Report of the 2007 session of the Joint EIFAC/ICES Working Group on Eels

Bordeaux, France, 3–7 September 2007

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This publication is the report of the 2007 session of the Joint European Inland Fisheries Advisory Commission (EIFAC) and International Council for the Exploration of the Sea (ICES) Working Group on Eels, held in Bordeaux, France from 3 to 7 September 2007.

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Abstract

This report summarizes the presentations, discussions, and recommendations of the 2007 session of the Joint EIFAC/ICES Working Group, which took place in CEMAGREF, Bordeaux, France, from 3 to 7 September 2007.

Information on recruitment, stock, and fisheries reviewed by the WG continues to support and reinforce the advice that the global European eel stock has declined in most of the distribution area and is outside safe biological limits. Recruitment of glass eel to the continental stock remains low, with no obvious sign of recovery. Most recent data indicate a continued downward trend in the stock–to–recruit relationship, heightening concern over possible depensation and concerns about the stock's ability to recover, even in the long term. The WG concluded that, before the practice of stocking was introduced, the presence of eel in the river systems connected to the Black Sea and the Danube was, at best, sporadic, and concluded that the area around the Black Sea is at the extreme limits of the natural geographic range for eel.

The WG welcomed the EU regulation that establishes measures encouraging the recovery of the stock and emphasized that this be implemented urgently. The urgent need to reduce mortality as soon as possible is clear. The objective of the regulation is the protection and sustainable use of the natural eel stock. To achieve this, Member States will develop eel management plans for their river basins, aiming at a reduction in anthropogenic mortalities so as to permit the escapement to the sea of at least 40% of the biomass of silver eel, relative to the best estimate of escapement that would have existed in the absence of anthropogenic influences on the stock. There are strong indications that recruitment might be impaired by the low spawning stock. Prioritization of restrictions on anthropogenic impacts will be consistent with the risk-averse strategy of the precautionary approach, while making best use of positive actions that potentially boost the stock.

In the 1970s, recruitment of the glass eel was still at historically high levels. This indicates that SSB was not limiting the production of recruits at that time. Quantification of the 1970s spawner escapement therefore is the simplest derivation of the reference level. Note that in this case, the full escapement of the silver eels in the 1970s (given the anthropogenic mortality of that time) corresponds to the escapement level advised by ICES. That is, one should set the reference point either at 100% of the 1970s silver eel escapement, or at a percentage of the notional pristine state.

It is of utmost importance that existing recruitment monitoring be continued and improved, easing the dependence on commercial fisheries, and extended where inadequate. A radical improvement in the assessment of the current state of the stock, including quantification of the impact of anthropogenic mortalities, is urgently needed and required in the Eel Management Plans (EMPs). Although comprehensive datasets exist in some river basins, this assessment will not be achievable in most river basins from currently limited data. Therefore, it is proposed that concerted research be initiated urgently to compile datasets, develop regression models of the relation between impacts and stock, and inter/extrapolate to the data-poor situations.

Though density-dependence has been demonstrated in several life stages by means of various mechanisms, it is not well understood, and knowledge is certainly inadequate to predict where it will occur or on what processes it will act (i.e. growth, colonization patterns, sexual differentiation and sex ratios, mortality). This affects both the calculation of restoration targets, and the assessment of the impact of fisheries and other anthropogenic factors.

Sampling methods available to provide the data for these population status and management action assessments were considered. Experience gained from the EU INDICANG programme, previous WG reports, published scientific literature, and the knowledge of

the WG participants was used to consider a pragmatic approach, given the short time available to develop the EMPs. These and other methods will also be used in further improving EMPs and in the post-evaluation of the effectiveness of the management measures.

Stocking and transfers of juvenile eel have been discussed at length by the Working Group (most recently ICES, 2006), mainly in conceptual and theoretical frameworks owing to a lack of hard data. Given that stocking is listed in the forthcoming regulation as one management option among others to aid stock recovery, it was agreed that the major need is robust evidence of the extent to which stocking and transfer on local, national, and international scales can contribute to improved spawner escapement. Glass eel to silver eel production and growth rates may be non-linear over the ranges of input stock densities in local studies (100–1600 glass eels ha^{-2}) reported to date, suggesting that optimum output expressed per glass eel equivalent is to be gained at the lower stocking densities. Little information is available on the effect of stocking on-grown eels, although studies suggest that growth, sex ratio, and return rates (numbers of silver eels per glass eel) prior to spawner emigration are in the same order of magnitude as in natural eel populations. Stocking programmes should be aware of the need to simulate natural processes as far as possible, because this is most likely to lead to high success rates, measured in biomass or numbers of silver eel escaping to the sea.

Considerable advances have been made in the collection of data on contaminants, parasites, and fat levels in eel, with many Member States commencing the monitoring of eel quality. WGEEL has established a European Eel Quality Database (EEQD). The eel quality data are highly variable, and identification of "black spots" is possible for low-quality eels. The parasite *Anguillicola crassus* appears to be widespread across Europe. Relating the database parameters to assess their impact on the stock or to management targets was not possible during WGEEL 2007, but eel quality parameters should be included in eel stock assessments.

The working group reviewed the anthropogenic impacts of impediments to upstream migration, downstream migration barriers, and turbine mortality. Assessing anthropogenic range restriction is therefore an important consideration in the assessment of compliance with the target of 40% of natural spawner-escapement levels. A system for categorizing the severity of individual and cumulative effects of obstacles to upstream eel migration into a single score, based on obstacle height, gradient, surface roughness, and bank characteristics, has been developed. It is important to maintain upstream continuity, especially where downstream access to the sea for spawners is assured. Hydropower has been recognized as one of several factors contributing to the dramatic decline in the eel population, and eels tend to have considerably greater mortality rates from downstream passage at hydropower stations than other fish species. There is a need to quantify these impacts further, as well as those possibly occurring at cooling water intakes, pumping stations, and tidal power plants. A variety of behavioural and mechanical mechanisms for reducing or avoiding mortality in turbines are discussed.

Natural mortality of eels is a major but relatively unknown factor in the population dynamics of the species. Mortality caused by predation is but one of the factors contributing to natural mortality (and may be compounded by other issues such as disease and parasitism). The EU regulation lists reducing predation as a possible management option that could be employed when attempting to reach escapement targets. Methods for assessing the levels of eel in the diet of predators were discussed, in particular for cormorants and otter, although determining the level of impact on the stock is difficult. Crude calculations indicated cormorant consumption of eel on the order of 30–50% of the 1993/94 commercial European catch. Measures for reducing the level of predation are presented and discussed in relation to the various protective regulations and directives.

FAO European Inland Fisheries Advisory Commission; International Council for the Exploration of the Sea. Report of the 2007 session of the Joint EIFAC/ICES Working Group on Eels. Bordeaux, France, 3–7 September 2007. EIFAC Occasional Paper. No. 39. ICES CM 2007/ACFM: 23. Rome, FAO/Copenhagen, ICES. 2008. 138p. (Includes a CD-ROM).

Executive summary

This report summarizes the presentations, discussions, and recommendations of the 2007 session of the Joint EIFAC/ICES Working Group, which took place in CEMAGREF, Bordeaux, France, from 3 to 7 September 2007.

In this section, the report's main outcomes are summarized, a review of the forward focus presented in the 2006 report is suggested, and the main recommendations are presented.

Summary of this report

A review of the available information on recruitment, stock, and fisheries continues to support and reinforce the advice that the global European eel stock has declined in most of the distribution areas and is outside safe biological limits. Recruitment of glass eel to the continental stock remains low, with no obvious sign of recovery. Most recent data continue the downward trend in the stock to recruit relationship, heightening concern over possible depensation and the stock's ability to recover, even in the long term. Current levels of anthropogenic mortality are not sustainable and should be reduced to as close to zero as possible. The working group concluded that, before the practice of stocking was introduced, the presence of eel in the river systems connected to the Black Sea and the Danube was at best sporadic, and concluded that the area around Black Sea is at the extreme limits of the natural geographic range for eel.

The working group welcomes the EU regulation establishing measures towards the recovery of the stock and urges that this be implemented as a matter of urgency. The urgent need to reduce mortality as soon as possible is clear. The objective of the EU regulation is the protection and sustainable use of the natural eel stock. To achieve this, Member States will develop eel management plans (EMPs) for their river basins, achieving a reduction in anthropogenic mortalities that permit the escapement to the sea of at least 40% of the biomass of silver eel relative to the best estimate of escapement that would have existed if no anthropogenic influences had impacted the stock. There are strong indications that recruitment might be impaired by the low spawning stock. Prioritization of restrictions on anthropogenic impacts (fisheries and other anthropogenic mortalities) will be consistent with the risk-averse strategy of the precautionary approach, while also making best use of positive actions potentially boosting the stock (e.g. stocking or trap-and-transport of glass eel).

In the 1970s, recruitment of glass eel was still at historically high levels. This indicates that SSB was not limiting the production of recruits at that time. Quantification of the 1970s spawner escapement, therefore, is the simplest derivation of the reference level. Note that in this case, the full escapement of the silver eels in the 1970s (given the anthropogenic mortality of that time) corresponds to the escapement level advised by ICES (2002a). That is, one should set the reference point either at 100% of the 1970s silver eel escapement or at a percentage of the notional pristine state.

It is of utmost importance that existing recruitment monitoring is continued and improved, easing the dependence on commercial fisheries, and extended where inadequate. A radical improvement in the assessment of the current state of the stock, including quantification of the impact of anthropogenic mortalities, is urgently needed. Although comprehensive datasets exist in some river basins, this assessment will not be achievable in most river basins from currently limited data. Therefore, it is proposed that concerted research is initiated as soon as possible to compile datasets, develop regression models of the relation between impacts and stock, and inter/extrapolate to the data-poor situations.

The first post-evaluation of the EU regulation is required at the end of 2012. Timely development of assessment procedures is required, geared to the data becoming available, while indicating the progress towards recovery of the stock.

Though density-dependence has been demonstrated in several life stages by various mechanisms, it is not well understood, and knowledge is certainly inadequate to predict where it will occur or on what processes it will act (e.g. growth, colonization patterns, sexual differentiation and sex ratios, mortality). This affects both the calculation of restoration targets, and the assessment of the impact of fisheries and other anthropogenic factors. Fundamental research will be required.

The working group considered the sampling methods available to provide the data for these population-status and management-action assessments. Experience gained from the EU INDICANG programme, previous working group reports, published scientific literature, and the knowledge of working group participants was used to consider a pragmatic approach, given that there is less than 18 months to develop the EMPs, but also that these and other/additional methods will be used later as the further improvements of EMPs and the post-evaluation of the effectiveness of the management measures, as required by the EU regulation. Recommendations were made for the use of particular methods for various eel-stage and habitat-type combinations, the standardization of methodological approaches where appropriate, and identification of areas for further research and development, or future technical support, required to inform this topic.

Stocking and transfers of juvenile eel have been discussed at length by the working group (most recently ICES, 2006). These discussions have covered the principles and extent of stocking, stock transfer practices, and their contributions to fisheries. The effect on escapement has been discussed mainly in conceptual and theoretical frameworks owing to a lack of hard data. Given that stocking is listed as one management option in the forthcoming EU eel regulation, among others, to aid stock recovery, it was agreed that what is now needed above all is robust evidence of the extent to which stocking and transfer on local, national, and international scales can contribute to improved spawner escapement.

Glass eel to silver eel production and growth rates may be non-linear over the ranges of input stock densities in local situations (100–1600 glass eel per ha) reported to date, suggesting that optimum output, expressed per glass eel equivalent, is to be gained at the lower end of this range. Relatively little information is available on the effect of stocking on-grown eels, but available studies suggest that the result in terms of growth, sex ratio, and return rates (numbers of silver eels per glass eel) prior to spawner emigration are in the same order of magnitude as in natural eel populations. Stocking programmes should consider the need to simulate natural processes as far as possible, because this is most likely to lead to high success rates measured in biomass or numbers of silver eel escaping to the sea.

Previous reports provided comprehensive reviews of anthropogenic mortality, issues relating to spawner quality, and the role and risks relating to stocking of eels. Recent advances are reviewed here and related to the EU Recovery Plan and recovery of the stock. Considerable advances have been made in the collection of data on contaminants, parasites, and fat levels in eel, with many Member States commencing the monitoring of eel quality. WGEEL has begun the establishment of a European Eel Quality Database (EEQD). The eel quality data are highly variable and indicate the possibility of identifying black spots for low-quality eels. The parasite *Anguillicola crassus* appears to be widespread across Europe. Relating the database parameters to assess their impact on the stock or to management targets was not possible during WGEEL 2007, but eel quality parameters should be included in eel stock assessments.

Anthropogenic impacts on the stock caused by impediments to upstream migration, downstream migration barriers, and turbine mortality were reviewed and new information presented. Assessing anthropogenic range restriction is therefore an important consideration in the assessment of compliance with the target of 40% of natural spawner-escapement levels. It should be recognized that the present state of knowledge is inadequate for making these assessments with confidence. In particular, the role of density-dependence in the functioning of eel populations is poorly understood, and the relationship between habitat and eel production is not well described. Such assessments of the impact of obstacles to upstream movement and the resultant loss of production should be carried out on a case-by-case basis, using locally derived parameters. A system for categorizing the severity of individual and cumulative effects of obstacles to upstream eel migration into a single score based on obstacle height, gradient, surface roughness, and bank characteristics has been developed. Here we argue that allowing the eel to re-colonize its natural range by the removal of artificial barriers, where there are no concerns regarding mortality when recrossing those barriers in a downstream direction, is an application of the precautionary principle because, first, it increases the potential range of habitats from which spawners can be recruited, and second, it must reduce (or at worst leave unchanged) density-dependent pressures on growth and mortality.

Hydropower has been recognized as one of several factors contributing to the dramatic decline in the eel population, and eels tend to have considerably greater mortality rates from downstream passage at hydropower stations than other fish species. There is a need to quantify these impacts further, and those possibly occurring at cooling water intakes, pumping stations, and tidal power plants. Quantification and a cost benefit analysis (biological and economic) of management options will be required. A variety of behavioural and mechanical mechanisms for reducing or avoiding mortality in turbines are discussed.

