes an unknown fraction to the entire European eel spawning stock, which in turn generates new glass eel recruitment), the efficacy of a single EMP cannot be post evaluated in isolation from the overall efficacy of all EMPs. Thus, Member States will have to set **reference points** for their own EMP(s), to which the state of the local stock and efficacy of their actions can be compared and true pos-evaluation will require summation of all the eel management units.

In its advice on fisheries management, ICES (2004b) applies a 'traffic light' colouring scheme, signalling the status of the stock and the impact of exploitation. The information on the stock status and the reference points are summarized in a so-called Precautionary Diagram (Figure 1), summarizing the criteria and status. This diagram presents the status of the stock (horizontal, low vs. high spawning-stock biomass determining whether the stock has achieved full reproductive potential) and the impact of fishing (vertical, low vs. high fishing mortality determining whether the exploitation is sustainable or not). A full description is available in the SGIPEE report (2010) on how this diagram might be modified so as to be applicable for eel (ICES 2010) (Figure 2).

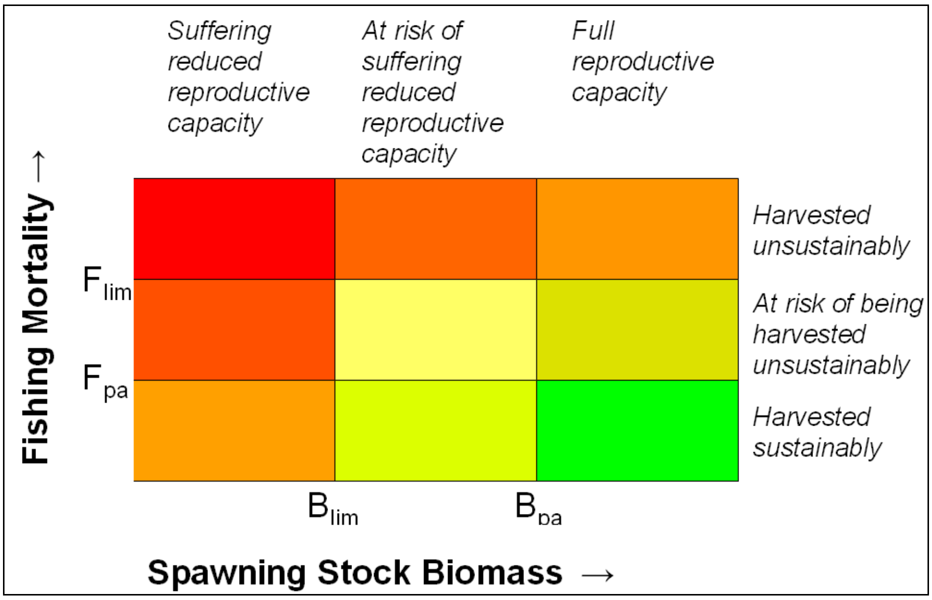

Figure 1. ICES Precautionary Diagram; in its scientific advice on fish stock management, ICES applies a standard terminology to quantify the status of the stock (horizontal) and the impact made by fishing (vertical). Source: ICES 2004b (diagram p. 1–7).

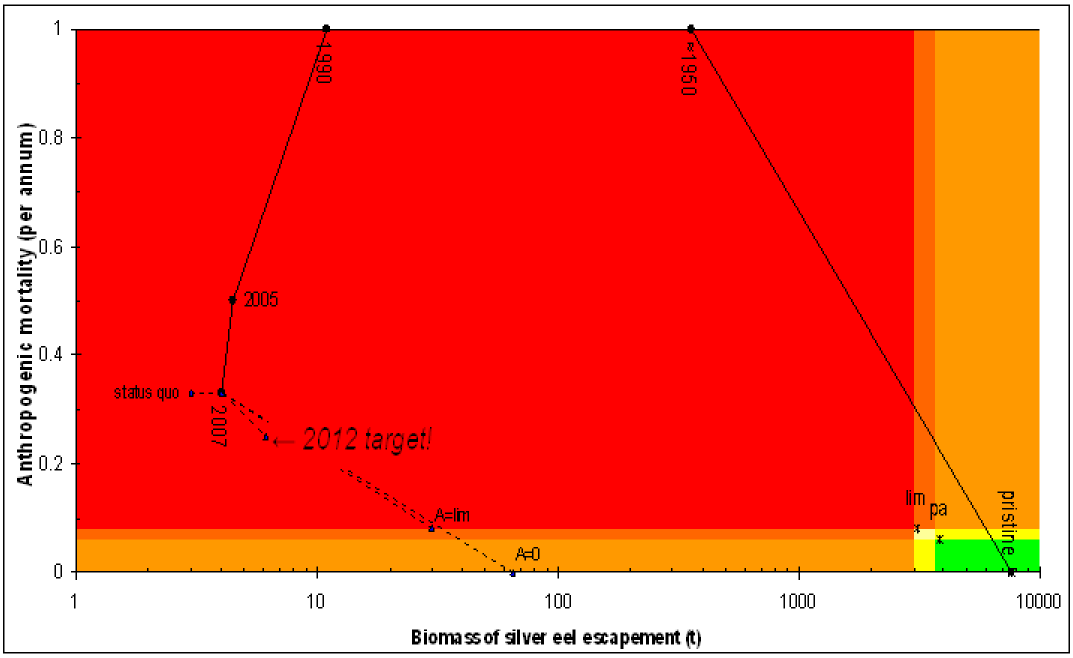

Figure 2. (ICES, 2010). Modified Precautionary Diagram for Lake IJsselmeer eel stock, indicating the biological reference points and the historical trajectory. (Source: Dekker, 2010. Data from the Dutch EMP, Dekker *et al.*, 2008 and supplemented by expert estimates. B_{pa} is set at 1.25*B_{lim}, and %SPR_{pa} at %SPR_{lim}*1.25).

Data requirements

Biomass

a) for each Member State, the proportion of the silver eel biomass that escapes to the sea to spawn, or the proportion of the silver eel biomass leaving the territory of that Member State as part of a seaward migration to spawn, relative to the target level of escapement set out in Article 2(4);

Summing up, the international stock assessment can be based on lower-level stock assessments, if those lower-level assessments supply the following biomass estimates[2].

EMP reporting must provide the following biomass data:

a) **B**post, the biomass of the escapement in the assessment year;

b) **B**o, the biomass of the escapement in the pristine state. Alternatively, one could specify **B**lim, the 40% limit of **B**0, as set in the Eel Regulation;

c) **B**best, the estimated biomass in the assessment year, based on the recently observed recruitment, but assuming no anthropogenic impacts (and without stocking) have occurred (neither positive nor negative impacts) and from all potentially available habitat.

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

[2] A full description of the biomass (3 Bs) and mortality (As) is given in the SGIPEE report (ICES, 2010)

The estimation of **B**best will require an estimate of **A** (anthropogenic mortality (e.g. catch, turbines)) for density-independent cases, and a more complex analysis for density-dependent cases.

For quality assurance reasons, the assessment should report the methods used and the values of all indicators derived.

If estimates of **B**0 are revised, these should be fully explained in the 2012 report.

Any new or revised amounts of accessible and total wetted areas (ha/km^2) should be provided along with the methods of how the estimates are derived.

[**Note**: for glass eel fisheries and stocking, care should be taken to avoid double banking, with biomass being accounted for at the glass eel fishery EMU and also being accounted for again at the recipient EMU where stocking occurs].

Fisheries

b) the level of fishing effort ~~that~~ and catches of eel each year, and the reduction effected in accordance with Articles 4(2) and 5(4);

Information reported should include:

- the level of fishing effort and the reduction achieved;
- the catch (kg) for each year since 2000;
- reports should be for recreational and commercial fisheries;
- where possible, reports should be separate for each life stage (glass eels yellow and silver eel);
- estimate of illegal and underreported catch.

Other anthropogenic mortalities

c) the level of mortality factors outside the fishery, and the reduction effected in accordance with Article 2(10);

The report should describe the types of other anthropogenic mortality identified in the Eel Management Plan and during the subsequent implementation of the plan.

These data could include:

- location of the turbine and wetted area/eel production above the turbine;
- turbine mortality (biomass) and/or mortality rate;
- cumulative mortality/mortality rate for series of turbines;
- mitigation strategies and reduction in biomass of eel killed;
- pumping number and mortality of eel;
- mitigation strategies and reduction in biomass of eel killed;
- cormorant number and mortality of eel;
- cormorant management strategies employed;
- mitigation strategies and reduction in biomass of eel killed;
- location of migration obstacles and wetted area/eel production above them;
- amount of catchment/wetted area made re-accessible;
- biomass produced from area made re-accessible.

Catch of eel <12 cm

d) the amount of eel less than 12 cm in length caught and the proportions of this utilized for different purposes.

Report the amount (weight) of eel less than 12 cm in length caught each year.

Report the proportion of catch:

- retained for stocking (and as a % of total catch of eel <12 cm);
- retained in Europe for culture/consumption;
- exported outside Europe;
- post-fishery mortality of catch.

Stocking data

Not mentioned in the reporting Article in the Regulation: needed as a positive anthropogenic impact.

Amount stocked (weight or number):

Density stocked at (No./ha):

Size stocked at (g):

- Biomass expected to be produced (including fishery catch, other anthropogenic mortality and escapement);
- Biomass estimated to survive to silver eel escapement from the EMU;
- Assessment method used;
- Survey of stocked eel: methods and results.

Recruitment survey data

Recruit surveys (glass eel, young yellow eel) are the prime source of information on the status of the oceanic reproduction. Even though they play a minor role in the national assessments, these are essential to the overall evaluation of the Eel Regulation.