Natural mortality of eels is a major, but relatively unknown, factor in the population dynamics of the species. Mortality caused by predation is but one of the factors contributing to natural mortality (and may be compounded by other issues such as disease and parasitism). The new EU regulation lists reducing predation as a possible management option that could be employed when attempting to reach escapement targets. Methods for assessing the levels of eel in the diet of predators were discussed, in particular for cormorants and otter, although determining the level of impact on the stock is difficult. Nevertheless, rough calculations may offer an insight into the order of magnitude of eel mortality caused by the cormorant, a top aquatic predator in relatively shallow salt, brackish, and fresh waters. Preliminary crude calculations indicated cormorant consumption of eel on the order of 30–50% of the 1993/94 commercial European catch. Measures for reducing the level of predation are presented and discussed in relation to the various protective regulations and directives. In the case of the cormorant, perhaps the commonest eel predator at the time of writing, attempts to mitigate against the species would involve formal requests to the relevant authorities and require compliance with the Birds Directive (often through national authorities). Other predators such as the otter have very high conservation status, and it is likely to be extremely difficult to obtain permission for potential mitigation activities. militate

Forward focus

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

Future focus of the working group might include:

a) the assessment of the trends in recruitment, stock, and fisheries indicative of the status of the global stock, and the impact of exploitation and other anthropogenic impacts; analysis of the impact of the implementation of the eel recovery plan on time-series data; evaluation of the eel stock at the international level;

b) the establishment of an international database for data on eel stock and fisheries, as well as habitat and eel-quality-related data; review and make recommendations on data quality issues;

c) the response to specific requests in support of the development of the stock recovery plans as necessary;

d) the development of methodologies for the assessment of the status of the local eel populations, the impact of fisheries and other anthropogenic impacts, and of implemented management measures.

Main recommendations

The 2007 session of the Joint EIFAC/ICES Working Group on Eels at CEMAGREF, Bordeaux, France, recommends that:

a) Because recruitment remains at an all time low since record keeping began and stock recovery will be a long-term process for biological reasons, all exploitation and other anthropogenic impacts on production/escapement of silver eels should be reduced to as close to zero as possible, until long-term recruitment recovery is assured.

b) It is of utmost importance that existing recruitment monitoring is continued, improved (e.g. removing the dependence on commercial fisheries), and extended. An assessment of the current status of the European spawning stock, including an assessment of the impact of anthropogenic mortalities, is urgently needed.

c) Research is urgently required to support the implementation of the EU regulation for recovery of the eel stock, including: development of proxies for mortality rates; development of coherent local stock assessment procedures; improvement of population models to assess compliance with the recovery target, and focus and evaluate management actions.

d) Fundamental research must also be immediately initiated and financed. The priorities include possible density-dependence effects on various processes (mortality, growth, movement, maturation, and sex differentiation), as well as evaluating the potential net benefit of stocking.

e) Guidelines, or best practice manuals, should be established for methodologies for assessing the status of the eel population, the impact of fisheries and other anthropogenic impacts, stocking of eel, and data quality assurance.

f) The European Eel Quality Database (EEQD) should be further developed and maintained, and Member States should harmonize monitoring strategies for eel.

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

Eel Working Group 2007, Bordeaux, France

By WGEEL, The Bard

You've got a Regulation, your Mercedes Benz
Your minds they might be twisted, but you are all still friends
In the master's chambers, you've gathered for the feast
You've stabbed it with your steely knives, but you just can't kill the beast
You cannot stop for the night
But work till morning light
This is your mission bell
So work it out yourself
It certainly isn't heaven, but neither is it hell.
So light us up a candle and show us the way
We'll wait outside - we're elsewhere
To hear what you say…

Welcome to the Hotel California
Such a lovely place (such an eely place)
such an eely face
You've lived it up at the Hotel California
Where there are no lies (What a nice surprise)
Keep the eel alive.

You can checkout any time you like,
But you can never leave!

(With apologies to the Eagles, and the "Real" Hotel California)

Contents

1 Introduction

1.1 The 2007 WGEEL

At the 94th Statutory Meeting of ICES (2006) and the 24th meeting of EIFAC (2006) it was decided that:

2007/2/ACFM23–The Joint EIFAC/ICES Working Group on Eels (WGEEL); Chair: Russell Poole, Ireland), 3–7 September 2007 in Bordeaux, France, to:

a) assess trends in recruitment, stock, and fisheries indicative of the status of the stock and the impact of exploitation; among others, this might involve the establishment of an international database on eel stock and fisheries, as well as habitat-related data;

b) review available methodology for assessing the status of the eel population, the impact of fisheries and other anthropogenic impacts, and of implemented management measures (that is, results of FP6 project Slime), and consider options for stock assessment at the population level;

c) report progress of work on improvements in the scientific basis for advice on management of European eel fisheries; among others, this might require the compilation of a comprehensive and realistic research agenda, aiming at elucidation of the causes of the decline in and quantification of their impacts on the stock (ocean and continent, anthropogenic and natural, etc.);

d) provide fast-track advice by correspondence to OSPAR on new species and habitats to be potentially listed on their "Threatened and Declining" list.

WGEEL will report by 14 September 2007 to the attention of ACFM and DFC.

Thirty-four people attended the meeting from fifteen 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, this report does not present a comprehensive overview, but should be read in conjunction with previous reports (ICES, 2000, 2002a, 2003, 2004, 2005, 2006).

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 June 2007, the EU regulation establishing measures for the recovery of the eel stock (EU 2007: COM (2005) 472–final) was accepted by the EU Council. The working group focused on providing scientific support for eel management plans (EMP) in the 2007 session.

The structure of this report does not strictly follow the order of the Terms of Reference for the meeting, because different aspects of subjects where covered under different headings and a rearrangement of the Sections by subject was considered preferable. The meeting was organized using the Agenda in Annex 2.

Chapter 2 presents trends in recruitment, stock, and fisheries indicative of the status of the stock and the impact of exploitation, data on stocking and aquaculture (ToR a.), advice to ICES on OSPAR listing of eel (ToR d.), and information relating to the distribution of eel in the Black Sea (ToR a–additional EU request).

Chapter 3 considers advances in information and advice in relation to stocking and stocking practices (ToR a and c).

Chapter 4 discusses eel quality as it relates to contaminants, parasites, and viruses. The working group has established an Eel Quality Database. Implications of contaminant consumption levels are discussed (ToR c).

Chapter 5 considers new information relating to loss of productivity caused by obstacles to upstream migration and mortality relating to hydropower dams. (ToR a and c).

Chapter 6 discusses the restoration process: concepts, methodologies, research needs. It looks in detail at the S–R relationship, density-dependence, possible time-scales for recovery, and stock assessment methods (ToR b and c).

Chapter 7 describes methods to describe the current local eel population, including assessments of each life stage and eel habitat (ToR c).

Chapter 8 looks at predation as one form of natural mortality in relation to possible management measures in the EU Recovery Plan.(ToR c).

Finally, **Chapter 9** summarizes the main research needs identified from this meeting (ToR c).

A compilation of the **summary conclusions and recommendations** are included in the Summary at the beginning of this report and in detail in Annex 7.

Individual **Country Reports** are included in Annex 9.

Terms of Reference a (revision of catch statistics) is the follow-up of the analysis made in the reports of the 2004 and 2006 meetings of the working group (ICES, 2005, 2006). A workshop was held under the umbrella of the European Data Collection Regulation (DCR) in September 2005, in Sånga Säby (Stockholm), Sweden. The workshop report presents catch statistics in greater detail than have been handled by this working group before. Additionally, further improvement of the catch statistics is foreseen, when the DCR is actually implemented for eel fisheries across Europe. For the time being, review and revision of the catch statistics were therefore considered rather ineffective.

1.2 ICES ASC 2006; Theme Session J: "Is there more to eels than SLIME"

The ICES theme session "Is there more to Eels than Slime?" in September 2006 was used by WGEEL as a public platform to discuss new research findings and their relevance to providing a scientific basis for the conservation of eel stocks. From the 26 oral presentations and 11 posters, 16 papers (Abstracts in Annex 3 of this report) were published in Volume 64, Number 7 (2007) of the *ICES Journal of Marine Science*, which is particularly timely now that the EU Council of Ministers accepted in June 2007 a regulation to support the European Commission's Eel Stock Recovery Plan. The accepted peer-reviewed papers cover initiatives to assess directly or to model the status of eel populations, and to elucidate and quantify anthropogenic impacts, the effects of climate change on recruitment, and the role of density-dependence in eel population dynamics, the movement and migratory behaviour of glass eels and silver eels, and mitigation measures, such as fish passes, stocking, and deflection schemes at hydropower stations. WGEEL concludes that the theme session achieved its goal, raising the profile of a multitude of issues surrounding the sustainability of the European eel, informing those tasked with developing national management plans for stock recovery, and establishing links between scientists working in many different disciplines and over a number of continents. The working group congratulates the conveners, Willem Dekker, Mike Pawson, and Hakan Wickstrom, and thanks Andy Payne, Editor-in-Chief of the *ICES Journal of Marine Science*, for making the abstracts available to be included in the working group report.

2 Trends in recruitment, stock, and yield

2.1 Data

This section presents the trends observed in recruitment, indicative of the status of the stock (ToR a), as well as trends in restocking and aquaculture production in Europe.

2.1.1 Trends in recruitment

Information on recruitment is provided by a number of datasets, relative to various stages (glass eel and elver, yellow eel) recruiting to continental habitats (Dekker, 2002). The longest dataseries, from 21 river catchments in 12 countries, have been examined for trends. The data analysed were derived from fishery-dependent sources (i.e. catch records) and fishery-independent surveys across much of the geographic range of the European eel, and cover varying time intervals. Some of them date back as far as the 1950s, and all as far as the 1970s. Table 2.1 presents time-series relative to recruitment in European rivers, and Figure 2.1 updates the trends to the last season available, 2006 or 2007.

Downward trends were evident over the last two decades for all time-series, reflecting the rapid decrease after the high levels of the late 1970s. The trend is similar in recruitment dataseries relative to glass eels in estuarine areas (Figure 2.2) and in time-series relative to yellow eel colonization, monitored in northern countries where transition to yellow eel stage occurs before entering fresh waters (Figure 2.3).

Data collected for 2006 and 2007 show that recruitment continues to be at a very low level in most catchments, some of them being at a minimum level (Erne and Shannon in Ireland, Gota Alv in Sweden, Tiber in Italy). On the other hand, some (Severn in UK, Den Oever and Katwijk in the Netherlands, Ijzer in Belgium) show higher values than the previous seasons.

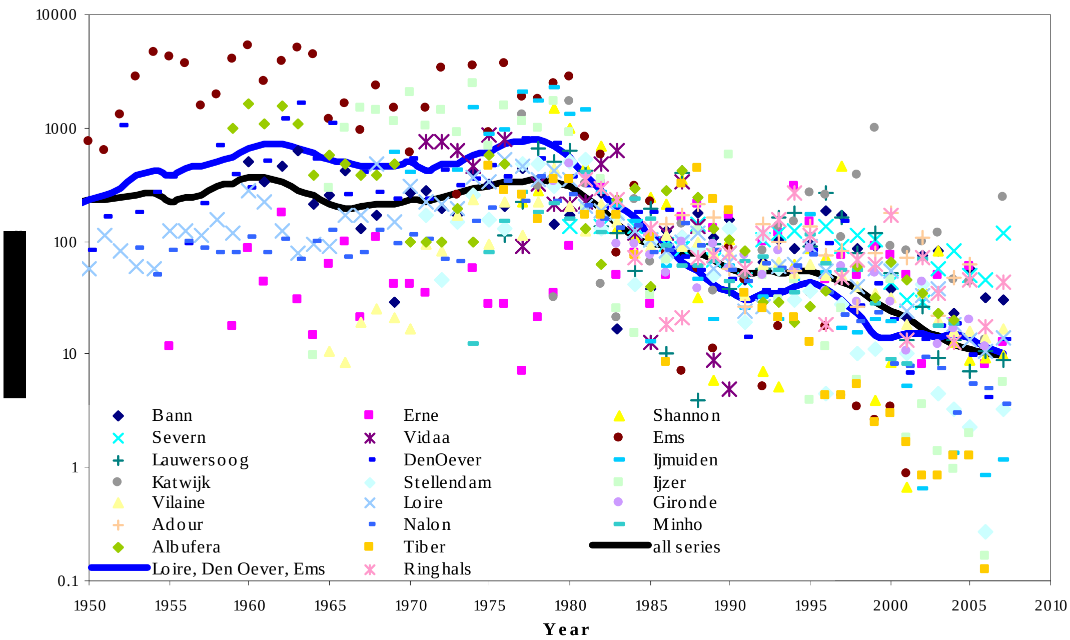

Figure 2.1. Time-series of monitoring glass eel recruitment in European rivers, for which data are reported for 2007. Each series has been scaled to its 1979–1994 average.

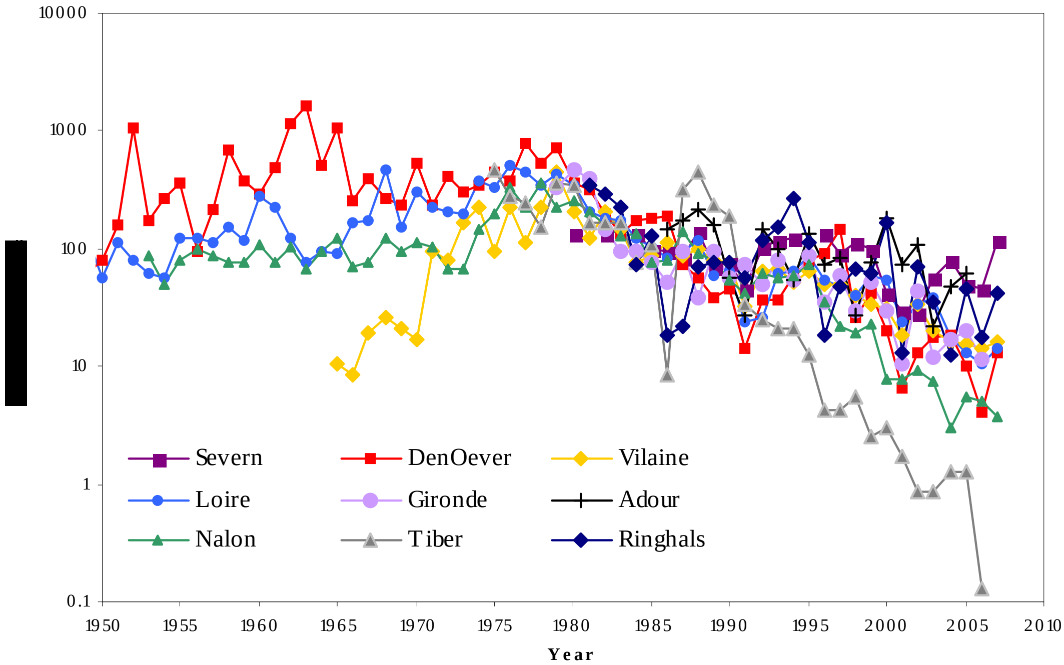

Figure 2.2. Time-series of monitoring glass eel (0+ age) recruitment in European rivers; data are limited to estuarine fisheries. Each series has been scaled to its 1979–1994 average.