Analysis of recruitment time-series has been one of the main tools in the past for providing advice on the status of the eel stock. These time-series have consisted of a combination of fisheries dependent and fisheries independent data on both glass eel and young yellow eel. Data discontinuities, particularly from commercial fisheries, can be expected following implementation of management measures (e.g. Eel Management Plan changes to fishing effort, season quota, size limits; CITES restrictions).

A preliminary review has indicated a total of 47 time-series of varying length are available for analysis (ICES, 2010 (SGIPEE)). For the glass eel recruitment-series, four are now closed and a further 14 are vulnerable to major changes. Only 17 of the 35 glass eel series are expected to be available for time-series analysis into the future and for bench marking changes in recruitment after 2010. It should be noted that ten of the 14 vulnerable glass eel series are for the Bay of Biscay and Iberian Atlantic with probably only <u>one</u> of these series remaining unaltered for this area. There is a paucity of recruitment data for the Mediterranean with three series remaining, and these are from commercial fisheries which may change in future.

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

The absence of any internationally driven requirement to maintain a recruitment dataseries needs to be corrected and SGIPEE highlights the recommendations of WGEEL 2008 and EU Contract 98/076: Establishment of an international recruitment monitoring system for glass eel.

Recruitment data required

Location;

Stage and mean size of eel;

Indicator data collected (numbers, biomass);

Method;

Time-series.

Yellow eel survey data

Yellow eel survey data are often collected under other programmes, such as Habitats Directive and Water Framework Directive, and as such are not obliged to be reported under the Eel Regulation. These data, especially in the reduction or absence of fisheries data, will be essential to evaluating compliance to interim targets and will also be required to fill a knowledge gap as a proxy where there is an absence of recruit information.

- Location;
- Method;
- Length structure;
- Abundance (number, biomass, cpue, density);
- Time-series.

Silver eel survey data

The objective of the EU Regulation is to increase production of silver eel escaping to spawn. Few silver eel surveys are currently undertaken and those data are deemed essential, in a similar way to the recruitment data. Ultimately, verification of the EMU compliance with the Regulation and effectiveness of the management measures will need to be measured in terms of reduction in mortality and increase in silver eel biomass.

Most silver eel data, with a very few exceptions, is based on fisheries capture. With the implementation of management measures and reduction in fishing effort it is likely that these data will also be vulnerable or discontinued.

- Location;
- Method;
- Length structure;
- Sex-ration;
- Abundance (number, biomass, cpue, density);
- Time-series.

Annex 6: Mark–recapture case studies

Case study 1

UK, N. Ireland, Bann

River Bann exit of Lough Neagh, Northern Ireland

Objective

Silver eel fishing is permitted under the Neagh-Bann management plan (UK) in interceptory weirs in the River Bann as it flows out of Lough Neagh at Toomebridge. A further site is fished at Kilrea some 10 km downstream. There is considerable annual variation in the timing of operation of these fisheries, which are heavily influenced by variable river flow patterns and resulting in variable fish behaviour. The two fishery sites differ in their optimum fishing conditions, the upper, more modern net array at Toome operating best at medium to high flow and the lower, more traditional structure working best at low flows. There is tendency for one or other site to be worked at any one time, though the precise operating regime is the decision of the commercial fishery owners.

These nets do not span the entire river width to permit free passage of a proportion of silver eels to spawn. Additional escapement arises from inherent features of the structures guiding fish to the nets, which can over-top, non-continuous fishing, night-time only fishing, etc. Mark–recapture of silver eels has been used to estimate escapement past these fisheries to the sea; there is no further anthropogenic mortality and therefore an escapement estimate past Kilrea is assumed to equate to a reasonable estimate of escapement from the Lough Neagh system. Escapement estimates to date are given in the UK Country Report to ICES/EIFAG WGEEL, 2010.

Methods

Since 2003, by agreement with the fishery, batches of silver eels have been bought when silver eels are actively moving downstream, from the previous night’s catch, tagged with Floy tags under anaesthetic (initially Chlorobutanol, Clove oil since 2004) and released back immediately upstream of a set of sluice gates regulating the outflow of Lough Neagh. The release point is approximately 1 km upstream from the first set of interceptory nets. One early pilot batch in 1993 was released at Ballyronan, some 6 km further into Lough Neagh. Floy tags, anchored in the dorsal side of the fish, are well suited to use at this commercial fishery as all eels from both capture sites are hand-graded on packing for sale, passing live and upright down a chute in a layer only one eel deep.

The fisheries have to date, for the purpose of data analysis, been assumed to form one functional unit for the purpose of escapement estimation. This permits a simple calculation of maximum possible escapement as from the total seasons catch (Annual, September to December), and the proportion of tags recovered.

Results

A summary of the output data is displayed in Table 1. The time between mark and recapture is given in Figure 1. The range of recapture percentages is wide, from 13 to 61%, with an average between batches of 27% for all tags summed, and an average of individual batches of 29.4%. It is worth noting that carry-over to subsequent years is generally low, with one exception, the first trial batch in 2003, for which 15 of 48 recaptures (31%) came in subsequent years, as compared with 2004 to 2009 batches for which carry over to subsequent years averaged less than 2%.

Strengths and weaknesses of the M–R escapement estimate

This work demonstrates that given the right conditions, and a fishery which handles large amounts of eel at a single location, simple and cheap batch marking with external floy tags can be an effective tool in estimating fishing efficiency. Clearly, the escapement estimate derived is from the number of tags not seen again and as such is subject to the uncertainties of interim mortality between release and recapture, either natural or due to the tagging operation. Confidence in the escapement assessment has to be based on minimizing these uncertainties, principally by reducing to as low as possible the time and space between tagging and recapture. To assess interim mortality, batches of tagged and un-tagged eels can be held at low densities for short periods post tagging in tanks in the river flow, an obvious check, but it has proven difficult to hold even untagged eels with such active migration behaviour, and while there has been no differential mortality between the control (untagged) and tagged eels, it is difficult to keep either alive for more than four weeks. The reasons for this are not known but can probably be attributed to the stress of holding fish whose natural impetus is to move downstream. Analysing the time to recapture, indicating that ca. 90% of tags are recovered within five weeks (often coinciding with the present or subsequent next dark phase moon) also lends confidence to the assumption that tagged eels move downstream as soon as they are able. Nevertheless, inherently unquantifiable uncertainty remains.

Live tracking of eels might help address the uncertainty over the fate of the unseen tagged eels, but even this will involve handling fish and potentially altering their behaviour. Direct observation of the escapement paths (the unfished elements of the channel using a DIDSON type sonar imaging camera might also be an option, albeit with high equipment costs. The issue of distance between the two capture sites, potentially occasional double mortality on the (few) occasions when both are operating, and the lack of independent assessment on the two weirs are issues to be addressed for continuing implementation and reporting on the Eel Management plan.

Table 1. Summary mark; recapture data from River Bann silver eel fisheries. 2003 to 2009.

Year	Date	No. of tags released	Recaptures in same season	Recaptures 1 yr later	Recaptures 2 yrs later	Total recaptures from Batch	Percent recaptures from Batch
2003	16-Oct	189	33	13	2	48	25.40
2004	04-Nov	838	317	13	0	330	39.38
2005	03-Nov	792	104	0	0	104	13.13
2006	27-Sep	500	65	2	0	67	13.40
2006	17-Nov	200	123	0	0	123	61.50
2008	02-Oct	490	101	1	0	102	20.82
2008	03-Nov	495	110	3	0	113	22.83
2009	03-Nov	486	187	1	0	188	38.68
	total	3990	1040	33	2	1075	26.94

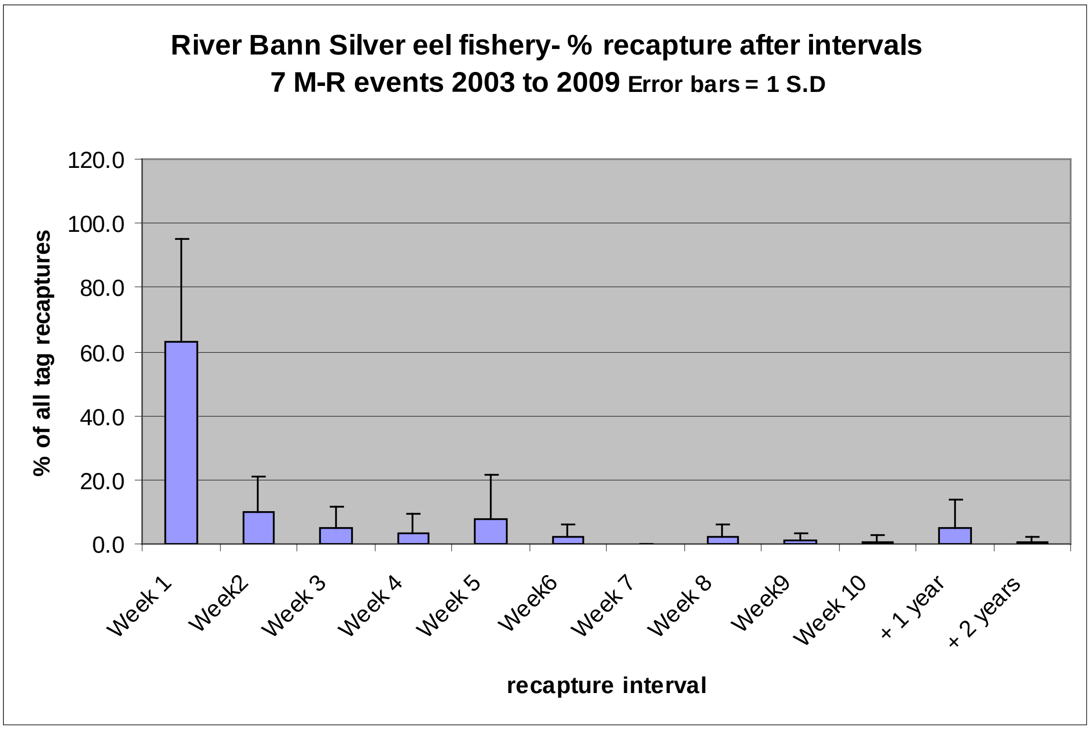

Figure 1. Silver eel mark–recapture intervals, River Bann exiting Lough Neagh.