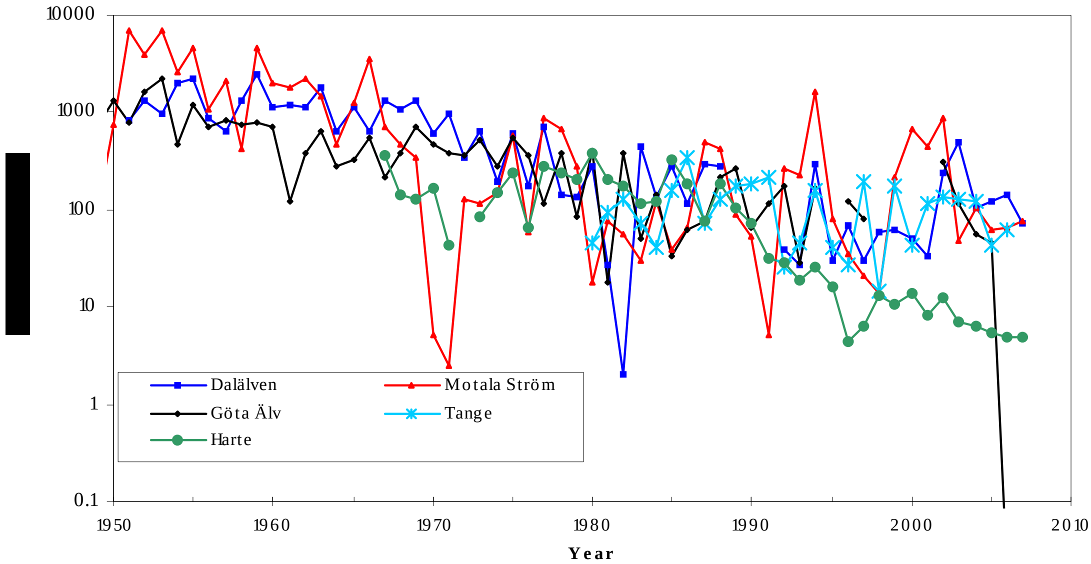

Figure 2.3. Time-series of monitoring yellow eel recruitment (older than one year) in European rivers, for which data are reported for 2007. Each series has been scaled to the 1979–1994 average.

Table 2.1. Recruitment dataseries. Part 1. Scandinavia, Germany, and Northern Ireland. The data units vary between dataseries; see the detailed country reports at the end of this report. Continued.

	N	SE	SE	SE	SE	SE	SE	DK	DK	DK	DE	N. Irl.
	Imsa	Ringhals	Göta Älv	Viskan	Lagan	Motala	Dalälven	Vidaa	Tange	Harte	Ems	Bann
Stage	elver	gl. eel	mixed	elver	elver	mixed	mixed	gl. eel	young	young	gl.	elver
Unit	Tot n	Av.	kg	kg	kg	kg	kg	kg	kg	kg	N	kg
1950			2947		419.9	305					875	
1951			1744		281.1	2713	210				719	
1952			3662		379.9	1544	324				1516	
1953			5071		802.2	2698	242				3275	
1954			1031		511.1	1030	509				5369	
1955			2732		506.6	1871	550				4795	
1956			1622		501.1	429	215				4194	
1957			1915		336.6	826	162				1829	
1958			1675		497.7	172	337				2263	
1959			1745		910.0	1837	613				4654	
1960			1605		552.2	799	289				6215	7409
1961			269		314.4	706	303				2995	4939
1962			873		261.1	870	289				4430	6740
1963			1469		298.8	581	445				5746	9077
1964			622		27.7	181.6	158				5054	3137
1965			746		28.8	500	276				1363	3801
1966			1232		216.6	1423	158				1840	6183
1967			493		24.4	283	332			500	1071	1899
1968			849		74.4	184	266			200	2760	2525
1969			1595		117.7	135	34			175	1687	422
1970			1046		24.4	2	150			235	683	3992
1971			842	12	45.5	1	242	787		59	1684	4157
1972			810	88	106.6	51	88	780			3894	2905
1973			1179	177	107.7	46	160	641		117	289	2524
1974			631	13	33.3	58.5	50	464		212	4129	5859
1975	42945		1230	99	78.8	224	149	888		325	1031	4637
1976	48615		798	500	20.0	24	44	828		91	4205	2920
1977	28518		256	850	26.6	353	176	91		386	2172	6443
1978	12181		873	533	75.5	266	34	335		334	2024	5034
1979	2457		190	505	165.5	112	34	220		291	2774	2089
1980	34776		906	72	226.6	7	71	220	93	522	3195	2486
1981	15477		40	513	78.8	31	7	226	187	279	962	3023
1982	45750	711	882	380	90.0	22	1	490	257	239	674	3854
1983	14500	553	113	308	87.7	12	56	662	146	164	92	242
1984	6640	175	325	21	68.8	48	34	123	84	172	352	1534
1985	3412	305	77	200	234.4	15.2	70	13	315	446	260	557
1986	5145	45	143	151	2.2	26	28	123	676	260	89	1848
1987	3434	52	168	146	69.9	201	74	341	145	105	8	1683
1988	17500	169	475	92	191.1	170	69	141	252	253	67	2647
1989	10000	184	598	32	44.4	35.2		9	354	145	13	1568
1990	32500	186	149	42	21.1	21		5	367	101	99	2293
1991	6250	138	264	1	161.1	2			434	44	52	677
1992	4450	283	404	70	42.2	108	10		53	40	6	978
1993	8625	374	64	43	8.8	89	7		93	26	20	1525
1994	525	636	377	76	30.0	650	72		312	35	52	1249
1995	1950	277		6	11.1	32	8		83	23	40	1403
1996	1000	44	277	1	2.2	14	18		56	6	20	2667
1997	5500	117	180	8	31.1	8	8		390	9	5	2533

Table 2.1 continued. Recruitment dataseries. Part 1. Scandinavia, Germany, and Northern Ireland. The data units vary between dataseries; see the detailed country reports at the end of this report. Continued.

	N	SE	SE	SE	SE	SE	SE	DK	DK	DK	DE	N. Irl.
	Imsa	Ringhals	Göta Älv	Viskan	Lagan	Motala	Dalälven	Vidaa	Tange	Harte	Ems	Bann
Stage	elver	gl. eel	mixed	elver	elver	mixed	mixed	gl. eel	young	young	gl. eel	elver
Unit	Tot n	mean week n	kg	kg	kg	kg	kg	kg	kg	kg	N	kg
1998	1750	164		5	62.6	6	15		29	18	4	1283
1999	3750	147		2	49.5	85	16		346	15	3	1345
2000	1625	400		14	13.0	270	12		88	18	4	563
2001	1875	32		2	26.6	178	8		239	11	1	315
2002	1375	171	685	26.2	102.0	338.8	58.6		278	17	-	11092
2003	3775	84	261	44.13	31.7	19	126.7		260	9	-	1156
2004	375	31	125	5	29.0	42	26.4		246	9	-	337
2005	1550	110	105	25.8	20.5	24.8	30.9		88	7		930
2006	350	42	0.04	2.7	38.1	25.9	35.1		123	7		456
2007		102	0	2.1	>70	30	18.4		62	~7		444

NB: Additional recruitment data are included in the Swedish country report (Table SE.i).

Table 2.1 continued. Recruitment dataseries. Part 2: Ireland, UK, and mainland Europe. Continued.

	IR	IR	UK	NL	BE	FR	FR	FR	FR
	Erne	Shannon	Severn	DenOever	Ijzer	Vilaine	Loire	Gironde (cpue)	Gironde (yield)
Stage	elver	elver	gl. eel	gl. eel	gl. eel	gl. eel	gl. eel	gl. eel	gl. eel
Unit	t	t	t	Index	kg	t	t	cpue	t
1950				7.84			86		
1951				15.79			166		
1952				101.64			121		
1953				17.21			91		
1954				25.65			86		
1955				35.45			181		
1956				9.27			187		
1957				20.75			168		
1958				68.02			230		
1959				37.3			174		
1960				28.19			411		
1961				48.68			334		
1962				114.13			185		
1963				162.78			116		
1964				50.68	3.7		142		
1965	0.9			104.88	115	5	134		
1966	1.4			25.24	385	4	253		
1967	0.3			38.71	575	9	258		
1968	1.5			26.47	553.5	12	712		
1969	0.6			22.67	445	10	225		
1970	0.6			51.57	795	8	453		
1971	0.5			22.86	399	44	330		

1972				40.94	556.5	38	311		
1973				29.49	356	78	292		
1974	0.8			34.15	946	107	557		
1975	0.4			44.19	264	44	497		
1976	0.4			36.18	618	106	770		
1977	0.1	1		76.27	450	52	677		
1978	0.3	1.3		51.41	388	106	526		
1979	0.5	6.7	40.1	71.45	675	209	642	19.7	286.2
1980	1.3	4.5	32.8	35.83	358	95	525.5	25.9	404.8
1981	2.8	2.1	32	30.42	74	57	302.7	20	332.2
1982	4.5	3.1	30.4	19.18	138	98	274	15	123.3
1983	0.7	0.6	6.2	12.86	10	69	259.5	13.6	80.3
1984	1.1	0.5	29	17.14	6	36	182.5	19.2	82
1985	0.4	1.093	18.6	17.33	13	41	154	9.6	64.5
1986	0.7	0.948	15.5	18.24	26	52.6	123.4	10.6	45.2
1987	2.3	1.61	17.7	7.08	33	41.2	145	14	82.4
1988	3	0.145	23.1	5.43	48	46.6	176.6	10.9	33
1989	1.8	0.027	13.5	3.74	30	36.7	87.1	7.2	80
1990	2.4	0.467	16	4.47	218.2	35.9	96	5.6	48.1
1991	0.5	0.09	7.8	1.37	13	15.4	35.7	7.7	64
1992	1.4	0.032	17.7	3.6	18.9	29.6	39.3	3.7	41.7
1993	1.7	0.024	20.9	3.61	11.8	31	90.5	8.2	69.4
1994	4.4	0.287	2.3	5.68	17.5	24	103	8.7	45.8
1995	2.1	0.398		7.94	1.5	29.7	132.5	8.2	73.2
1996	0.6	0.332	23.9	9	4.5	23.2	80.8	4.8	30.7

Table 2.1 continued. Recruitment dataseries; Part 2: Ireland, UK, and mainland Europe. Continued.

	IR	IR	UK	NL	BE	FR	FR	FR	FR
	Erne	Shannon	Severn	DenOever	Ijzer	Vilaine	Loire	Gironde (cpue)	Gironde (Yield)
Stage	elver	elver	gl. eel	gl. eel	gl. eel	gl. eel	gl. eel	gl. eel	gl. eel
Unit	t	t	t	Index	kg	t	t	cpue	t
1997	1.1	2.12	16.2	14.46	9.8	22.85	70.8	6.5	50.5
1998	0.7	0.275	20.1	2.59	2.3	18.9	66	4.3	25
1999	1.2	0.018	18	4.01		16	86.9	7.5	44.1
2000	1.074	0.039	7.6	1.96	17.85	14.45	79.9	6.6	25.1
2001	0.699	0.003	5.4	0.65	0.7	8.46	33	1.9	9
2002	0.1132	0.178	5.1	1.29	1.4	15.9	42	4.9	36.8
2003	0.693	0.378	10	1.74	0.539	9.37	53	2.7	10.4
2004	0.2693	0.058	14.4	1.77	0.381	7.49	27	2.5	14.5
2005	0.8363	0.041	8.8	0.97	0.787	7.36	17		17
2006	0.1175	0.042	8.2	0.41	0.065	6.6	15		10
2007	0.1823	0.045	21.2	1.282	2.214	7.7	21		

Table 2.1 continued. Recruitment dataseries; Part 3: France, Spain, and Portugal. Geomean presents the geometric mean of the three longest glass eel dataseries (Loire, Den Oever, and Ems) after standardization to their 1979–1994 level. Continued.

	FR	ES	ES	P/E	It	
	Adour	San Juan de la Arena market	Albufera	Minho	Tiber	Geomean
Stage	gl. eel	gl. eel	gl. eel	gl. eel	gl. eel	
Unit	t	kg	kg	t	t	
1950						240
1951						239
1952						247
1953		14529				243
1954		8318				248
1955		13576				223
1956		16649				244
1957		14351				230
1958		12911				265
1959		13071	10000			264
1960		17975	17000			292
1961		13060	11000			278
1962		17177	16000			246
1963		11507	11000			210
1964		16139	4000			194
1965		20364	6000			168
1966		11974	5000			175
1967		12977	4000			187
1968		20556	4000			183
1969		15628	5000			180
1970		18753	1000			203
1971		17032	1000			194
1972		11219	1000			214
1973		11056	2000			230
1974		24481	1000	1.65		285
1975		32611	6000	10.6	11	290
1976		55514	5000	20	6.7	318
1977		37661		36.6	5.9	360
1978		59918		24.3	3.6	388
1979		37468		28.4	8.4	352
1980		42110		15.9	8.2	343
1981		34645	1309	50	4	263
1982		26295		16.4	4	187
1983		21837	2387	30	4	148
1984		22541	2980	30.1	1.8	121
1985		12839		13	2.5	97
1986	8	13544	2845	15	0.2	96
1987	9.5	23536	4255	8.2	7.4	83
1988	12	15211	2513	8	10.5	81
1989	9	13574	1322	8.5	5.5	59
1990	3.2	9216	1079	6.1	4.4	49

1991	1.5	7117	831	6.9	0.8	42
1992	8	10259	300	13.4	0.6	47
1993	5.5	9673	303	5	0.5	40
1994	3	9900	199	10	0.5	43
1995	7.5	12500	271	15.2	0.3	44
1996	4.1	5900	366	8.7	0.1	38

Table 2.1 continued. Recruitment dataseries. Part 3: France, Spain, and Portugal. Geomean presents the geometric mean of the three longest glass eel dataseries (Loire, Den Oever, and Ems) after standardization to their 1979–1994 level.