Case study 2

Ireland, Shannon, River Shannon

Objectives

Lower River Shannon mark–recapture tagging experiments, initially undertaken in 1992 and periodically undertaken until the present time, are primarily intended to evaluate the fishing efficiency of the Killaloe eel weir and thereby allow estimation of the number and biomass of the seaward migrating silver eel populations that move downstream (McCarthy *et al.*, 2008). The eel weir is described in several publications (e.g. Cullen and McCarthy, 2000; Cullen and McCarthy, 2003). In recent years the focus of the work has been changed to provide information required by the Shannon International River Basin District eel management plan, as well as being an important site for silver eel conservation. Though in initial research, such as the intensive 1992-1994 study, the interest in eel weir operational efficiency was linked to attempts to improve the commercial potential of the fishery, nowadays the Killaloe eel weir research is an essential to estimation of spawner biomass escapement from the River Shannon. The eel weir mark–recapture experiments are therefore part of a more complex research programme that includes acoustic telemetric assessment of the effects of hydroelectricity generation, monitoring of silver eel trap and transport, etc. Silver eels migrating down river from Killaloe can alternatively migrate via the River Shannon (natural bypass route) or via the headrace canal leading to the Ardnacrusha hydropower station. Telemetry indicates that route selection is mostly determined by hydrometric factors, including natural and regulated discharge flow patterns (Cullen and McCarthy, 2003). Information concerning the population dynamics of silver eels in the Killaloe section of the River Shannon is also required for development of alternative escapement assessment tools, such as use of Didson acoustic camera index site counts, and for evaluation of potential mitigation measures, such as controlled spillage at the hydroelectricity systems Parteen regulating weir.

Methods

Eels used in mark–recapture experiments are obtained from the catches made at the Killaloe eel weir. This was formerly operated as a commercial fishery but now is operated exclusively in connection with a silver eel trap and transport mitigation measure by the Electricity Supply Board. Care is taken to ensure that healthy eels are selected and that the size frequency does not differ significantly from the overall size frequency of the catches made at the weir. Eels are tagged in the afternoon, having been retained in perforated tanks near the river bank, and retained in fine-meshed storage bags after tagging. Both Floy and PIT tags have been used, PIT tags were used extensively in 1992–1994, when it was possible to screen large catches with hand-held Trovan PIT tag detectors and these were revealed to be less harmful to male eels. Subsequently, because of cost implications, changes in fishery operations, and because the silver eel population is predominantly female, Floy tags were used in most experiments. However, with advances in technology, full screening of catches, is again possible and PIT tags are now used for most experiments. Special care is taken to ensure that eel handling is kept to a minimum and that only experienced staff members are involved in eel tagging. In earlier experiments Chlorbutanol was the usual anaesthetic but nowadays clove oil is used. Experience has suggested that eel handling is less stressful to fish, and more effective for mark–recapture, when eels are anaesthetized sequentially in small subgroups (5–10) and that lighter sedation/rapid recovery can be achieved in this way. The release points used for eel weir efficiency studies, other than for special experiments, are within 1 km of the weir and the normal practice is to release the eels in three subgroups across the river. Eels are released after dark, timing varies with date, and generally within periods when active migration of eels is suggested by environmental conditions (lunar cycle, discharge, weather) and has been confirmed by daily monitoring of eel weir catches. Approximately 95% of eels are recaptured within two days after release, most in the first nights fishing. Over 1000 eels are now tagged annually.

Results

The efficiency of the weir varies, according to discharge and numbers of nets set. In times of extreme low flow, which regularly occur prior to the start of the silver eel migration season, the eel weir is very ineffective, but in peak runs, which typically are associated with high discharge, it operates at maximum efficiency. In 1992–1994 experiments the range of efficiency values obtained by mark–recapture experimentation was 4–40%. However, the range of values in more recent studies is not so extreme. This reflects more standardized fishing activities and lack of tagging at times when eel migration is low. Telemetry, using radio-tags in 1992–1994, confirmed that eels could freely pass both upstream and downstream in still water conditions. Effects of discharge on eel movements in the Ardnacrusha headrace canal were demonstrated using hydroacoustic techniques (McCarthy *et al.*, 2008). Low recapture rates were recorded when, for special reasons, tagged eels were released in the littoral zone of Lough Derg, e.g. at a point 4 km upstream in 2009 recapture rate was 4.8% vs. 25% for a batch release in the normal river release point. Likewise, lower recovery rates were recorded from batches of eels released in the upper river basin in 1992–1994 when a catchment-wide fishery was in operation (McCarthy *et al.*, 2008).

At peak run times, approximately 30% of eels are captured annually at the Killaoe eel weir. However, fishing has sometimes been affected by technical problems or extreme flooding such as occurred in late November–early December 2009. In 2009, the total catch was 12.14 t and, largely because the weir was unfishable during extreme winter floods, only 19.2% of eels passing downstream were captured. Thus, it was estimated that 54.41 t passed down river. Didson camera observations were used for the first time in 2009 at the weir and close to the marked eel release point. These observations were used in estimating eel numbers and biomass during eel weir closure. They were also used to confirm that eel weir fishing period was appropriate and that the population estimate was complete.

Strengths and weaknesses

The Killaloe site has many advantages in respect of mark–recapture experiments, including the fact that the fishery is owned and operated by the Electricity Supply Board which now use it exclusively for its silver eel trap and transport programme. The daily and annual catch records are used for Shannon eel stock monitoring and research. The catches are also screened for PIT tagged fish released Loughs Ree and Derg, as part of a national study by Inland Fisheries Ireland on silvering rates in index lakes being intensively surveyed using fykenets.

The river location allows for release of tagged eels into flowing water and full catch analysis for tag recovery/detection is possible. Concerns about safety of eel weir operators, and other river users, in extreme floods may restrict use of the eel weir in future. However, population assessments may not be as dependant on the mark–recapture experiments, if mitigation measures or increased trap and transport fishing occurs at upriver sites. Under such circumstances, and subject to results of an ongoing evaluation of Didson camera population indices, eel weir operations may be determined primarily by trap and transport targets rather than the full season fishing that has been the normal practice.

The fishing at the Killaloe eel weir is undertaken by external contractors, with considerable eel fishing experience, rather than by the former full-time commercial fishery staff. They fish on designated nights and they facilitate research programmes. Information obtained by mark -recapture studies, and other indicators of eel migration intensity, assists in planning fishing date schedules and in cost-effectiveness of conservation actions such as the silver eel trap and transport.

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Case study 3

Ireland, Corrib

Objective 1: to determine silvering rate

Yellow eels were tagged in Lough Corrib (upstream of the silver eel fishery) during summer. All eels captured at the silver eel fishery in autumn were passed through a PIT (passive integrated transponder) detector to record any maturing eels tagged in the earlier yellow eel surveys on Lower Lough Corrib.

Method

Yellow eels were caught in fykenets on the lake, anaesthetized with a solution of 1,1,1 –trichlor-2-methyl-2-propanol-hemihydrate and PIT tagged with Trovan tags. Tags were inserted in the dorsal muscle with a tagging gun. Eels were held in a mesh bag in the lake until all had recovered and released after a number of hours.

Tag type

Trovan pit tag, 11.5 mm.

Objective 2: to estimate the efficiency of the silver eel weir

To estimate the efficiency of the weir and the silver eel escapement, a Mark–Recapture exercise was carried out at the Galway Fishery on two darks with 210 and 206 eels pit-tagged after capture at the eel weir and released approximately 1 km upstream of the fishery in the Corrib River in October and November respectively.

Method

About 200 silver eels caught in the coghillnets were placed in a holding tank and held overnight. The next day eels were anaesthetized, PIT tagged in the dorsal muscle and allowed to recover for a number of hours before being released 1 km upstream in the river. All silver eels captured were passed through a PIT tag detector in order to record PIT tagged eels (Table 1).

Tag type

Trovan PIT tags.

Results

The silver eel escapement was estimated by three different methods (Table 2) and by some traditional mark–recapture models (Table 3).

1) The monthly recapture rate of tagged eels was applied to the nightly catch for the relevant month (36% for October and 34% for November).
2) The average of the two recapture rates was applied to each nightly catch (35%).
3) The average of the two recapture rates (35%) was applied to the total catch (12.6 tonnes) for silver eel run.

Applying the monthly recapture rate of 36% and 34% for October and November respectively results in a total estimate of 36.13 t of silver eels escaping from the Corrib catchment in 2009 with 23.48 t of silver eels estimated to escape past the nets at the eel weir. Applying the average recapture rate of 35% implies that 23.4 t of silver eels escaped past the weir with a total escapement of 36.06 t The final method using the total catch from the weir and the average recapture rate gives an estimate of 23.48 t of silver eel escaping past the weir with a total of 36 t of silver eel escaping from the Corrib catchment. Overall, the three methods give roughly the same estimate of 36 t of silver eel escaping from the Corrib catchment. This compares with 48 t estimated current (2001–2007) production reported in the Irish EMP.

Three yellow eel tagged in summer 2009 had matured and were also recorded by the PIT tag detector migrating as a silver eel during the autumn silver eel run.