	FR	ES	ES	P/E	It	
	Adour	San Juan de la Arena market	Albufera	Minho	Tiber	Geomean
Stage	gl. eel	gl. eel	gl. eel	gl. eel	gl. eel	stage
Unit	t	kg	kg	t	t	
1997	4.6	3656		7.4	0.1	29
1998	1.5	3273	616	7.4	0.13	25
1999	4.3	3815	323	6.8	0.06	18
2000	9	1330	678	7.7	0.07	15
2001	2	1285	466	1.1	0.04	15
2002	2 4	1569	357	9.243	0.02	14
2003	0 6	1231	233	2.414	0.02	16
2004	1.7	506	209	2.47	0.03	11
2005	3.2	914		3.02	0.03	12
2006		836		1.14	0.003	4
2007		615		1.65		12

2.1.2 Trends in restocking

Data on stocking were obtained from a number of countries, separate for glass eels and for young yellow eels. The size of "young yellow eel" varies between countries. Most data available were on a weight base. Weights were converted to numbers, using estimates of average individual weights of the eels at the size stocked. These were 3.5 g for Denmark, 33 g for the Netherlands, 20 g for (eastern) Germany, and 90 g for Sweden. An overall number of 3000 glass eels per kg was applied to data from Belgium and Northern Ireland. An overview of data available up to 2007 is compiled in Tables 2.2 and 2.3.

Stocking in other EU countries:

Lithuania. The first stocking was in 1928–1939, when 3.3 million elvers were released in the lakes. Since the 1960s, about 50 million elvers or young yellow eels have been stocked.

France. No stocking on a national level.

Italy. Stocking in considerable amounts in lagoons and lakes, but no national recording.

Germany. No national database for eel stocking.

Spain. No stocking on a national level.

Portugal. No stocking on a national level.

Ireland. No stocking on a national level. Upstream transport of elver and bootlace eel on the Shannon and Erne; see country report.

The trend obtained by summing all the glass eel stocking series might be confusing and show a drop in 1969, because at that time, Polish stocking figures ceased to be recorded (Figure 2.4). If the data from Poland are not considered, although there is a high between-year variability, there is an increasing trend in glass-eel stocking since the dataseries started until the late 1970s, when the stocking started to drop, that has continued until now.

From 1945 until the 1990s approximately 2 million young eels were stocked yearly in Europe. During the 1990s stocking of young eel showed a sharp increase and dropped again in the late 1990s (Figure 2.5).

Table 2.2. Stocking of glass eel. Numbers of glass eels (in millions) stocked in (eastern) Germany (D east), the Netherlands (NL), Sweden (S), Poland (PO), Northern Ireland (N. Irl.), Belgium (BE), Estonia (EE), Finland (FI), and Latvia (LV). Continued.

	D EAST	NL	SE	PO	N.IRL.	BE	EE	FI	LV
1927									0.3
1928									0.0
1929									0.0
1930									0.0
1931									0.4
1932									0.0
1933									0.3
1934									0.0
1935									0.2
1936									0.0
1937									0.3
1938									0.0
1939									0.2
1940									0.0
1941									0.0
1942									0.0
1943									0.0
1944									0.0
1945					17.0				0.0
1946		7.3			21.0				0.0
1947		7.6							0.0
1948		1.9							0.0
1949		10.5							0.0
1950	0.0	5.1							0.0
1951	0.0	10.2							0.0
1952	0.0	16.9		17.6					0.0
1953	2.2	21.9		25.5					0.0
1954	0.0	10.5		26.6					0.0
1955	10.2	16.5		30.8	0.5				0.0
1956	4.8	23.1		21.0			0.2		0.0
1957	1.1	19.0		24.7					0.0
1958	5.7	16.9		35.0					0.0
1959	10.7	20.1		52.5	0.7				0.0
1960	13.7	21.1		64.4	25.9		0.6		3.2
1961	7.6	21.0		65.1	16.7		0.0		0.0
1962	14.1	19.8		61.6	27.6		0.9		1.9

1963	20.4	23.2		41.7	28.5		0.0		1.5
1964	11.7	20.0		39.2	10.0		0.2		0.9
1965	27.8	22.5		39.8	14.2		0.7		0.4
1966	21.9	8.9		69.0	22.7		0.0	1.1	0.0
1967	22.8	6.9		74.2	6.7		0.0	3.9	1.0
1968	25.2	17.0			12.1		1.4	2.8	3.7
1969	19.2	2.7			3.1		0.0		0.0
1970	27.5	19.0			12.2		1.0		1.8
1971	24.3	17.0			14.1		0.0		0.0
1972	31.5	16.1			8.7		0.1		1.6
1973	19.1	13.6			7.6		0.0		0.0
1974	23.7	24.4			20.0		1.8		0.0
1975	18.6	14.4			15.1		0.0		0.0
1976	31.5	18.0			9.9		2.6		0.6
1977	38.4	25.8			19.7		2.1		0.5
1978	39.0	27.7			16.1		2.7	3.7	0.0
1979	39.0	30.6			7.7		0.0		0.0
1980	39.7	24.8			11.5		1.3		0.0
1981	26.1	22.3			16.1		2.7		1.8
1982	30.6	17.2			24.7		3.0		0.0
1983	25.2	14.1			2.9		2.5		1.5
1984	31.5	16.6			12.0		1.8		0.0
1985	6.0	11.8			13.8		2.4		1.5
1986	23.8	10.5			25.4		2.5		0.0
1987	26.3	7.9			25.8		2.5		0.3
1988	26.6	8.4			23.4		0.0		2.2
1989	14.3	6.8			9.9		0.0	0.0	0.0
1990	10.7	6.1	0.7		13.3		0.0	0.1	0.0
1991	2.0	1.9	0.3		3.5		2.0	0.1	0.0
1992	6.4	3.5	0.3		9.4		2.5	0.1	0.0
1993	7.6	3.8	0.6		9.9	0.8	0.0	0.1	0.0
1994	7.6	6.2	1.7		16.4	0.5	1.9	0.1	0.0
1995	1.0	4.8	1.5		13.5	0.5	0.0	0.2	0.6
1996	0.1	1.8	2.4		11.1	0.5	1.4	0.1	0.0
1997	0.4	2.3	2.5		10.9	0.4	0.9	0.1	0.0
1998	0.3	2.5	2.1		6.2	0.0	0.5	0.1	0.0

Table 2.2 continued. Stocking of glass eel. Numbers of glass eels (in millions) stocked in (eastern) Germany (D east), the Netherlands (NL), Sweden (S), Poland (PO), Northern Ireland (N. Irl.), Belgium (BE), Estonia (EE), Finland (FI), and Latvia (LV).

	D east	NL	SE	PO	N.Irl.	BE	EE	FI	LV
1999	0.0	2.9	2.3		12.0	0.8	2.3	0.1	0.3
2000	0.0	2.8	1.3		5.4	0.0	1.1	0.1	0.0
2001		0.9	0.8		3.0	0.2		0.1	0.0
2002		1.6	1.4		6.6	0.0		0.1	0.0
2003		1.6	0.6		9.2	0.3		0.0	0.0
2004		0.3	1.1		3.0	0.0		0.1	0.0
2005		0.1	0.7		5.2	0.0		0.1	0.1
2006		0.6	1.2		2.1	0.3			
2007		0.2	0.9		1.9	0.0			

Table 2.3. Stocking of young yellow (bootlace) eel. Numbers of young yellow eels (in millions) stocked in (eastern) Germany (D east), the Netherlands (NL), Sweden (S), Denmark (DK), Belgium (BE), Estonia (EE), Finland (FI), and Latvia (LV).

	D EAST	NL	SE	DK	BE	EE	FI	LV
1927								0.0
1928								0.0
1929								0.0
1930								0.0
1931								0.0
1932								0.0
1933								0.0
1934								0.0
1935								0.0
1936								0.0
1937								0.0
1938								0.0
1939								0.0
1940								0.0
1941								0.0
1942								0.0
1943								0.0
1944								0.0
1945								0.0
1946								0.0
1947		1.6						0.0
1948		2.0						0.0
1949		1.4						0.0
1950	0.9	1.6						0.0
1951	0.9	1.3						0.0
1952	0.6	1.2						0.0
1953	1.5	0.8						0.0
1954	1.1	0.7						0.0
1955	1.2	0.9						0.0
1956	1.3	0.7						0.0
1957	1.3	0.8						0.0
1958	1.9	0.8						0.0
1959	1.9	0.7						0.0
1960	0.8	0.4						0.0
1961	1.8	0.6					0.1	1.0
1962	0.8	0.4					0.1	0.7
1963	0.7	0.1					0.0	0.4
1964	0.8	0.3					0.1	0.4
1965	1.0	0.5					0.1	0.3
1966	1.3	1.1					0.1	0.0
1967	0.9	1.2					0.0	0.8
1968	1.4	1.0					0.0	0.0
1969	1.4	0.0					0.0	0.0
1970	0.7	0.2					0.0	0.4
1971	0.6	0.3						0.0
1972	1.9	0.4						0.0

1973	2.7	0.5						0.0
1974	2.4	0.5						0.0
1975	2.9	0.5					0.0	0.0
1976	2.4	0.5					0.0	0.3
1977	2.7	0.6					0.0	0.0
1978	3.3	0.8					0.0	0.0
1979	1.5	0.8					0.1	0.0
1980	1.0	1.0						0.0
1981	2.7	0.7						0.0
1982	2.3	0.7						0.3
1983	2.3	0.7						0.4
1984	1.7	0.7						0.0
1985	1.1	0.8						0.0
1986	0.0	0.7						0.0
1987	0.0	0.4		1.6				0.0
1988	0.0	0.3		0.8		0.2		0.8
1989	0.0	0.1		0.4				0.0
1990	0.1	0.0	0.8	3.5				0.0
1991	0.1	0.0	0.9	3.1				0.0
1992	0.1	0.0	1.1	3.9				0.0
1993	0.2	0.2	1.0	4.0	0.2			0.0
1994	0.2	0.0	1.0	7.4	0.1			0.0
1995	0.7	0.0	0.9	8.4	0.1	0.2		0.0
1996	0.9	0.2	1.1	4.6	0.1			0.0
1997	1.5	0.4	1.1	2.5	0.1			0.0
1998	1.2	0.6	0.9	3.0	0.1			0.0
1999	1.1	1.2	1.0	4.1	0.1			0.0
2000	1.0	1.0	0.7	3.8	0.0			0.0
2001		0.1	0.4	1.7	0.0	0.4		0.0
2002	0.4	0.1	0.3	2.4	0.0	0.4		0.2
2003		0.1	0.3	2.2	0.0	0.5		0.0
2004		0.1	0.2	0.8	0.0	0.4		0.0
2005			0.1	0.3	0.0	0.4		0.0
2006			0.0	1.6	0.0			0.0
2007			0.0	0.8	0.0			0.0

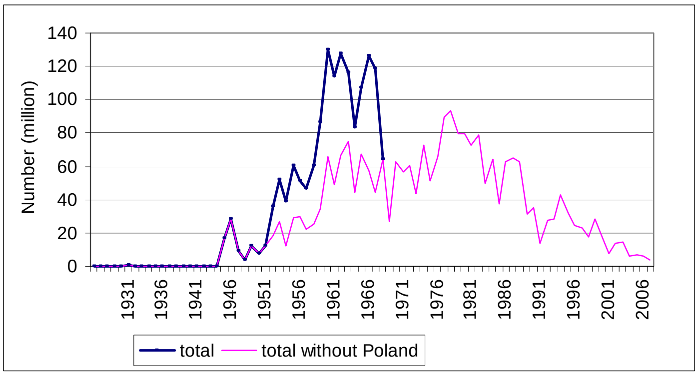

Figure 2.4. Stocking of glass eel and young yellow eel in Europe (East Germany, the Netherlands, Denmark, Poland, Sweden, Northern Ireland, Belgium, Finland, Estonia, and Latvia), in millions restocked. The dataseries of Polish stockings were discontinued in 1968, while the remaining stockings continued.

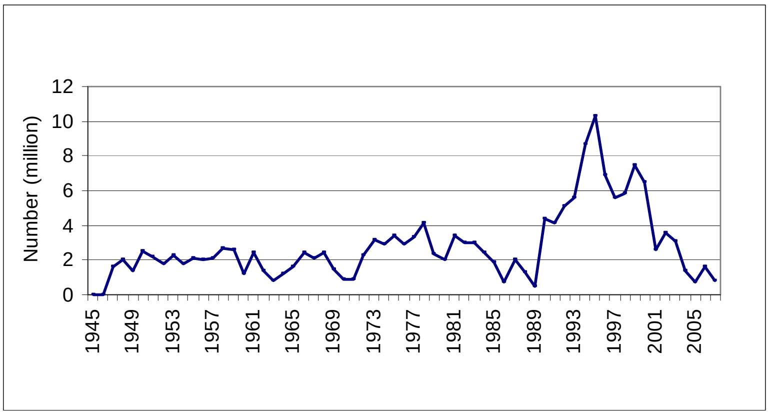

Figure 2.5. Stocking of young yellow eel in Europe (East Germany, Netherlands, Denmark, Poland, Sweden, Belgium, Finland, Estonia, and Latvia), in millions stocked.