The standard mark–recapture models listed in Table 3 gave a range of estimates of escapement. The Lincoln-Petersen (known to overestimate population size), Baileys modification (reduces the overestimate especially when sample size is small) and the Chapman estimate (the preferred unbiased estimate) all gave similar estimates to each other and to those calculated from pure percentages in Table 2. Other estimates varied more, such as the Schnabel and the Schumacher-Eschmeyer. Promising estimates were also obtained by incorporating the Chapman in a Bayesian framework and by using a Bayesian mark–recapture estimate. It is intended to develop these methods in future.

Table 1. Silver eel Mark Recapture Surveys carried out in 2009.

Location	Galway fishery	
Date	20/10/2009	11/11/2009
Tagged	210	206
Total recaptured	79	70
Aug dark	-	-
Sept dark	-	-
Oct dark	76	9
Nov dark	-	61
Dec dark	-	-
No. sacrificed	53	58
Yellow recaptures	3	0
% recapture	36%	34%

Table 2. Estimated silver eel escapement for Corrib catchment.

	Monthly recapture rate	Mean recapture rate (36%)	Total recapture 36%
Catch at weir (tonnes)	12.65	12.65	12.645
Catch past weir (tonnes)	22.59	22.42	22.48
Total escaped eel (tonnes)	35.23	35.70	35.125
Numbers escaped	119 822	119 157	117 248

Table 3. Mark–recapture estimates of escapement using different models.

Method	Estimate
Lincoln-Petersen	121 342
Bailey's modification	120 806
Chapman	120 519
Schnabel	68 458
Schumacher-Eschmeyer	33 333
Chapman in Bayesian	113 500
Bayesian Framework*	121 800

Problems/solutions

It is presumed that for the determination of weir efficiency, all PIT tagged eels passed the silver eel fishery, and that there was an average recapture rate of 35%. The possibility of eels moving upstream, not migrating downstream or migrating down other side channels than the main silver eel fishery are not taken into account.

It is proposed to use acoustic tags and PIT tags on 40 silver eels and release them at the location 1 km upstream of the fishery. Some eels will enter the eelnets and be recorded by the PIT tag detector. Receivers placed in the river above the release point and below the silver eel fishery will determine whether eels not recaptured moved downstream and passed the fishery. It is hoped this will collaborate that the weir efficiency is 35%.

Transitional waters survey 2009

Objective–to determine the eel stock density of eels in a large estuary

In order to determine the population density within an important eel habitat a spatially explicit mark recapture experiment was carried out in the Waterford Harbour in July 2009.

Method

This method consisted of 2–4 grids of 15–20 fykenets, with each fykenet spaced 50 m apart. Fykenets were set in grids along the right and left bank of the transitional waters, avoiding the main shipping channel. Nets were not set on consecutive nights as the anaesthetic suppresses appetite and therefore tagged eels are unlikely to forage directly after release impacting on their recapture rate. Data indicate that eels feed every 2–3 days (Tesch, 1977; Moriarty 1978). The fykenets were not baited to avoid attracting eels into the study area (Morrison and Secor, 2004).

On the Suir, two locations were selected, one upstream of the bridge in Waterford city and one downstream. The upstream site was only fished for one night. The downstream site was fished for four nights spread out over seven nights. One site on the Barrow estuary was fished for five nights spread out over nine nights with an additional two sites (upstream and downstream of the main site) on the last night. Three charter boats were hired to assist in the survey.

Results

In total 1888 eel were captured in the fykenet survey in the Suir transitional waters with a catch per unit of effort of 11.58. 483 eel were captured in the upstream site (upstream of bridge) and 712 eel were tagged in the downstream site (downstream of bridge). No eel from the upstream site were recaptured in the downstream site during the study period. Within site 2 (downstream of Bridge), 30 eel were recaptured over the time period giving a recapture rate of 4%. No tagged eel were recaptured more than twice in this survey.

In the Barrow transitional waters 1410 eel were captured with a catch per unit of effort of 6.56. 849 eel were tagged and 52 eel were recaptured giving a recapture rate of 6%. No tagged eel were recaptured more than three times in the trapping session.

Moriarty (1986) concluded that recapture rates of 5.5–18.5% could be expected if a population was non-migratory, rates below 2% indicating a very mobile population. In the Suir tagged eel were caught at most twice and in the Barrow only three eel were caught three times. This low recapture rate could be due to trap shyness or because the home range of the species in question is greater than the trapping area. The WFD team will sample Waterford Harbour in 2010 and will use a PIT detector to identify any tagged eel from the 2009 survey. Hightower and Nesnow (2006) suggested that a three day mark recapture survey is sufficient to get an indication of the density of the population.

Problems/solutions

The number of fykenets used was limited due to time constraints of setting and processing. Consideration could be given to using pots which could be hauled more easily. Consider fishing on consecutive nights to get a better catch of untagged eel.

Case study 4

Scotland

A) Mark–recapture of yellow eels on the Girnock Burn, Scotland

The Girnock Burn is a small upland stream in Scotland, occupying a catchment of 2970 ha and with a wetted area of 9.4 ha, and is one of three index streams for eel production in Scotland RBD. Since 2004, eight sites on the Girnock Burn, comprising approximately 0.14 ha in total, or 1.5% of the wetted area of the stream, are electro-fished annually during summer, using 3-passes. Surveys target eels, salmon and trout, the only three species present in the burn. All eels are anaesthetized, lengthed, weighed and checked for marks. Any untagged eels greater than 200 mm in length are PIT-tagged, using an 11 mm Trovan PIT tag inserted in the body cavity. An incision of ca. 2 mm in length (i.e. just sufficient in to admit the tag) is made in the belly of the eel just off the centre, using a narrow-pointed (rather than curved) scalpel blade. The PIT tag is inserted into the body cavity, and the area lightly massaged to ensure the tag is aligned parallel with the body wall. No sutures are used on the wound, and eels are allowed to recover for approximately one hour before being released in an area of still water close to where they were captured. Since 2009 the minimum size for PIT-tagging has been reduced to 160 mm, and since 2010 the PIT tags used have been changed to the type capable of detection using portable instream detectors.

Additionally, elvers entering the burn are trapped and individually marked using either Visual Implant Elastomer marks (VIE: NW Marine Technology Inc) (for eels <140 mm) and either VIE or PIT tags (for eels >140 mm). VIE tags are injected subcutaneously, using a unique combination of colours at four recognizable locations immediately posterior to the anus. A previous study using VIE marks has demonstrated no detectable impact of eel survival, and very good tag retention (Imbert *et al.*, 2007).

Individuals are recovered either during subsequent electrofishings or at the whole river trap near the mouth of the burn.

Objectives

There are several purposes for the mark–recapture programme.

1) To gather information on individual growth rates;
2) To investigate local movements of eels;
3) To establish electro-fishing efficiency, and ultimately;
4) To estimate mortality and silvering rates and create life table analysis.

Results

1) Growth rates

We have estimated mean growth rates from 66 eels with a period of one or more years between first and last capture. These individuals had a mean initial length 257±7 mm (s.e.) (min. 171 mm, max. 398 mm), and their mean growth rate was measured as 10.7±0.7 mmyr^{-1}.

2) Within-stream movements and site-fidelity

A total of 527 eels have been PIT tagged during electrofishing. Of these there has been an opportunity for 457 (mean length 239±3 mm) to have been recaptured at least once. Of these 103 (20.9%) were actually recaptured at least once. These had a mean initial length of 261±3 mm. Some eels have been re-caught as many as nine times, and more than 10% have been apparently resident at the same site for more than four years. Only 5.8% (6 of 103) eels that were initially and subsequently caught during electrofishing surveys were caught at a different site, indicating a high degree of refuge site fidelity, at least among a portion of the population. Those eels that moved between captures were on average shorter (initial length 213±13 mm) than those that did not (initial length 264±6 mm). Because eels that were recaptured were larger than eels not recaptured, while eels recaptured in a different location were smaller than those recaptured at their initial location, we assume that local movements are size related, and that larger individuals are more likely to have a permanent residence. This accords with a recent study from a small catchment in France (Imbert *et al.*, 2010).

3) Given the strong site loyalty of eels, and given repeated visits to a single site, it may be possible to estimate electrofishing efficiency indirectly from the pattern of recaptures, at least for larger eels. Several individuals have already been captured multiple times, and more than 10% of eels have been found repeatedly at the same site for greater than four years. Sufficient data to conduct an initial analysis is anticipated within five years.

4) Silvering rates and mortality

Thus far only a single PIT-tagged eel has been trapped when emigrating from the burn, and many more years of study will be required before any analysis will be possible.

Problems and solutions

1) Growth rates

The mean growth rate measured at the Girnock was lower than any previously reported study of European eels. Furthermore, on a nearby catchment at higher altitude and using the same techniques we have estimated mean growth rate to be 5.6±0.8 $mmyr^{-1}$ (n=21). Because these growth rates are so low, and because no previously published growth-rate studies have used PIT tags, and because we insert the PIT tag in the body cavity, we were concerned that PIT tags themselves might be influencing growth rates, perhaps by competing with the stomach for volume in the body cavity. In order to assess this possibility, we began an experiment using a different marking technique (VIE) to investigate a possible impact of PIT tags on growth. Additionally we designed the experiment to detect an interaction between eel size and growth rate for the two marking techniques, reasoning that if PIT tags were reducing growth by competing with the stomach for volume then any differential in growth rates between eels marked with PIT tags and those marked with VIE would be greatest among smaller eels. For this purpose we allocated all eels >140 mm in length that we trapped ascending into the burn into VIE or PIT tag groups on a stratified random basis. Thus far we have not obtained sufficient recaptures to bring to bear on the question. Most recaptured eels with VIE marks reveal little or no change in the visibility of the marks, however, in a few cases the marks, while remaining readable, have separated out and moved toward the tail.