2.1.3 Stock and recruitment relationship

The recruitment of glass eels to Europe has shown a sharp decline in past 25 years. The historical low levels observed in recent years are an indication that the stock is clearly out of safe biological limits (ICES, 2005; this report).

Recruitment and SSB (derived from landings) data show a decline (Figure 2.6), which is potentially much faster than would be expected if recruitment were still proportional to the decline in SSB (Dekker, 2003b, 2004a). This indicates the existence of a critical depensation or "Allee effect" (Allee, 1931), whereby negative feedback effects occurring at low spawning-stock biomass accelerate the decline of recruitment to a very low level or even to zero. Should eel SSB have fallen to levels where spawning becomes unsuccessful because of low densities of adults on spawning grounds, depensation could occur. The figure presented here updates the 2006 report, and the most recent points strengthen the relationship, indicating a functional link between SSB and recruitment. The recruitment data for the most recent years (since 2000) strongly confirm the ongoing decline and raise an even greater concern about the possibility of depensation.

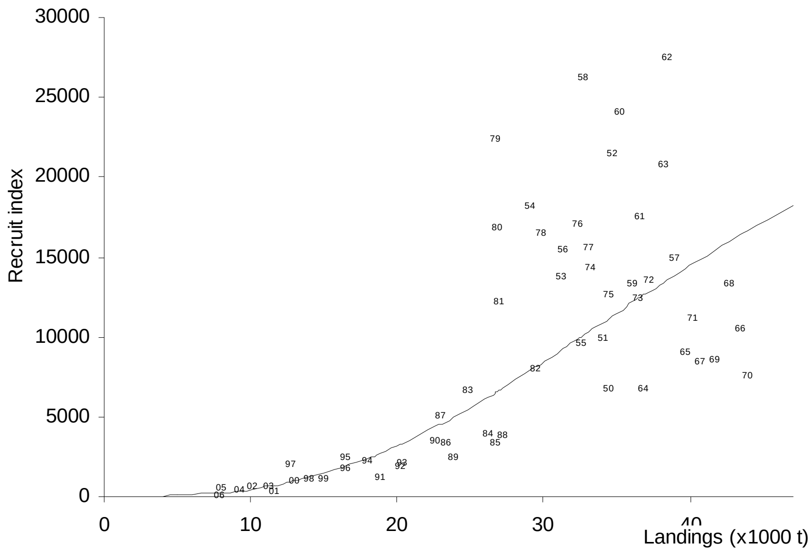

Figure 2.6. The relation between landings (all stages) and glass eel recruitment. This indicates that reproduction might well be strongly impaired at current low stock abundance. The glass eel recruitment index represents the common trend in the data presented in Table 2.1; the total landings are reconstructed from the common trend in individual dataseries per country, to compensate for missing data (Dekker, 2003b, updated). Two-digit labels indicate the years of recruitment 1950–2006. (Source: Dekker, 2004a; data updates from Dekker, in prep.).

2.1.4 Trends in aquaculture

In Table 2.4, aquaculture production data for European eel in all countries from 1984 to 2001 are given, compiled by integrating different sources (FAO database, National Reports of previous meetings, FEAP), while Table 2.5 presents the production trend in the past seven years, compiled by FEAP, limited to European countries, although some discrepancies still exist between databases and the national reports annexed to this report. Both datasets show a growth of the aquaculture sector, caused by the increase of intensive production in northern countries, namely Denmark and the Netherlands. In the same period, a decrease in some countries, e.g. Italy, occurred, while in other countries eel culture was abandoned (France, Belgium, UK, Ireland). Furthermore, there has been a decrease in the importance of culture of eels in some eastern countries. In recent years, the peak of production in Europe was reached in 2000, while most recently it seems to be fluctuating around 9000 t. The number of eel farms estimated for 2006 was 59, 29 of which were in the Netherlands, 9 in Denmark, and the rest scattered in other countries.

2.1.5 Trends in glass eel price

The trend in glass eel price has been analysed using three sources of data (Figure 2.7): glass eel import and export prices of the French trade statistics (available from 1970), a chronological series of prices provided from a French trader (from 1961), and the price recorded by the Austrian government in the fishers' guilds (from 1983). The prices have been corrected for local inflation and are expressed relative to the 2006 value. Two main conclusions can be derived from the analysis of those trends. The worldwide market is driving the price because it is very similar between the series, and there has been a considerable steady increase in prices since the 1960s.

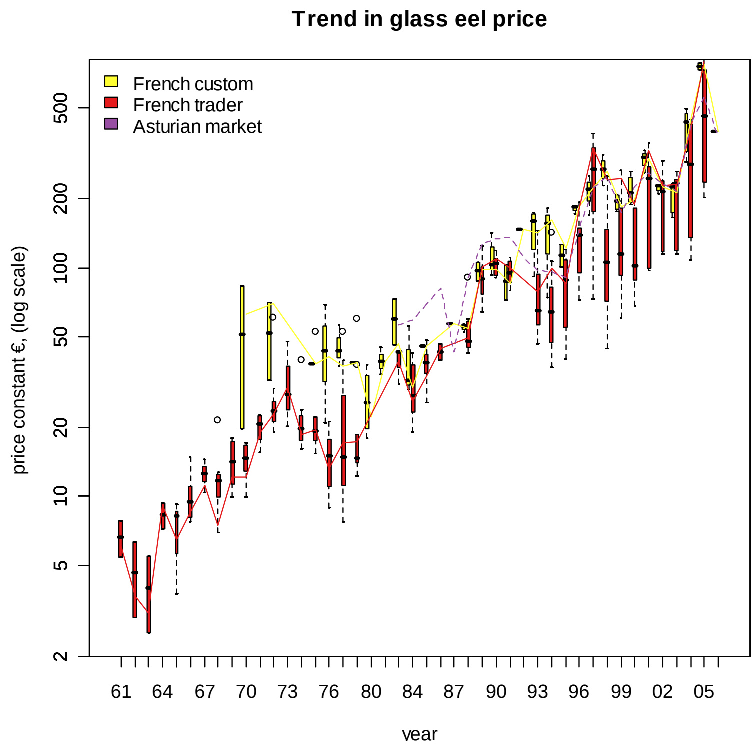

Figure 2.7. Trends in glass eel price from 1960, boxplots showing the variation in price according to the destination, and lines corresponding to the weighted mean (Source: Bonhommeau and Briand, unpublished; Lucia Garcia, Austrian government, pers. comm.).

Table 2.4. Aquaculture production of European eel in Europe, 1984–2001. Compilation of production estimates (tonnes) derived from reports of previous working group meetings, FAO, FEAP, and other sources.

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Norway										120	200	200	200	200				
Sweden	12	41	51	90	203	166	157	141	171	169	160	139	161	189	204	222	273	200
Denmark	18	40	200	240	195	430	586	866	748	782	1034	1324	1568	1913	2483	2718	2674	2000
Ireland																	100	
UK				20	30	0	0				25		25					
Germany												186	204	221	260	400	422	347
Netherlands				100	300	200	600	900	1100	1300	1450	1540	2800	2450	3250	3500	3800	4000
Belgium/Lux.					30	30	125	125	125	125	150	140	150	150	40	20	50	55
Spain	15	20	25	37	32	57	98	105	175	134	214	249	266	270	300	425	200	259
Portugal	60	60	590	566	501	6	270	622	505	979	200	110	200	200	200	200		
Morocco							35	41	68	85	55	55	56	42	27	28	60	28
Algeria					72	53	22	1	0	22	20	17	17	17	22	15	18	20
Tunisia							150	151	250	260	108	158	147	108				
Italy	2600	2800	4200	4600	4250	4500	3700	4185	3265	3000	2800	3000	3000	3100	3100	3100	2750	2500
Greece			6	4	10	54	94	132	337	341	659	550	312	500	500	300	600	735
Turkey																		
Macedonia									1	0	70	83	60	72	60	50	32	
Yugoslavia	44	52	48	49	19	10	5	1	8	2	9	5	5	5	6	6	5	4
Croatia								7	5	5	7	6	7					
Hungary					90	39	73	33		50		50			19	19		
Czech. Rep.									2	4	4	3	3	3	1	1	1	1
Sum EU	1950	2229	3448	4729	5517	5159	6667	6098	6818	7721	7689	8935	9031	10646	11059	10839	10510	8435
Japan		3000															10000	

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

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

2.2 OSPAR

Term of Reference (d) '07: Provides fast-track advice by correspondence to OSPAR on new species and habitats to be potentially listed on their "Threatened and Declining" list.

In November/December 2006, participants of the 2006 joint EIFAC/ICES Working Group on Eel reviewed by correspondence the two proposals for the nomination of the eel *Anguilla anguilla* to the OSPAR list of threatened and/or declining species; one by the WWF and the other by Germany. The nomination by WWF was the more up to date, although both were weak, unbalanced, and lacking in supporting arguments. Despite the weaknesses of the proposals as indicated, their factual basis was sound, and they made the case that eels should be afforded the best possible management and protection. The reports from EIFAC/ICES Working Group on Eel, 2004 (Galway) and 2006 (Rome) provided the most complete and up-to-date reviews of the expert judgment on the decline of eel recruitment and stock status, including potential factors implicated in the decline of eel. The scientific advice on the need to protect eel has been almost exclusively based on the analysis of historical time-trends, which were poorly reflected in the nominations. The full report of the working group's review and recommendations is included in Annex 4.

2.3 Black Sea

In June 2007, ICES received a request for advice from the EU as follows: "A Council Regulation establishing measures for the recovery of the stock of European eel was adopted on 11 June. According to this Regulation the Commission is required to take a decision as to whether the Black Sea and the river systems connected to it constitute natural habitat of European eel." WGEEL has interpreted the reference to "natural habitat" as to mean "natural geographic range".

Expert opinions and references have been compiled to address the question posed by the EU relating to whether or not the Black Sea and the river systems connected to it constitute natural habitat for European eel. However, there is not a general consensus regarding this subject (Table 2.6). Information from Romania indicates that isolated individuals were recorded on the coast of the Black Sea, the lagoons, and the tributaries of the Danube in former times. Distribution records of eel have historically been shown to include the Black Sea (Lebedev, 1969), and seven eels were caught in 1989 near Bandar Anzali, Iran (Birzaks, pers. comm.). Berg (1949) reported occasional records in the Volga River penetrating canals connecting with rivers entering the Black Sea, and Coad (1980) reported occasional catches in the South Caspian Sea. Iranian fishers started to catch eel 15–20 years ago and in the past 10–15 years, their annual catch varied from 40–60 specimens (Birzaks, pers. comm.). Current fisheries in the Black Sea area are restricted to some occasional catches of individual or small quantities of eels (Dekker, 2003a).

On the contrary, few studies report the absence of eel (Dekker, 2003a). Schmidt (1906, 1909, 1925; cited in Dekker, 2003) reported the absence of eel in the Black Sea region, and this may be the only comprehensive study of the distribution area of eel. Herzig and Herzig-Straschil (2001) cited Marsilius (1726) and Alberto Magnus (1545) who stated that eel was never found in "thonaw" and its tributaries, and that it was most likely that eels could escape from transportation barrels. They also state that, in the Black Sea, eels only seem to occur in the vicinity of the Bosporus. Lusk *et al.*, (2004) corroborates these observations and states that eels are non-native to the Danube river basin (River Morawa, Czech Republic), and presence of eel in the Danube is solely the result of stocking, a view shared by R. Celebým (pers. comm.), who stressed the lack of scientific evidence of natural occurrences of eel in the Danube.

Although there is little doubt that eels occurred within the outer limits of its geographical range, nothing has been published on the density levels of such observations (Dekker, 2003a; Tesch, 1999). The compiled information by the working group shows that the presence of eel, before the practice of restocking was introduced in the river systems connected to the Black Sea and the Danube, corresponds to sporadic observations and not to the general presence of eel. Therefore, it can be concluded that the area around Black Sea is at the extreme limits of the natural geographic range for eel, and the densities were probably low in the past before stocking practices began. In the absence of stocking, the occurrences of eel in the Black Sea were not sufficient to support fisheries.

Section 6.6 provides a discussion of the need to manage eel stock and fisheries in the extreme peripheries of the distribution area.

2.4 Conclusions for trends in recruitment, stock, and yield

Available information on recruitment, stock, and fisheries continues to support and reinforce the advice that the global European eel stock has declined in most distribution areas and is outside safe biological limits.

Recruitment of glass eel to the continental stock remains low, with no obvious sign of recovery. Most recent data indicates a continued downward trend in the stock–to–recruit relationship, heightening concern over possible depensation and the stock's ability to recover, even in the long term.

Stocking of eel continues in some countries, although the numbers of 0+ age and young eels stocked has declined sharply since the mid-1990s, and continues to drop.

Two main conclusions can be derived from the analysis of the trends in glass eel market prices: the worldwide market is driving the price as it is similar between the series, and there has been a considerable steady increase in prices since the 1960s.

Two nominations for eel *Anguilla anguilla* to the OSPAR list of threatened and/or declining species were reviewed by the working group and both were found to be weak, unbalanced, and lacking in supporting arguments. Despite the weaknesses of the proposals, however, their factual basis was sound, and they made the case that eels should be afforded the best possible management and protection.

The working group concluded that, before the practice of stocking was introduced, the presence of eel in the river systems connected to the Black Sea and the Danube was at best sporadic and concluded that the area around Black Sea is at the extreme limits of the natural geographic range for eel.

Table 2.6. Summary of collated information sources on the occurrence of eel in the Black Sea and its tributaries.