2) Local movements of eels

Less than 5% of re-captured eels were found in a different electro-fishing site from the one in which they were caught. However, almost 80% have not yet been recaptured at all. We aim to discover more about their movements by introducing an annual single-pass electrofishing survey, in early autumn, targeting different sites, and covering a greater spatial extent (ca. 2.5% of the total wetted area).

3) Electrofishing efficiency

Use of the pattern of recapture of an individual at a site to assess electrofishing efficiency requires an heroic assumption that eels apparently resident at a site are indeed exclusively attached to that site, rather than attached to several sites. Since 2010 the PIT tags used in the study are of a type capable of detection by a hand-held PIT tag detector, even when concealed under cobbles. Use of this equipment will allow determination of whether 'resident' eels are exclusively located at individual sites, or simply frequent revisitors to multiple sites. Furthermore, used simultaneously with routine electrofishing, the portable instream PIT tag detector should yield direct estimates of electrofishing efficiency.

4) Silvering rates and mortality

To estimate silvering rates based on recaptures requires a very long-term study, particularly in habitat with slow growth rates, such as the Girnock Burn. Additionally, accurate estimates of the efficiency of the downstream migrant trap will be required (see **case study of silver eel escapement at the Girnock**). Given the high site fidelity of a large portion of eels in the study site however, it may eventually be possible to estimate instream mortality with reasonable confidence, and to generate life tables for the burn.

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B) Mark–recapture of silver eels at the Girnock Burn, Scotland

The Girnock Burn, an upland stream with a catchment area of 2970 ha and a wetted area of 9.4 ha, is one of three small streams used to estimate silver eel escapement in Scotland RBD. A trap near the mouth of the burn, initially designed to catch all downstream migrating salmonids, has been used to catch downstream migrating eels since 1966. In the region of 100 silver eels are trapped annually. Its efficiency for eels is assumed to be close to 100% in normal flows, but may be of low efficiency during periods of high flow in autumn, when leaves may block the trap and cause spillage. Unfortunately these latter conditions are exactly those that often accompany the greatest number of eel downstream movements in the catchment, where migratory events appear to respond principally to flow conditions rather than moon phase.

Objective

To assess the efficiency of the Girnock trap for catching silver eels under a range of conditions, with the aim of developing calibration methods for silver eel escapement estimates (if required).

Method

Silver eels are caught in the trap, anaesthetized, lengthed and weighed, and assessed for marks. If the eel has no PIT tag, it is marked using 11mm Trovan PIT tags. Tags are inserted in the body cavity. An incision of ca. 2mm in length (i.e. just sufficient in order to admit the tag) is made in the belly of the eel just off the centre, using a narrow-pointed (rather than curved) scalpel blade. The PIT tag is inserted into the body cavity, and the area lightly massaged to ensure the tag is aligned parallel with the body wall. No sutures are used on the wound, and observations suggest healing is rapid. Eels are allowed to recover for approximately two hours before being released at an area of still water some 5 km upstream of the trap site. All silver eels caught in the trap are checked for PIT tags, and recaptures are recorded, re-measured, and released downstream. Because tags remain effective for the lifespan of the fish, and because the trap operates year-round, and trapped migrants are routinely checked for PIT tags in all years, even eels which migrate in subsequent years may be detected.

River stage at the trap is automatically logged each minute so that trap spillage can be characterized, and related to recapture patterns.

Results

This work began in August 2010, and it is too early to report any results.

Problems and solutions

Mortality

Unless all marked eels are recaptured, any analysis of the data to determine trap efficiency must either make some assumption about mortality post-release and prior to recapture, or attempt to measure mortality directly. We will attempt to quantify mortality by seeking for the marked eels/PIT tags which are not recaptured at the trap, using a hand-held mobile PIT tag detector designed for instream use. However, because this system will be able to detect an (unknown) proportion of remaining eels/PIT tags and it is likely that substantial uncertainty will remain about the fate of eels which are not recaptured.

Generic problem

Another generic problem of mark–recapture techniques is the assumption that the initially trapped animals are representative of the population. However, if some eels are inherently less susceptible to being caught than others, the mark–recapture methods will lead to an overestimate of trap efficiency, and hence and underestimate of silver eel escapement. Similarly if, having once been caught, eels are less-susceptible to recapture, mark–recapture techniques will lead to an underestimate of trap efficiency, and hence an overestimate of escapement. It is sometimes possible to address these two issues by using alternative capture techniques, but frequently it is simply hoped that the two issues are either trivial in effect, or cancel each other out. A flat bed PIT recorder, designed to automatically log all tags that pass over it, would form an ideal second capture technique at the Girnock, but is at present prohibitively expensive (ca. 70 000 Euros in 2010).

Pre-release recovery/retention time

We selected two hours as a recovery/retention period for the eels, aiming to strike a balance between jeopardizing eels by on the one hand releasing them prior to complete recovery from anaesthetic and surgery and on the other by causing increased stress from maintaining the eel in captivity for longer than necessary. This period of two hours is no better than a guess, but we have no plans to conduct studies which might help us optimize retention times, nor to assess post-marking mortality in captive individuals. This is because the number of silver eels produced by the catchment is insufficient to provide the likely statistical power required for such studies to generate firm conclusions while simultaneously allowing estimates of trap efficiency. If low recapture rates are indicated, and high mortality is suspected, future years may require such post-capture recovery of retained individuals to be assessed. Information from other studies on optimal time period for retaining eels would be valuable.

Flow conditions and recapture

Of particular interest in this study is the efficiency of the trapping system during periods of high flow, when the trap may spill, and when most migrants appear in the trap. However, if there is high variability among re-capture periods, then it will not be possible to relate recapture rates from different release batches/dates to particular conditions of river flow/trap spillage, perhaps necessitating ongoing assessment of trap efficiency on an annual basis. An allied problem is that relatively few nights, generally those nights when river stage rises substantially after a dry spell, account for a significant proportion of the total emigration from the catchment. If no marked eels are migrating on such a night, and particularly if trap spillage is simultaneously occurring, the assessment of trap efficiency may be flawed even if conducted across the entire season.

Case study 5

Sweden

1) Silver eel tagging in the Baltic Sea

Objective

Silver eels have been tagged for more than 100 years in the Baltic Sea. During the early 1900s the objectives were of scientific interest, to learning about eel biology and the spawning migration of silver eels. Since the mid 1900s most Swedish tagging studies were carried out in to investigate impacts of human activities as e.g. paper pulp production, marine constructions as the long bridges between Sweden and Denmark and the introduction of sub-marine electrical cables. More recently, the question as to whether stocked eels migrate and navigate differently from naturally recruited ones. A series of tagging studies were therefore initiated to find out if stocked and natural recruits differ in migration routes, speeds, etc. (Westin, 2003).

Although not originally planned for the purpose of estimating the escapement and fishing mortality in silver eels, data derived from mark–recapture studies of this kind were the only data available and thus used when the Swedish EMP was produced.

Methods

External tags as the Carlin-tag (McFarlane *et al*., 1990; Sjöberg *et al*., 2009) were used in most experiments, although a few eels during recent taggings were also fitted with ultrasonic tags internal Data Storage Tags (DST, www.eeliad.com).

When implanted tags (DST) were used, eels were anaesthetized using benzocaine, while for tagging only with Carlin- and external US-tags, they were handled without sedation. After tagging, eels were observed for hours before being released either close to where they caught or in a nearby location.

Most recaptures of tagged eels were reported by commercial eel fishers, who were paid a reasonable reward for their extra work.

Tag-type

Mostly Carlin-tags of different types were used in these tagging programmes (McFarlane *et al*., 1990). The US-tags were mostly of the VEMCO-type while the internal DST-tags came from Cefas in the UK (cf. www.eeliad.com).

Results-outcome

Results from both the historical and the most recent tagging experiments were described in a number of papers (Sjöberg and Petersson, 2005; Sjöberg *et al*., 2008; Sjöberg *et al*., 2009). The main results relevant in this context were:

1) that the old view of migration routes in the Baltic was confirmed and slightly modified;

2) that recapture rates have fluctuated quite considerably over time with a peak at about 50% in the mid 1960s, probably mirroring the fishing pressure. Today's recapture rate is about 30%;

3) There was a significant impact by *Anguillicoloides crassus* as more heavily infested eels were recaptured earlier and within shorter distances than eels with less parasites. This observation could also be associated with a

decrease in the risk of being caught, increase in the distance and time to capture. Distance travelled to recapture has increased consistently since the 1960s, before *Anguillicola* arrived.

Uncertainties/problems

Recapture depends totally on the fishery for eel in general and the fishers' willingness to report in particular. Their co-cooperativeness does fluctuate over time with respect to new regulations enforced, etc. As other countries as Denmark also catch eels from Sweden also their willingness has to be considered.

Solutions

So far we have handled potential problems of this kind through a very intensive and personal contact with as many fishers as possible.

Future actions/plans

The recapture data has recently been reanalysed and corrected for distance (risk of being caught) and known fishing mortality in different areas. This work in progress demonstrates that today's recapture rates are lower than previously thought (10% rather than 30%) and thus the escapement from the Baltic Sea is much larger than earlier believed (Dekker, pers. comm.).

This work in progress will be incorporated into a Pan-Baltic approach encompassing a large-scale tagging study where most countries around the Baltic Sea tag their silver eels in order to find out where the silver eels produced in different parts of the Baltic actually are caught. Such an extensive tagging study may also result in a better estimate of the total production of silver eels in the Baltic Sea. Taken together this will become a basis for a Pan-Baltic management programme for eel.