Country	Source	Reply	Rationale
Romania	Ion Navodaru Senior fisheries Scientist Danube Delta National Institute	YES	• Black Sea and river systems connected to it belonging to Romania are a native range for eel. • In Romania, isolated examples were recorded previously in the coast of the Black Sea, the lagoons, and the tributaries of the Danube. Danube delta stocked in last 20 years.
Latvia	Janis Birzkas	YES	• Lebedev (1969) mentioned that eel distribution includes rivers of the Black Sea. • Seven specimens were caught near Bandar Anzali (Iran) in 1989. • Berg (1949) occasional records in the Volga River penetrating through canals connecting with rivers entering the Black Sea. • Coad (1980) reported occasional catches in the South Caspian Sea. • Iranian fishers started to catch eel 15–20 years ago, and in the past 10–15 years, their annual catch varied from 40–60 specimens.
Turkey	Sukran Yalcin-Ozdilek Cannakkle Onsekiz Mart University	Not Black Sea?	• Found eels in 2007 in a river that discharges into Marmara Sea, which is connected with the Black Sea.
Austria	Albert Jagsch Federal Agency for Water Management	NO	• He quotes Herzig and Herzig (2001; in German), who cited Marsilius (1726) and Alberto Magnus (1545), who stated that eel was never found in “thonaw” and its tributaries, and that it was most likely that eels could escape from transportation barrels. In the Black Sea, only found in the vicinity of the Bosporus. • Lusk *et al*., (2004), states that eels are non-native in the Danube River basin (River Morawa, Czech Republic), and they occur solely as a product of stocking.
Turkey	Ramazan Celebý National Correspondent and Local Organizer Ministry of Agriculture and Rural Affairs	NO	• The Black Sea and its rivers do not constitute natural habitat for eel; there is not scientific proof of it.

3 Stocking and transfers of eel as an aid to stock recovery

3.1 Introduction

Stocking and transfer of eel have been discussed at length in previous reports of the working group, with a detailed discussion in the 2006 report (ICES 2006). These previous discussions covered the principles and extent of stocking, stock transfer practices, and their contributions to fisheries. The effect on escapement had been discussed mainly in conceptual and theoretical frameworks owing to a lack of data. It is agreed that what is now needed above all is firm evidence of the extent to which stocking and transfer on local, national, and international scales can contribute to improved spawner escapement. This is particularly important now that stocking is listed as one option, among others, to aid stock recovery in the forthcoming EU regulation. The regulations focuses on the objective of achieving stock recovery by collective and coordinated action in individual silver eel producing areas.

3.1.1 Stocking and transfers as discussed in the 2006 working group report

In 2006, the working group report covered stocking of glass eel under the headings of (summarized):

- The concept of a surplus of glass eel; i.e. can glass eel be captured from sites of (relatively) high abundance and moved to new areas, resulting in increased overall spawner escapement?
- Evolution of advice on stocking for enhancement – how new information has changed the balance of advice given by the working group over the past decade.
- Extent of stocking activity.
- Evidence for and against stocking resulting in enhanced spawner production case studies, problems, and risks.
- Given a surplus, are there enough glass eel available for stocking all waters?
- Choosing between risks (associated with stocking/not stocking).
- Stocking to enhance Europe-wide spawner emigration.
- Development of stocking strategies (a conceptual framework and practical steps to be taken).

The resultant 2006 working group conclusions were (summarized) as follows:

- There is an urgent need for guidelines for best practice.
- Experimental stocking programmes should be commenced, designed for both long-term "insurance" and short-term "quick results".
- Stocking should have post-evaluation built in from the outset.
- Habitat assessment methods are needed to support decisions to stock or not.
- There is scope to use the ca. 100 t of glass eel currently fished and removed from the stock to restore the most depleted local stocks of eel.

3.1.2 Progress in the 2007 working group

Much of the 2006 report section discussion is still relevant in 2007. The 2007 working group focused on the discussion of issues where new data or analyses have become available or where progress could be made. These include:

- A new analysis of the Lough Neagh (Northern Ireland) dataset, indicating the shape of an input-stock-to-spawner-output relationship.

- Further results from Swedish coastal tagging studies suggesting a significant contribution from long-term stocking programmes to silver eel escapement and fisheries.
- New eel management planning in North America considering the options for stock transfer from the east coast to enhance depleted inland stocks in the US and Canadian waters (Symonds, 2006).

3.2 New material brought to the 2007 working group

3.2.1 Density-dependent survival rates of stocked eels: a provisional analysis of the Lough Neagh dataset

The eel population of Lough Neagh, Northern Ireland, has been manipulated since the 1930s. Following the construction of a water flow regulation scheme, natural upstream migration has been impeded, but not totally prevented. Since then, glass eels have been trapped annually at the tidal head in specially constructed boxes, with one prolonged break in this practice in the 1940s and 1950s, and transported upstream some 40 km to Lough Neagh by tanker. Under the current integrated management of the Lough Neagh and Bann system eel fisheries by the Lough Neagh Fishermen's Co-operative Society, numbers of glass eel transported have been recorded since 1959. Additional glass eels purchased from elsewhere for stocking Lough Neagh have also been annually recorded as numbers of individuals. This practice was commenced following a drop in natural immigration in 1983. Total weights of catches of yellow eel in the lake and silver eel in the outflow have also been recorded annually since 1959. These fishery data, supplemented by knowledge of sex ratios and silver eel escapement from current research, enable a simple numerical analysis of survival rates from 0+ immigration or stocking-to-fishery or spawner-escapement-to-sea.

Using the catch data in weights from Lough Neagh and known current mean weights of yellow (250 g), male silver (180 g), and female silver (360 g), along with silver eel sex ratio, all data can be converted to an estimated number of eels caught or escaping over time. Sex ratio data for silver eels is available for much of the time-series, the ratio of males to females apparently dependent on stock density as manipulated by stocking (Rosell *et al.*, 2005). An additional annual estimate, based on work carried out from 2002 onwards (UK country report, ICES, 2006), estimates average annual silver eel escapement at 2.5 times the actual silver catch. Effort levels in the silver eel fishery have been relatively constant using the same fixed weirs over the past 20 years. It is known that the mean ages of male silver, female silver, and yellow eel in catches are on the order of 12, 17, and 14 years, albeit with considerable spread of ages around these figures.

The annual total estimate of the "output" number of eels escaping to spawn or captured in the fishery can be assigned to the original input density in glass eel equivalent, enabling a numerically based analysis of survivorship to the point of leaving Lough Neagh as catch or escapement (Figure 3.1).

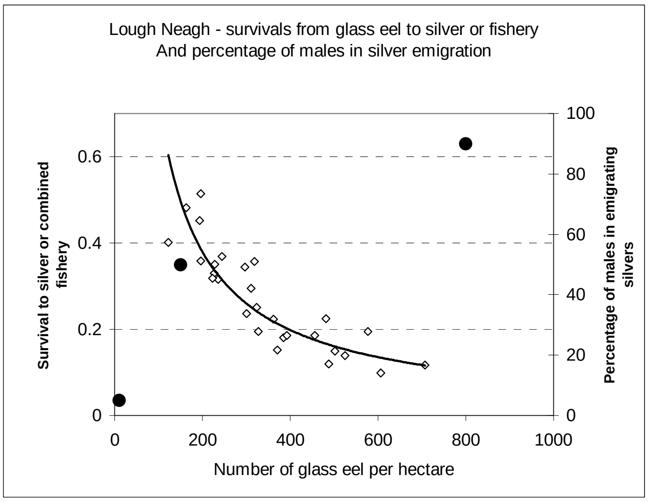

Figure 3.1. Estimated rate of survival (%) of Lough Neagh glass eel over lifespan, to emigration or fishery capture combined, in relation to stocking density. Trend line over open diamonds: actual data, 1977–2006 outputs, 1960–1977 inputs; black circles: proportion of males in the silver eel catch at three estimates of stock input densities since 1930.

Conclusions reached from this preliminary analysis must take into account the following points:

a) In the early part of the time-series (prior to 1980), it is known that an unquantified number of 0+ eel were routinely observed making the annual migration to Lough Neagh naturally past or over the in-river barriers (e.g. through fish-farm outlets and inlets), but that in the latter part of the time-series (mid-1980s onward) as natural glass eel have become less abundant, this annual migration is no longer observed. This would cause survival to be overestimated in the above graph at the high stocking rates.

b) There is no means of directly estimating natural mortality in Lough Neagh. Significant natural mortality between maturation and escapement to sea would also cause the fishery-study-based estimates of survivorship to be over-estimates. Survivorship to fishery includes prefishery natural mortality.

c) There may be a problem inherent in attempting to look for relationships between the two steadily declining time-series of input and output. Nevertheless, if shorter or longer time-lags are applied to the various age components of the output term (yellows, male silvers, female silvers), no clear relationships emerge, whereas lags within one year of the optimum used here produce similar results to those plotted.

d) Two data points have been deliberately excluded from the graph, where isolated years of poor recorded recruitment occurred among regular high recruitment. Inclusion of these data leads to impossible survival rates being recorded for those input years (i.e. >1!). This outcome is clearly caused by the high spread of ages at which eels mature or are caught: Poor recruitment in a single year can be easily buffered by production of eels from earlier or later years.

Perhaps more important than the absolute quantification of this relationship is the shape of the suggested density-dependent relationship: The best fits to this graph are all curved, with the suggestion of a negative exponential between input stock and eventual output. Current Lough Neagh stocking targets are on the order of 150–200 glass eel per hectare, thought to be sufficient to supply a managed fishery and allow adequate escapement.

Also of interest is the percentage of males in the emigrating silver eel catch. This catch is not thought to be selective for sex, implying a true record of sex ratio, at least partly dependent on input stock density. As male eels leave earlier and are much smaller, this suggests that at very high stocking levels, output number of silver eels may increase but without a net benefit in biomass of eel produced, perhaps suggesting habitat saturation.

3.2.2 New data from Swedish coastal tagging studies: Do stocked eels contribute to the spawning stock?

It has been argued that stocked eels, although performing well in nature until the migratory phase, do not migrate and orientate normally and thus do not support the breeding population. This discussion is mainly based on results from tagging studies with stocked eels from one single lake situated on an island in the Baltic Sea (Sweden). The eels used for stocking were, at that time, French glass eels on-grown under culture conditions for almost half a year (Westin, 2003). As current stocking today is done with quarantined elvers grown on for the practical minimum of about ten weeks to a weight of 1 gramme each, those results are perhaps not representative for the stocked eels of today.

To justify stocking as a stock enhancement measure, we have to know if it is reasonable to assume that stocked eels can migrate in the appropriate directions and find their way out of the Baltic Sea. The following examples refer:

Tag experiments recently performed in the Baltic Sea (Figure 3.2) show a great proportion (42%) of silver eels with a supposed stocked origin (Table 3.1). There are quite bold assumptions behind the classification into different life-history categories. This classification was done from otolith microchemistry data (P. Clevestam, pers. comm.). No significant differences have been found between natural vs. stocked eels concerning distance migrated, speed and direction, fat content, or Anguillicola infection rate. According to these preliminary results, eels of both natural and stocked origin are migrating along the Swedish east coast in a similar fashion.

A minority (11%) of all recaptured eels had been into fresh waters (Table 3.2). Among the eels that reached the outlet area of the Baltic Sea, the corresponding figure was 19% (N. Sjöberg, pers. comm.).

Figure 3.2. Distribution of recaptures from two tagging experiments in 2006.

Table 3.1. Numbers of recaptures in tag experiments along the Swedish east coast assigned according to supposed origin, natural or stocked. Also shown are the ones that managed to migrate to the outlet straits of the Baltic Sea.

	Natural	Stocked
No. of recaptures	110 (58%)	81 (42%)
No. recaptured in the Baltic outlet straits	12 (44%)	15 (56%)

Table 3.2. Numbers of recaptured eels having fresh-water experiences vs. those that stayed in brackish environments.

	Fresh-water experience	Brackish waters
No. of recaptures	21 (11%)	171 (89%)
No. recaptured in outlet straits	5 (19%)	22 (81%)

In an earlier similar study close to the outlet of the Baltic Sea (i.e. Öresund), Limburg *et al.* (2003) found 27% of silver eel to be of presumed stocked origin.

Another ongoing study of the origin of silver eels in the Baltic suggests that 32% of 690 eels with classifiable origins are conceivably derived from stocking (H. Wickstrom, pers. comm.). About 20% fell into the category of "eels with any apparent experience of fresh water".

Results from two only sites in Öresund might be compared with data from the tagging study above. The proportion of eels conceivably derived from stocked origin was 35% (of 474 where classification is possible) compared with the 56% in the tag experiment (Table 3.1). Owing to the inherent assumptions required to categorize the origins, the figures on origins are provisional, but one can say that the proportion of stocked eels is quite considerable.

This can be compared with the situation in some fresh-water lakes situated to the north ("upstream") of the sites covered by this extensive study, where as many as 90% of silver eels sampled were of certain stocked origin (H. Wickström, pers. comm.).

Although we cannot yet prove that stocked eels do support the spawning stock, these studies from the Baltic Sea demonstrate that a considerable proportion of silver eels leaving for Kattegat–Skagerrak are of stocked origin, mostly produced in the brackish water environment but also from fresh water.

3.2.3 Developments in North America and Canada for *Anguilla rostrata*

Canadian approach

Eel stocking is a very recent practice in Canada, begun in 2005 (Table 3.3). Stocking with elvers and on-grown elvers from Atlantic Canada was carried out in Richelieu River–Lake Champlain and Lake Ontario. For Richelieu River–Lake Champlain, the Eel Fishermen's Union of Québec is in charge of this activity, and financial and scientific support is provided by Hydro-Québec and provincial agencies. For Lake Ontario, the Ontario Power Generation company was in charge of the stocking. A monitoring programme was initiated by provincial agencies in recent years.

Before eel stocking, an assessment must be done under the Canadian National Code on Introductions and Transfers of Aquatic Organisms (Anon., 2003) and accepted by government authorities. To avoid parasite transfers, screenings have to be done before stocking, and virus searches (for IHNV, ISAV, IPNV, and EVH) must be performed. To ensure the maximum benefit for the species, eel fisheries must be absent or closed in locations where stocking is performed.

A comprehensive review of stock enhancement as it might apply to *A. Rostrata*, (Symonds, 2006) has been conducted. This review summarizes most of the available information relating to stocking and stock transfers of European eel and applies the principles to the North American situation.