To circumvent the uncertainties related to the eel fishers' fluctuating willingness to collaborate and correctly report recaptures the use of internal tags as PIT-tags has been discussed, with screening of large numbers of silver eels at the most important fisheries as well at some dominating wholesalers. Additionally, a more elaborate statistical analysis of the recapture data will probably allow the detection (and correction) of suspect return rates.

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Westin, L. 2003. Migration failure in stocked eels *Anguilla anguilla*. Marine Ecology Progress Series 254: 307–311.

2) Ultra-sonic tagging/tracking in connection with hydropower issues

Objective

Mortality in silver eel related to the downstream passage of hydro power installations is one major source of today's total mortality in eel and is therefore seriously considered in the Swedish EMP. In attempts to facilitate this migration several methods have been tested. One has been the installation of finer trash-racks placed at an angle of about 30- with the bottom of the headrace channel. Other deflecting devices are also tested. To evaluate the effects in such operations, tag-recapture studies using ultra-sonic tags (less common radio-tags) in combination with fixed logging receivers are often performed.

Method

A number of eels are caught upstream the HP, or from some neighbouring site. This number is in general quite restricted due to the high costs of the tags. The receivers are placed so they will cover both up- and downstream options including possible alternative routes. The US-tags are attached externally just in front of the dorsal fin, using a steel wire. This operation, including measuring length, weight and eye size, is normally done by an experienced technician without sedating the eels. By comparing the signal strength from different receivers a rough estimate of the individual eel's position can be achieved. A similar setup can be done using radio-tags (Westerberg and Lagenfelt, 2008; Calles *et al.*, 2010).

Tag-type

Within the Swedish Board of Fisheries external tags and receivers of the VEMCO-type are mainly used. Others use radio-systems where the transmitters normally are placed in the body cavity.

Results-outcome

Preliminary results from two large hydropower plants in River Göta Älv indicate that the mortality was about 30% in total. However, very few eel continued downstream from the point of release in Lake Vänern; i.e. the results are in this case quite uncertain.

Uncertainties/problems

Tag-loss due to entanglement in roots, etc.

Non-detected passage due to a noisy environment.

Future actions/plans

Studies similar to those in the Göta Älv case will probably continue for a number of years.

Beside more elaborated technical solutions an easy action when trying to mitigate the mortality induced by HP's is trap and transport of silver eels passing to below the most downstream HP. The fate of such transported eels has to be studied and analysed. US-tracking is then a suitable method to find out the proportion of eels continuing towards the sea as anticipated.

References

Calles, O., I. C. Olsson, C. Comoglio, P. S. Kemp, L. Blunden, M. Schmitz and L. A. Greenberg. 2010. Size-dependent mortality of migratory silver eels at a hydropower plant, and implications for escapement to the sea. Freshwater Biology 55: 2167–2180.

Westerberg H. and I. Lagenfelt. 2008. Sub-sea power cables and the migration behaviour of the European eel. Fisheries Management and Ecology, 2008, 15, 369–375.

3) $SrCl_2$-marking to facilitate the assessment of restocking success

Objective

Stocked eels have been tagged and marked to estimate their growth and survival. In earlier pilot studies, eels were tagged (PIT-tags) or marked chemically in their otoliths before being released. From such experiments we realized that a full-scale marking programme would facilitate and simplify an assessment of the Swedish eel stocking programme. A parallel approach using chemical analysis of otoliths did not give clear and unambiguous answers whether an eel grown in the brackish environment in the Baltic Sea were from stocking or from natural recruitment. Since 2009 all eels stocked in Sweden have in practice to be marked chemically.

Method

In the pilot scale experiments small eels were either chemically marked using a bath of Alizarin Complexone (in 1997) or with a combination of PIT-tags and immersion in a weak $SrCl_2$ solution (Dean *et al.*, 2007).

Tag-type

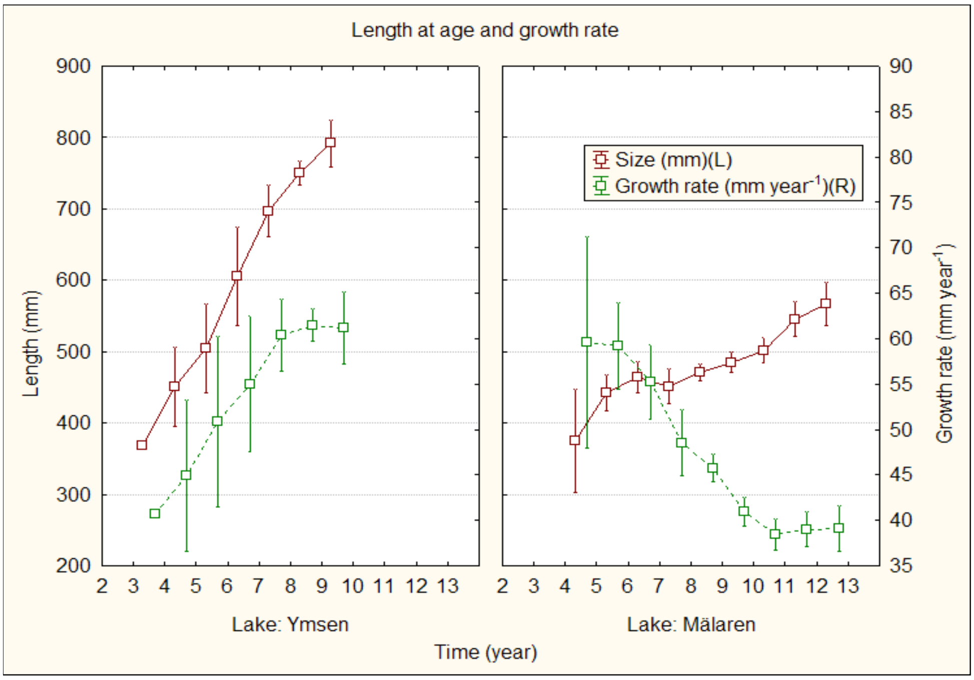
PIT-tags (Trovan ID-100, (11,5 mm)), Alizarin Complexone and strontium chloride ($SrCl_2$).

Results-outcome

Eels down to below 10 grammes each were successfully tagged with PIT-tags and no immediate (within days) damage or disturbance were observed. All PIT-tagged eels were also marked with $SrCl_2$ in order to select which individuals to be checked for an induced ring of strontium in their otoliths. Most PIT-tagged eels analysed have demonstrated a clear ring from the strontium treatment. As a check for fluorescence in otoliths is more easily done than with the quite complex strontium method, all eels caught from that experiment could be analysed. Marked eels could after 12 years in nature still be easily identified. Differences in growth rates were deduced both between and within two different lakes (Figure below).

The results from marking eels as small as 1 gramme initiated a full-scale programme where all eels stocked in Sweden have to be marked with strontium chloride. In 2010 some 1,9 million eels were marked as glass eels before they were stocked as one gramme eels in nature. Work in progress indicates all eels were successfully marked.

The proportion of stocked young eels can within a few years be assessed from yellow eel sampled in appropriate areas and in the long run also the run of silver eels can be sampled with respect to a strontium mark in their otoliths.



Differences in growth rates were deduced both between and within two different lakes.

Uncertainties/problems

The main uncertainty is whether or not all eels bathed in a solution of $SrCl_2$ according to our protocol take up and incorporate strontium in their otoliths, i.e. the "success-rate" of this method. The analytical method used so far (a WDS-microprobe) is quite laborious and expensive.

Solutions

Random samples are taken from different batches before being stocked. The analytical work is in progress and other analytical methods are investigated.

Future actions/plans

Ensure all stocked eels are marked and a sampling programme is commenced in two steps, first for growing yellow eels then for silver eels.

References

Dean L., Courtney, K. and P. Severin. 2007. Validation of otolith increment daily periodicity in captive juvenile sablefish (*Anoplopoma fimbria*) experimentally immersed in strontium chloride (SrCl2), Fisheries Research 83: 246–252.

Case study 6

Denmark

A) Open coast, tag recapture using Carlin tag, on silver eels, Denmark

Objective: Assessing the fisheries mortality in the poundnet fishery in Oresund

Method and results

On the open coast in Oresund (Baltic) a poundnet fishery is catching migrating silver eels. The silver eels originate in local Danish growth areas as well as growth areas in other parts of the Baltic Sea. A total of 1198 captured female silver eels mean length 71.9 ± 9.3 cm (sd) and weight 829 ± 285 g (sd) were anaesthetized with chlorobutanol, Carlin-tagged and released south of the poundnet fishery in Oresund. The tagged eels were released, the same day as they were tagged on 8–10 of October 1996.

In two semi-closed areas locally caught silver eels were treated as described above. They were released on the 29th and the 30th of September 1998 in the inner parts of the fjords. A total of 500 tagged male silver eels were released in the Isefjord (mean size 37.8 ± 2.1 cm and weight 86 ± 17.5 g) and 500 male silver eels were released on Roskilde Fjord (mean size 38.0 ± 2.4 cm and weight 98.0 ± 17.7 g).

The Carlin tags were equipped with individual numbers and return address. In Øresund 227 tags were returned corresponding to 19% of the released eels (Table 1). Within seven days after release 50% of the recovered eels were captured. The last eel was caught 66 days after release. They were captured in the Danish poundnet fishery from the site of release and north toward the Atlantic Sea. However, 17 eels choose a southward direction and were captured more than 20 km south from the site of release. Thirteen silver eels crossed the Danish Sound and were caught on the Swedish Coast in Kattegat and one eel was recorded as far north as Oslo Fjord in Norway, by a trawlboat.

In the semi-closed areas Roskilde Fjord and Isefjord recoveries were significantly more frequent (Table 1) suggesting that migrating silver eels are easier to capture in these areas. Within 10 and 11 days after release 50% the recovered eels were captured. The last eel was caught 36 days after release in 1998. Additionally three tagged eels were recovered in spring 1999. All eels were captured inside the semi-closed areas and no tagged eels were captured elsewhere on the migrating route in Kattegat.