Symonds (2006) has reviewed the literature on the use and success of restocking to enhance American eel populations, with the aim of summarizing current knowledge of eel stocking as a way to enhance local and regional sub-populations and the potential for increasing spawner escapement. She discusses stock enhancement as a fishery management strategy in the context of the wider literature available and attempts to identify the knowledge gaps in, and risks and uncertainties associated with, eel stocking as an enhancement tool. The review focuses primarily on the greater body of literature on European eel and applies this to the potential for the American eel owing to the similarity of the two species. Symonds concludes that, should it be decided that stocking is a strategy to be followed, further information is required (for American eel), under the following summary headings:

- Determination of clear and measurable objectives of a stocking plan;
- Distribution and abundance of the American eel. Identification of populations with potentially excess capacity and limited risks associated with transfers;
- Price and availability of glass eel for restocking, and required biomass to restore eel populations;
- Evaluation of the use of cultured eel for restocking;
- Criteria for assessing eel habitats and identification of recipient habitats most likely to increase spawner escapement;
- Post-stocking monitoring of recipient habitats-methods, ability to evaluate success;
- A strategy for answering the key question of whether translocated eel could spawn and produce more young than if left in their original environment;

- Analyses of restocking costs, benefits, and resources available;
- Development of appropriate methods for capture, transportation, and stocking;
- A more thorough understanding of American eel genetics: potential for temporal and spatial differences;
- Scope for provincial, national, and international collaboration;
- Stakeholders involved and their role;
- Funding sources: Who is to pay and for how long?
- Database development to coordinate and analyse the data collected;
- Identification of existing models to enhance management decisions;
- Utilization of the information and research: Monitoring and reporting should be planned with end users and available in understandable form.

It is clear from Symonds' review that the problems facing the managers of European and American eel (with regard to the potential for stocking) are more or less the same, and the approaches required are likely to be interchangeable. The area focused on by the review's commissioners (South Shore Trading) is the northeastern seaboard of the USA and southeastern Canada and the St Lawrence–Great Lakes system. The eel population and its current status in this area are highly similar to those of the European eel in the northeastern extreme of its distribution, i.e. the Baltic Sea and Scandinavia, with a similar scale of declining stocks and recruitment.

Table 3.3. Numbers and weights of American eel stocked in Canadian waters.

Year	Richelieu River–Lake Champlain		Lake Ontario	
2005	600 000	105 kg	–	–
2006	1 000 000	200 kg	144 300	100 kg
	421 500	74.2 kg	450 000	90 kg

In March 2007, experts from management agencies responsible for the American eel in Canada, including the Department of Fisheries and Oceans and the Provinces of Ontario and Québec, as well as from US management agencies, universities, fishers, and the private sector from around the world, reviewed information related to eel stocking to ensure that potential risks were minimized or mitigated, and to maximize learning opportunities. Management agencies have implemented experimental stocking and are considering the large-scale stocking of American eel as a short-term measure to lessen the effects of catastrophic recruitment declines into the Great Lakes basin.

Four theme areas were selected as being the most critical in terms of required scientific advice: (i) how to reduce the risk of transferring pathogens and "fellow travellers" through stocking; (ii) identifying what technical steps are required to successfully stock American eels; (iii) how will stocked populations be monitored; (iv) what science can be applied to ensure that questions surrounding the potential risks are adequately addressed. Experts on each of these themes were identified prior to the workshop and asked give presentations addressing the uncertainties. All participants then reviewed the information in breakout sessions. A summary of the presentations and the following discussions, currently in preparation, will provide conclusions based on the deliberations.

Reference

Pratt, T., Threader, R., Mathers, A., and O'Connor, L., (Chairs). Review of potential risks and best management practices associated with conservation stocking of American eel. Department of Fisheries and Oceans, Canada, Science Advisory Secretariat. Workshop proceedings, 27–28 March, Montreal, Québec. In preparation.

3.3 The role of aquaculture and on-growing of eel prior to release for stock enhancement

3.3.1 Handling seed stock – practice around Europe

Stocking occurs in a number of countries (Ireland, Belgium, Denmark, Sweden, Germany, Belgium, the Netherlands, and Poland. The process involves either trap-and-transport where the eels are stocked directly, situations where the eels are kept in quarantine (e.g. in Sweden for ten weeks), or on-grown from glass eel, e.g. in Denmark, Germany, where eels are on-grown for month in aquaculture before they are stocked.

3.3.2 On-growing practices

In Denmark, glass eels on-grown in aquaculture are used as stocking material, and there is no explicit concern relating to this practice. The seed stock, originally from the wild, comes from commercial eel farms. In eel farms, glass eels are transported from southern Europe, December–March. At this time of year, the wild eel population is still hibernating, and the temperatures are too low for stocking. Therefore, stocking is postponed until May or June when water temperatures are above 10°C, and food is plentiful in the stocking environment. During the 3–6 months in aquaculture, the eels increase tenfold in weight and reach ca. 2–5 grammes. It is expected that the survival of 2–5 gramme elvers is much higher than the survival of glass eel; this, however, has never been proven. Because of the risk of infection, at the eel farm, the fish are checked by the Veterinarian Institute for parasites (*Anguillicola crassus*) and certain viruses, e.g. infectious pancreas necroses (IPN). Infected eels will not be stocked. Other requirements are based on the concern that the eels bought from eel farms may be old non-growing or predominantly male, and therefore it is required that the eels are captured in southern Europe the winter before being stocked during the following summer.

Because it is well known that eels produced in farms have a sex ratio of 90% males and only 10% females, it is of concern that stocked farmed eels also turn into males and stop growing at a very early stage. Studies have been undertaken with the objective of understanding if growth and sex ratio differed between wild and cultured eels. A study was done in a small lake, 6 ha. The lake was stocked with wild (19 g) and cultured eels (40 g). A survey conducted 7–8 years later showed that all caught eels were females, and survival was estimated at 55–75% (wild eels) and 42–57% (farmed eels). Incremental growth was the same for wild and stocked eel (Pedersen, 2000). Another study was made in the River Giber. Wild eels were caught by electrofishing and tagged individually with visual implant (VI) tags. At the same time, cultured eels were tagged with VI tags and released in the same stretches as the wild eels. After one year, the recapture rate was twice as high for the wild eels as for the stocked eels, but growth was at the same order of magnitude (2–5 cm; Bisgaard and Pedersen, 1991).

Stocking of marked eel has also been carried out in marine areas with small initial returns 0.2–2.7% (Pedersen, 1998). Ongoing experiments with tagged eel give recapture rates of up to 10%.

In Sweden, glass eels are held in quarantine for ten weeks for temperature acclimatization and disease control. During the quarantine, the glass eel grow threefold and are stocked as 1 gramme large eels. From an experiment in Sweden where a lake (Fardume Trask) was stocked with on-grown elvers, a relatively large proportion of males was observed. Based on these results, it is recommended to stock the eels as close as possible to the glass eel stage to avoid any effect on sex determination.

In Germany, on-grown eels, of size 5–10 grammes, are used as seed stock. There are no data on post-stocking evaluation of growth, sex ratio, or return rates.

3.4 Where to stock? – setting priorities

The geographical unit for stocking is taken as the same area over which the escapement target is to be determined, the area of a catchment defined by the Water Framework Directive (WFD). This will take into account fresh-water, transitional, and coastal habitat of eel.

Within the total geographic area, the productivity of different parts of the total area will vary and priority for stocking should be given to areas that provide the best opportunity for survival to maturity and growth. These will include areas where there is free access to the sea and any anthropogenic mortality is minimal, i.e. were there is no yellow or silver eel fishery and is located downstream of hydropower turbines (unless they have been effectively screened and have a safe alternative route to sea).

To optimize survival, stocking should be undertaken in those areas where the risk of predation by, for example, other eel, catfish, crayfish (*Procambarus clarkii*) burbot, and cormorants is low. In the case of the latter, they appear to select for eel >350 mm in length, and so predation on the early stages is likely to be minimal.

Growth rate depends on temperature and food supply. Optimum temperature for growth in eel is 20–26°C, and eels tolerate temperatures between 0 and 39°C (Sadler, 1979; Tesch, 1983; Gousset, 1990). Growth stops at temperatures below 10°C (Elie and Daguzan, 1976), and digestion rate is very low at 12°C (Sinha and Jones, 1975). As eels live near the bottom, water temperatures at the bottom are more relevant than surface water temperatures. Such data are seldom available. Surface water temperature in shallow systems depends on air temperature and radiation, and follows a seasonal pattern. Temperature (Figure 3.3) as a habitat variable for eel growth is not relevant when less than 10°C. Both the average temperature during the growing season and the length of the growing season affect eel growth, with the number of days when temperatures exceed 14–16°C often considered critical (Tesch, 1977; Deelder, 1984; Wickström *et al*., 1996; Figure 3.3).

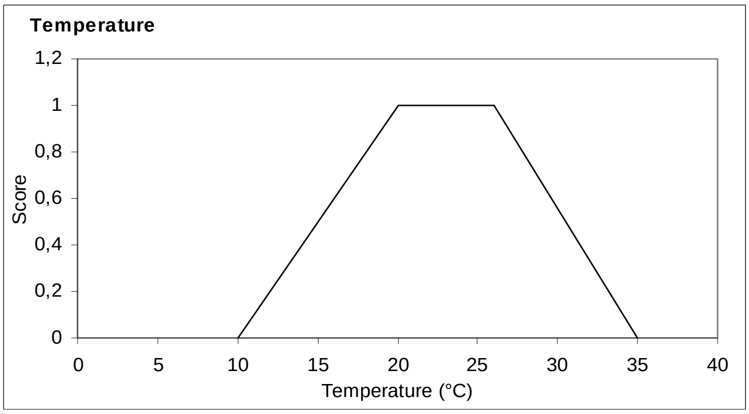

Figure 3.3. Habitat suitability related to average water temperature during the growing season (ICES, 2003).

Many factors affect food availability and therefore growth and production. At higher densities, growth of eel decreases (Klein Breteler *et al*., 1990), probably as a result of limiting food supply. The food supply for eel is not only affected by the trophic status of the ecosystem, but also by the structure of the system, the influx and outfluxes of the system, and the interaction with terrestrial systems. Natural trophic status (within the natural limits of the water body) affects primary production and supports secondary production. In theory, eel production in eutrophic ecosystems might therefore be higher than in meso- or oligotrophic systems. Klein Breteler *et al*. (1990) reported pond mesocosm experiments in Holland where stocking rates of 20 to 60 kg per ha of yellow eel, and glass eel stocking at 1600 glass eel per ha resulted in observed density-dependent limitations on eel growth.

Hypertrophic situations may have an adverse effect on eel growth and survival. German stocking practices in lakes, and advice on this topic, suggest a sharp increase in suitability of the eel habitat in relation to the trophic index and a dependence on stratification of lakes (ICES, 2003; Figure 3.4).

Also, areas flooded (ir)regularly in the growing season supply terrestrial food items, such as earthworms and snails (Tesch, 1983) and constitute profitable forage areas. It is assumed that the forage base for eels increases in relation to the ratio of flooded area to the total aquatic.

In general, little quantitative information is available on the productivity of the available habitat, and surrogates are likely to be needed to prioritize those areas that are most suitable for stocking. Data will be available from many sources, but most importantly through the water Framework Directive process. For example, nitrates levels can be used as a surrogate for trophic status.

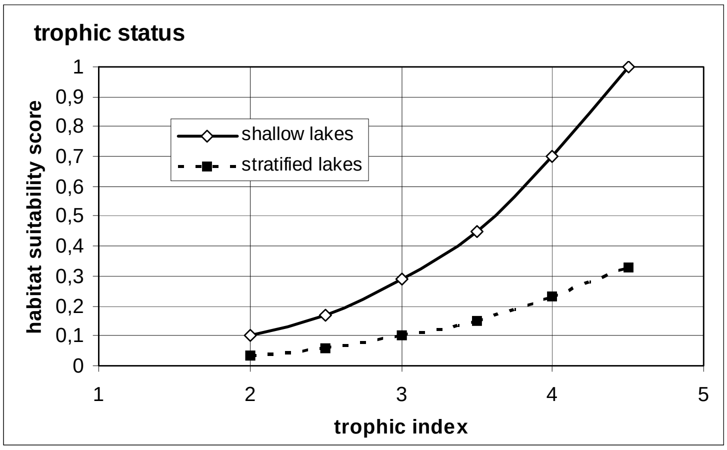

Figure 3.4. Habitat suitability related to trophic status of water bodies (ICES, 2003).

3.5 Notes on good stocking practice

Habitat from 0–10 m should be regarded as suitable habitat for stocking; deeper water is generally considered to be unproductive or unsuitable for small eel. The ideal habitat should be heterogeneous in nature, because habitat structure has been shown to influence eel stock levels in rivers (Knights *et al*., 2001), with eels being most commonly found at sites where they can burrow or hide during the day, e.g. sites with soft substrate, suitable crevices, or vegetation.

Concerns have been expressed about possible undesirable interactions with resident species of high conservation importance, for example salmonids and various crayfish. Eels can prey on fish eggs or fry, and on crayfish, and large crayfish can eat small eel. Potentially negative interaction for eel or high value species in the receiving environment should be avoided.

Eel should be stocked in areas of good water quality where the dissolved oxygen concentration is greater than 5 mg l^{-1} and a pH in excess of 5. Consideration also must be given to pollution with PCBs, flame retardants, pesticides, and heavy metals. Priority should be given to sites where such contaminates are absent or at a low level (information available through the Eel Quality Database, Section 4.5). Palstra *et al*. (2006) has shown that dioxin-like contaminants (PCB) can impact eel reproduction, and it is suggested that priority be given to stocking habitats where the final concentration of dioxin-like contaminants is <1 ng TEQ per kg muscle (ICES, 2006).

3.5.1 Eel health issues

Eels used for stocking should be free of parasites, diseases, and contaminants. Pathogens such as *Anguillicola crassus*, viruses (e.g. EVEX), *Pseudodactylogyrus* spp, *Ichtyophterius multifiliis* can infest eels at a very early stage in estuarine zones (refer to Indicang). Eels for stocking should have as near perfect health status as possible. Hence, preference should be given to stocking early stage glass eels collected in the lower reaches of estuaries, because they are less likely to be infected. Transfer of eels should be accompanied by the relevant fish health (veterinarian) documentation.