Table 1. Recovered Carlin tagged silver eels in Øresund 1996 and Roskilde Fjord and Isefjord 1998.

Study area	Carlin tagged and release, n	Recoveries, n	Recoveries, %
Roskilde Fjord	500	189	37.8
Isefjorden	500	131	26.2
Øresund	1198	227	19.0

Advantages and disadvantages:

The Carlin tag is easily attached to the eel and may easily be seen by a fisher or any observer. The tag may be stuck in vegetation or nets and therefore lost from the eel. Some recaptured eels were reported with open wounds where the Carlin tag was attached.

Reference

Pedersen M.I. and Dieperink C. 2000. Fishing mortality on silver eels, *Anguilla anguilla* (L.) in Denmark. Dana 12: 77–82.

B) Anthropogenic mortality of silver eels on the River Gudenå

Objective

In the River Gudenå , ongoing studies use acoustic tags and PIT tags and remote listening stations to assess anthropogenic mortality (hydropower, fisheries) on migrating silver eels.

Method

Downstream migrating silver eels are captured during autumn in a permanent eel trap at the Vestbirk Hydroelectric power station. The eels are held in pens in the river for 1–8 days before tagging. They are anaesthetized in benzocaine and a PIT tag is inserted in the body cavity by a scalpel. The tagged eels are released as soon as they have recovered the same day. Remote listening stations are placed in the bypass streams at two hydropower stations located downstream of the site of release.

Provisional results suggest that in migrating a distance of ca. 100 km, in the middle part of the river Gudenå, between 2 and 6 percent are successful in bypassing the lower hydropower station in the River Gudenå. From there the silver eels have ca. 40 km of river before they reach the tidal zone.

Fifty acoustic transmitters (9×34 mm, weight in air of 5.3 g,) were used to study escapement rates in part of the River Gudenå where the river was too wide to use the PIT-tags due to the detection range of the PIT system. Acoustic tags were implanted in the body cavity of silver eels (>56 cm) by surgery and released as soon as they were recovered. Following tagging the eels were kept in holding tanks, and at the end of the day released in to the study area of river Gudenå.

Automatic listening stations (ALS; VR2, VEMCO Ltd., Canada) were placed at six sites in the river and the ability of the VR2 to detect acoustic signals in a range wider than the river was tested on all listening stations.

The results suggest that overall escapement to the tidal limit was 23% predominantly due to difficulties in bypassing the hydropower dam and possible mortality on the bar racks in front of the turbines.

Advantages and disadvantages: The lifespan of PIT tags are not restricted as acoustic tags. The lifespan of acoustic tags depends on the capacity/size of the battery and a long lasting tag is therefore much bigger. In contrast a PIT tag requires no power, and so will remain effective throughout the lifespan of the fish. The detection range of PIT tags are, however, much smaller and PIT systems can only be applied to smaller systems of about 5 m width as opposed to Acoustic listening stations that may be arranged as an array covering a large area.

Case study 7

Germany, River Elbe

Objective

M–R has been applied to three sites (two in tributaries to river Elbe, one in river Elbe stream) in an attempt to estimate the number of silver eel passing that point on their way to the North Sea.

Methods

The methodological approach has been to estimate the catch rate of an individual fishing gear by marking silver eel caught in that very gear and releasing them upstream close to the gear. Because these gears are run all through the year (except some month in late winter when the surface is covered by Ice) by commercial fishers, full year catch statistics are provided and allow in combination with individual catch rates for an estimation of silver eel escapement from the upstream tributary. The study was combined with a telemetry study in order to get an impression of average migration velocity. Only silver females of stages >= III and males of stage II (Durif – index) were chosen for marking. Marking was performed during peaks of silver eel runs in autumn and spring.

Technical details

Anaesthetic used: clove oil

Recovering time before release: app. 5 h

Distance between release point and gear: 1–2 km depending from site

Gear type: stownet (two stations), 50 trapnets setup within a lake-like river stretch (one station)

Marking: VIE-Tags

Results

In the period 2005–2008, between 77 and 500 silver eels were marked every season at different stations (Table 1). The total length covered a range of 31–97.5 cm (weight 59–1706 g), indicating that both sexes were included.

From 1818 marked eels, 144 (7.9%) had been recaptured until the end of 2008. Depending of the station, first recaptures took place within 24 hours after release while one eel regardless of the short distance between the point of release and the fishing gear was caught 950 days post release. The majority of recaptures was detected within 24 hours in the main channel and within a month in one of the tributary rivers (Figure 1).

Table 1. Number and size of marked eels.

Station	Marking period (autumn/spring)	Number marked	Average total length (cm)
Upper Havel River	2005/2006	150	55.2 (36.5–85.5)
	2006/2007	77	61.9 (37.0–86.5)
	2007/2008	140	57.1 (38.0–79.0)
River Rhin	2005/2006	150	45.1 (34.5–79.5)
	2006/2007	151	44.0 (31.0–82.5)
	2007/2008	150	44.0 (35.5–76.0)
River Elbe	2006/2007	500	64.7 (38.5–91.5)
	2007/2008	500	64.9 (36.0–97.5)

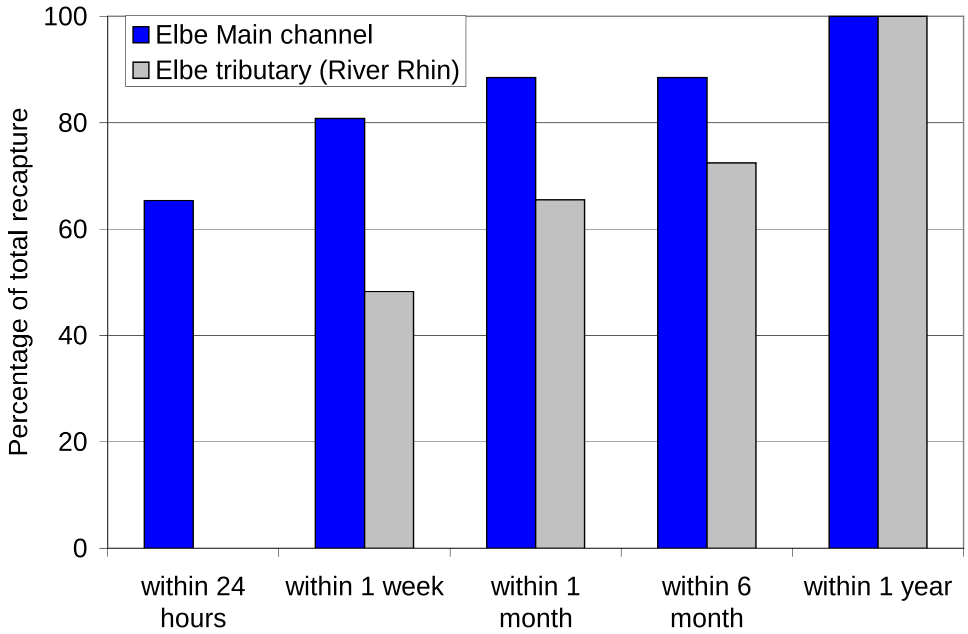


Figure 1. Time lag between release and recapture in River Elbe main channel (blue) and at one location in the tributary (grey).

Catch rates fluctuated strongly between gears and seasons. While the values for the stownets varied between 6–16% (Upper Havel River) and 1–3% (River Elbe main channel), they reached in sum 0.2–0.6% for 50 trapnets. This demonstrates that catch rates of gears are strongly variable with regard to type, location and season and results cannot be generalized.

In combination with yearly catch statistics, a silver eel escapement between a few thousands individuals in tributary waters and up to 280 000 individuals in the main River Elbe channel was estimated. This compares with an escapement of 0.7–6.2 individuals per hectare upstream water surface area (Table 2). Differences of up to 300% between years are supposed to originate mainly from strong fluctuations in water discharge between seasons, which lead to different levels of silver eel escapement as well as to varying catch rates of the gears.

Table 2. Estimated Silver eel escapement in tributaries to River Elbe (Upper Havel. Rhin) and River Elbe main channel.

River	Gear	Marking period (autumn/spring)	Estimated silver eel escapement (Individuals)	
			total	per hectare
Upper Havel River	Stownet	2005/2006	4500	0.8
		2006/2007	3900	0.7
		2007/2008	7800	1.4
River Rhin	Trapnets	2005/2006	7500*	2.1
		2006/2007	14 000*	3.8
		2007/2008	5000*	1.4
River Elbe main channel	Stownet	2006/2007	280 000	6.2
		2007/2008	91 700	2.0

*** Mainly males due to upstream obstacle for escapement of eel larger app. 50 cm TL.**

Problems and weakness

The observed low recapture rate of app. 8% on average very likely contributes to high variations of estimates between seasons and therefore leads to a comparably high degree of uncertainty. A second drawback is the time-lag between release and recapture particularly in the tributary, which increases the risk of mortality for marked eels and therefore lowers the precision of estimates.

Annex 7: Draft proposal for a study group or working party on sustainable (eel) fisheries

Background

Eel have been fished since historical times and were included in the diet of our ancient ancestors throughout the ages (Tesch, 2003). Harvesting eel has been described in many publications and traditional fisheries different between regions, between catchments and between the different life-history stages being exploited. In general, glass eel were exploited in the central part of the range and silver eel fishing dominating in the north (Moriarty and Dekker, 1997). Traditional fisheries can, and have, adapted to cope with changes in stock and market options, where as legislation modifies rather than determines exploitation (Dekker, 2003).

With the decrease of eel fisheries at all stages due to (i) the strong decline of the stocks, (ii) the implementation of the EU Regulation and Eel Management Plans limiting effort and catch (e.g. CITES quotas for glass eel), (iii) the contaminations of eels in several areas involving bans on fishing and consumption of eel, the maintenance and continuance of the eel fishery (and the livelihood of eel fishers) becomes problematic.

ICES advice in recent years has consistently been to reduce fishing and other forms of anthropogenic mortality to as close to zero as possible. However, within the management options of the EU Regulation, fishing continues to be an option open to various degrees of restriction and modification. It is obvious that in some fishing areas, the continuation of eel fishery is in contradiction with the status of the stock and the biological requirement of the EMP. But even in such fishing areas, some professional eel fishers remain and in other areas where common conditions of fishing are required (captures with or without quota allowed, human consumption not forbidden), eel professional fishers continue to practise their job seek a livelihood through fishing. In many cases, and increasingly so, eel is one species in a multispecies fishing effort by individual fishers, where diversification is possible. In some cases, however, reducing eel fishing may also have impacts on the other species by increasing the pressure on those. In addition, where fisheries depend on a number of other diadromous species (e.g. shads, salmon) and those species also come under conservation pressure along with eel; those fisheries are in serious jeopardy.

Proposal

Management of fisheries includes economic, social and political issues along with scientific advice on the status of the exploited stocks. Where so-called traditional fisheries are involved, this puts additional pressure on the system as many traditions, practices, techniques and even local gastronomies and recipes may be changed or lost.

Climate change is putting additional pressures on the system with fisheries and fisheries managers have to adapt to cope with changing environment and species abundance and availability. Diadromous species, and their fisheries, are particularly vulnerable in this context.

It is proposed to establish a project to examine and document the eel fisheries, their extent, socio-economic status and future.

- Establish the previous status of the eel fishery in the various regions and river basins with a **historical** approach that would permit a reference situation on a social, economic and ecological point of view: what we had, what we have lost (what is the loss), what could be the objective of restoration.
- The maintenance of an eel fishery and obviously the objective of restoration, development of this activity in future as proposed above, needs to meet with the conditions of sustainable development.

These need to use basic biological and socio-economic indicators (see Indicang; Adan *et al.*, 2008; Castelnaud and Beaulaton, 2008). For practical reasons, the historical approach generally only uses these basic indicators particularly in socio-economic (population, production, turnover) but the current approach and a prospective approach could involve research with elaborate sociology and economic indicators that require the application of methods geared to these fields.

Additional questions to be tackled might include:

1. Is the species in its fishing area able to accept a fishing pressure and of what magnitude?
2. Are the eel fisheries economically viable in connection with the fishery context of the fishing area (*mono-* or *multispecies*, *full-* or *part-time* activity)?
3. Are the fishers able to integrate tje concept of sustainable development for their activity and participate in a global management process? What are the conditions and consequences?

In order to tackle these questions, point 1 needs fishery biology indicators, point 2 needs economic indicators and point 3 needs sociological indicators.

Points 1 and 2 are connected with the fishery monitoring systems for a part of the information required and the objective of assessment of eel fisheries sustainability give a new interest to the traditional statistics. Such assessment and diagnosis involves the improvement and creation of appropriate monitoring systems which help in their basic theoretical function which is to fill-in local, national and FAO fisheries statistical databases.

Point 3 gives a central role to the fishers in the feasibility of the investigation and the process of evaluation and decision, which will consider the vision of a particular user of the inland water services. This will challenge the scientists and the community concerning the priorities to be taken into account for the management of eel in its socio-politic, economic and ecological context. This would also feed into a review of how the EU Regulation has impacted on individual fishers and local communities.

References

Adam G., Feunteun E., Prouzet P., Rigaud C. (Coord.). 2008. L'anguille Européenne, indices d'abondance et de colonisation. Projet Européen Intereg Indicang. Edition QUAE. 400 p.

Castelnaud G. and Beaulaton L. 2008. Indicateurs d'abondance et de pression issus des pêcheries. Chapitre 6 in L'anguille Européenne, indices d'abondance et de colonisation, Adam G., Feunteun E., Prouzet P., Rigaud C. (Coord.), Projet Européen Intereg Indicang. Edition QUAE. pp. 189–220.

Dekker, W. 2003. O the distribution of the eel and its fisheries. *Canadian Journal of Fisheries and Aquatic Sciences*, **60;** 787–799.

ICES. 2006. Report of the 2006 Session of the Joint EIFAC/ICES Working Group on Eels. Rome, 23–27 January 2006. CM2006/ACFM, 16: 352p.

Moriarty, C. and Dekker, W. (eds.) 1997. Management of the European Eel. Fisheries Bulletin (Dublin); **15**; 110pp.

Tesch, F.W. 2003. The Eel. Blackwell Science. 408pp.

Annex 8: Technical minutes from the Eel Review Group

- RGEEL
- By correspondence 9–12 November
- Participants: Erkki Ikonen (Chair), Andre Forest, Henrik Svedäng and Russell Poole (WG Chair)
- Working Group: WGEEL

General

The Review Group considered the following stocks:

- European eel (*Anguilla anguilla* L.).

And the following special WGEEL tasks:

a) assess the trends in recruitment and stock, for international stock assessment, in light of the implementation of the Eel Management Plans;

b) develop methods to post-evaluate effects of management actions at the stock-wide level (in conjunction with SGIPEE);

c) 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 (in conjunction with SGAESAW 2);

d) provide practical advice on 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;

e) review and develop approaches to quantifying the effects of eel quality on stock dynamics and integrating these into stock assessments;

f) respond to specific requests in support of the eel stock recovery Regulation, as necessary; and

g) report on improvements to the scientific basis for advice on the management of European and American eel.

André Forest: This is a comprehensive, informative and well-organized report. It includes a great amount of basic scientific background information for a good understanding of the specific problems related to the assessment of the eel stock. The report is 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.

The main message is that the eel stock has been in a very poor state for many years, and this is consistent with the previous reports.

There is a clear need to standardize various methods, including sampling, estimates of wetted areas, estimation of current eel production, contaminants, etc. The WG is developing quite sophisticated (and interesting) methods for stock assessment and post-evaluation, but the quality of the available data could strongly limit the interpretation of the results. The WG is aware of that and provides a list of items to be improved.

The WG provide a preliminary assessment of stock status in 40 Eel Management Units, with the corresponding graph but at the same time, it is said that “data might be incomplete, inconsistent, or false; though problems are known, no corrections have been made”. Furthermore, it is quite a surprise to see that most of the EMUs are in the orange zone and not in the red one whereas glass eel recruitment average 1 to 7% of its historical level, and yellow eel recruitment is 9% of its historical level; in other words, the general picture provided by this graph seems to be less dramatic compared to the recruitment trends. It seems that these estimates need to be improved before to be use, on which the WG is aware of.

Research needs: some priorities are listed under Section 7, but various recommendations are disseminated in various part of the report. It could be useful to make a synthesis of all these recommendation and to define priorities, although it is understandable that the list shouldn’t be made too extensive.

Some technical points

Page 43–44: Section 4.2.1 the same sentences (starting with “single point studies” and finishing with “the individual case studies (Annex 6) appear at the end of the first and the second paragraph.

Page 50, 3rd paragraph from the end : “… this poses some difficulties when using the models describes below…” does this sentence means that the WG do not recommends to use of ELSA, EDA, Probability Model, SMEP II and DemCam for stock assessment purpose? Or what are the recommendations of the WG.

Henrik Svedäng: It states that the species is still in decline and at risk, but this core message has to be further emphasized. The momentum of the decline in recruitment should be put forward to managers as it threatens to reduce the recruitment even more in forthcoming eel generations.

Although eel management plans have been adapted, the reader should be made aware of the fact the variations between countries and EMUs are considerable. In some areas such as in Eire, eel fishery has been stopped, whereas in other countries like Sweden and Germany the restrictions are rather soft on the fisheries, and the outcome of the plans are also dependent on eel stockings, a practice which may be counter-productive to the aim of increasing the effective spawning stock. These flaws in the national eel management plan need to be further scrutinized in forthcoming assessments.

The report from WGEEL is far too long and needs to be structured to be more readable, otherwise important information might get lost to managers. In the future, the assessment reports could be divided into two parts: one giving an assessment of stock status together with a critical evaluation of different eel management plans, the second dealing with technical issues such eel biology, evaluation of assessment instruments and so on. In short, all major instruments/tasks in the management toolbox/agenda should be evaluated in a precautionary context. Where are we, what could be done in the short and medium-term perspective, with emphasis on how robust the management tends to be.

a) Are existing restrictions on the fishery giving the results within the catchment area t we/the management are expecting? In other words, are there improvements to be made for different management plans?

b) Are the schemes for evaluation of EMUs applicable, realistic and relevant?

c) Is stocking precautionary? All arguments pros and cons concerning stocking should be scrutinized on a yearly basis as long as stocking is used as management tool in order to mitigate the restrictions on other anthropogenic mortalities, in particular fishing.

d) To what extent have eel habitats been improved in the different EMUs? Listing by EMUs year by year.

e) Eel quality. The changes in eel quality status should be followed and evaluated.

Annex 9: Country Reports 2010: Eel stock, fisheries and habitat reported by country

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.

Participants from the following countries provided an (updated) report to the 2010 meeting of the Working Group:

- The Netherlands
- Belgium
- Norway
- Sweden
- Finland
- Poland
- Germany
- Denmark
- Ireland
- The United Kingdom of Great Britain and Northern Ireland
- France
- Spain
- Italy
- Portugal
- Latvia

For practical reasons, this report presents the Country Reports in electronic format only (URL). Available at:

http://www.ices.dk/reports/ACOM/2010/WGEEL/CountryReports_2010.pdf