3.5.2 Collection of material

Fishing methods should be adapted to minimize all sources of stress during the collection process. Best practice would be to use stock caught using gentle techniques such as a hand dipnet or "tela" net. To improve the quality of the material collected using trawls, preference should be given to those where collection was made during a short trawling duration and at low speed.

3.5.3 Transport methods

Prior to transport, the material should be screened and dead eel removed. The time between fishing and transport should be kept to a minimum. In case of immediate release after transport, avoid releasing water of origin into the stocking site.

3.5.4 Timing of stocking

Survival of released eels depends on the water temperature; therefore, fish would be released before summer when the water temperature exceeds 10°C and is below 26°C. A release in spring offers the opportunity for a size increase throughout the growing season and maximizes the chance of survival.

3.5.5 Frequency of stocking

Stocking once, or every eel generation, would be a cautious approach (the generation time is the mean age of silver females) in order to stock within the carrying capacity of a system. A low frequency of stocking also reduces the risk of transfer of pathogens or invasive species.

3.5.6 Post-stocking evaluation

In order to ensure that optimum use is made of the (limited) stocking material, it is essential to learn from past practice and so ensure that best practice is maintained. Thus, as part of any stocking programme, an active post-stocking evaluation of survival rates and eventual contribution to spawner emigration should be undertaken and built in at the outset. It is also important to assess the impact of stocking eel on other species. To date, this type of data is only available from a very limited number of studies.

3.6 Towards a manual for stocking of eel

The conceptual framework of decision processes required, leading to the implementation a stocking programme, and the more detailed of the decision process within an active stocking programme, were outlined in flow diagrams in the 2006 working group report (Section 7) and cited and discussed in Symonds (2006), with reference to A. Rostrata. These thought processes have not changed significantly and do not need repetition.

The working group noted that work should begin (and is under way in some cases) towards quantifying appropriate stocking rates, and potential outputs per unit stock into these models or frameworks. Although there is insufficient data available not to merit the formulation of a detailed and quantitative manual for those intending to stock eel for conservation or spawner enhancement purposes, the few examples that do exist are worth noting here.

3.7 Survival rates from glass eel to silver eel

Vøllestad and Johnson (1988) estimated lifetime (glass eel in to silver out) survival rates at 27%. This equates to an instantaneous annual mortality rate (if assumed as constant through life) of 0.167.

Moriarty and Dekker (1997) reviewed European data and gave a range of glass eel to silver eel survival of 12% to 30%.

From an ongoing experiment with marked (Alizarin Complexone) eels stocked in an open environment (Lake Mälaren, Sweden), the summed number of recaptures corresponds after ten years to 6% of the stocked number. Many more recaptures are expected, because the stocked eels are not more than ca. 50 cm, and thus far from silvering. Another stocking experiment resulted in a total recapture of 12%. (Wickström *et al*., 1996; H. Wickström, pers. comm.).

From a completed stocking experiment finalized (Wickström *et al*., 1996), the instantaneous natural mortality (M) after 23 years was estimated at 0.17 (M. Åström, pers. comm.). This is an estimate or M, free from silver eel escapement and fishing. Fishing and escapement might be one reason among others why e.g. the estimate from an open coastal area in Sweden was as high as 0.03 (Svedäng, 1999). A similar mortality rate (M = 0.07) was found in River Imsa (Vøllestad and Jonsson, 1988).

The analysis of potential density-dependence in the Lough Neagh Dataset (see Section 3.2.1; Rosell, pers. comm.) estimates lifetime survival, in a fished situation, managed to permit some spawner escapement, within the range of approximately 10% from high stocking densities (800 glass eel per hectare) to 40% at low stocking densities (100 glass eel per hectare).

Danish government-sponsored stocking is carried out at rates of up 300 individual eels, grown on from glass eel in farms to 2–5 g in weight, per hectare, or 600–1500 g per hectare. The outcome of these stocking rates, in terms of survival estimates, is reported in Section 3.3 above.

3.8 Summary and conclusions on stocking

There is a clear need for the production of quantified guidelines that add to existing conceptual decision frameworks for the stocking of European eel, as an aid to stock recovery. This will require new research consisting of stocking experiments with effective post-evaluation programmes, addressing the issue of contribution to the support spawning stock.

New evidence indicates that the possible conclusion that glass eel to silver eel production rates may be non-linear over the ranges of input stock densities (100–1600 glass eel per ha) studied so far, suggesting that best spawner production expressed per glass eel equivalent is to be gained at the lower end of this range. This relationship should be evaluated in other catchments.

New mark-recapture studies in Swedish coastal waters show that eels classified as of probable stocked origin are caught in a manner similar to eels of wild origin as they migrate towards the outlet area of the Baltic Sea. This suggests, in contrast to some earlier studies, that eels of stocked origin may indeed contribute, along with wild eels, to the potential spawning stock.

Relatively few studies are available on the effect of stocking on-grown eels, but available studies suggest that the result in terms of growth, sex, and survival rates are on the same order of magnitude as in natural eel populations.

Stocking programmes should consider the need to simulate natural processes as far as possible, because this is most likely to lead to high success rates.

4 Eel quality

4.1 Introduction

In recent years (e.g. EIFAC/ICES WG EEL 2006), the working group has described the risks of deteriorated biological quality of eels. In 2005, the EU-EELREP (Estimation of the Reproduction Capacity of European Eel) programme concluded that contamination with PCBs impaired fertility, while infections with pathogens/parasites were devastating for swimming eels.

The recommendations of WGEEL (2006) highlighted the need to monitor and to collect information on:

1) pollution and disease status in order to designate areas producing high quality spawners (i.e. with low contaminant and parasite burdens) in order to maximize protection for these areas;
2) the chemical status of eel under the implementation of the WFD.

4.2 Contaminants

Owing to specific ecological and physiological traits, eels are particularly sensitive to bioaccumulation of lipophilic contaminants. From recent scientific evidence (Belpaire *et al*., 2007), there is reason for serious concern because the level of measured concentrations of some contaminants has been shown to have adverse effects on the reproduction success of the silver eel.

EELREP (EELREP, 2005a, 2005b) and Palstra *et al*. (2006) suggested that current gonadal levels of dioxin-like contaminants, including PCBs, in eels from most European locations impair normal embryonic development and that PCBs and other contaminants may have contributed to the decline of eel recruitment observed since 1980. This conclusion is further strengthened by the fact that the emission of PCBs in the environment (van Leeuwen and Hermens, 1995) preceded the decline of European eel, and it is therefore likely that dioxin-like PCBs contributed to the current collapse of the European eel populations (ICES, 2006).

Geeraerts *et al*. (2007) described the results of a literature overview on the ecotoxicological effects of pollutants in European eel. An extensive dataset of contaminants has been analysed by statistical modelling to show relationships between fitness (lipid content and eel condition) and a range of environmental variables. The authors found that PCBs (especially the higher chlorinated ones) and DDTs had a negative impact on the lipid content of the eel (Geeraerts *et al*., 2007).

4.3 Pathogens/parasites

The occurrence of diseases and parasites in eels has been recorded for some time. Until now, the consequences of these infectious agents on the ability of eels to carry out their long-distance migration and reproduction were unknown, although they have been suggested as potential causes for the decline in eel populations.

4.3.1 Anguillicola crassus

The available information on the introduction and spread of *Anguillicola crassus* through Europe illustrates how the live transport of eels, within and between countries, and through stocking programmes has rapidly dispersed the parasite to all major spawner-producing areas (Table 4.1). The parasite is widespread in European inland waters and also occurs in mixohaline waters, such as the Baltic and various estuaries and coastal lagoon habitats.

The EELREP study demonstrated that *Anguillicola crassus* infections can adversely affect spawner quality in European eel by reducing the migratory capacity of silver eels. In addition, eels with damaged swimbladders, as a consequence of previous infections from which they had recovered, were similarly limited in their migratory abilities.

Data presented by Sweden at the meeting gave further indications of the negative impact of *Anguillicola* on the migration behaviour of silver eels. Distance migrated correlated negatively ($p = 0.054$) with the number of *Anguillicola* in recaptures from silver eel tag experiments in 2006, and the number of days between release and recapture rate decreases by number of *Anguillicola* in the swimbladder ($p = 0.047$). Obviously the chance to get caught tends to increase if the eels are infected by many worms (Niklas Sjoberg, pers. comm.).

Table 4.1 Distribution and infection parameters of *Anguillicola crassus* across Europe.

Area	Status	Prevalence (%)	Comments
Belgium	widespread	88.85	Detailed analyses of distribution and infection parameters.
Denmark	widespread	33.33	
Estonia	established	20–40	Introduced to L. Vortjarv with stocked juvenile eels from Germany.
Finland			No data available.
France	widespread		Common in Brittany and southern coastal lagoons, no recent review on distribution.
Germany	widespread	74.45	Introduced from Asia n 1982, all major rivers affected. Additional unanalysed data available.
Ireland	established	43.37	Introduced in 1987, spread rapidly to most commercial fisheries.
Italy	established	20.03	Data for Tiber River, and seven coastal lagoons.
Latvia	present		No accessible data.
Lithuania			No data available.
Norway	unpublished records		Dispersal low.
Poland	established	55.57	Present in Vistula lagoon limited data on other localities.
Portugal		46.63	
Spain	present	28.87	
Sweden	widespread	58.87	Increasing prevalence noted along coast from Kattegat to mid-Baltic.
The Netherlands	widespread	50	Recorded from 1985, initially higher prevalence noted, widespread by 1990.
United Kingdom	widespread	78.83	Distributional maps available.
Outlet Baltic	widespread	43	No other information on locality.

4.3.2 Viruses

Virus infections, such as EVEX and *Herpesvirus anguillae*, which have been reported in wild and/or farmed eels in widely separated parts of the world, represent a potentially serious threat to European eel. The EELREP project found that the EVEX virus significantly reduced the migratory capacity of infected silver eels, and concern about potential damage to eel stocks by such pathogens suggests that more systematic monitoring is required.

4.4 Overview by country

4.4.1 Contaminants analysis

Twelve countries submitted data on contaminants in eel for inclusion into the European Eel Quality Database (EEQD; see Section 4.5).

Belgium

Extensive information was already provided in the WGEEL 2006 report (Belpaire, 2006) while Maes *et al*. (2007a) have described the results of a spatial and temporal analysis of the data from the Flemish eel pollution network. This network has been in place since 1994 and aims to use yellow eel muscle tissue as an indicator of environmental and potential human dietary exposure by hazardous chemicals of surface waters and sediments. It also gives direct indications of the health of the eel, with respect to the presence of these chemicals.

Denmark

There are few surveys and no recent specific studies examining contaminants in eel. However recent data for PFAS and organotin compounds in the aquatic environment are provided by Strand *et al*. (2007).

Estonia

No information.

Finland

No information.

France

No information.

Germany

Concentrations of pollutants/contaminants in the musculature of eels from the River Elbe have been measured by the Elbe River Water Quality Board (ARGE ELBE) from 1999. Along the entire German length of the Elbe, contaminant levels were detected in excess of the maximum allowable levels. This was particularly evident for HCB (hexachlorobenzene) content. Occasionally, maximum levels for other contaminants, e.g. DDT have been exceeded.

Ireland

There are no specific surveys examining the presence of contaminants in eel. However, samples of eel collected in 2005 are currently undergoing analysis for contaminants (PCBs, dioxins, BFRs).

Italy

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

Latvia

No contaminant analysis has been undertaken.

Lithuania

No contaminant analysis has been undertaken.

Netherlands

The longest dataseries for bioaccumulation of contaminants in eels is available from the Netherlands, where a monitoring network for PCBs, OCPs, and mercury in eel has been in place since the 1970s. Results are annually reported (Pieters *et al*., 2005), focusing on areas where consumption norms are exceeded. Although general decrease occurs, levels are still well above effect levels and even recommended consumption levels in the majority of habitats.

Norway

There are no recent data or specific studies examining contaminants in eel. Data on PCBs and pesticides from 1996 and 2000 were provided for the database.

Poland

Investigations into lipid content, concentration of heavy metals, and dioxins were undertaken in 2007.

Portugal

At a national level, several eco-toxicological studies using eels from different catchment areas have been published, e.g. Aveiro lagoon (Ahmad *et al*., 2004; Pacheco and Santos, 2001), Pateira de Fermentelos (Ahmad *et al*., 2006; Maria *et al*., 2006; Teles *et al*., 2007), and the Minho, Lima, and Douro rivers (Gravato and Guilhermino, 2007). Information about trace metals in several fish species of the Rio de Aveiro, including eels, is also provided by Cid *et al*. (2001).

Spain

Although there are no specific surveys examining the presence of contaminants in eel, it is sometimes found among the species included in the biotic analyses performed to determine river quality. In this way, information regarding PCBs, pesticides, and heavy metals in eels from rivers of the Basque country is available. Some recent research has determined PCB levels in eels from the Ebro and the Miño (Santillo *et al*., 2005), and the Jucar (Bordajandi *et al*., 2003); pesticides in the Jucar (Bordajandi *et al*., 2003), heavy metals from the Jucar (Alcaide and Esteve, 2007; Bordajandi *et al*., 2003), and Guadalquivir (Usero *et al*., 2003).

Sweden

The National Food Administration in Sweden analysed yellow and silver eels sampled in 2000 and 2001 from nine different sites with respect to 17 dioxins and furans and ten dioxin-like PCB congeners. Pooled samples showed that eels had less than 1 pg TEQ per g fresh weight of sum TCDD/F in muscle (TEQ = Toxic Equivalents), which equated to 3.8 pg PCB-TEQ per g fresh weight. Silver eels had higher levels than yellow ones. Compared with the other fish species analysed, eels had a higher ratio of PCB to dioxins. However, owing to the high costs for this type of analysis, it is planned that only a few eels will be sampled regularly in the future. Recent contaminant analysis has been undertaken on yellow eels from the Sound (between Sweden and Denmark) for dioxins and dioxin-like PCBs. The 2006 results found that dioxins varied between 0.9 and 4.7, with an average of 2.2 WHO-PCDD/F-TEQ pg per g. The PCBs varied between 3.9 and 12.7 with an average of 6.6 WHO-PCDD/F-PCB-TEQ (Source: SLV (National Food Administration)). Analyses of mercury (Hg) in eels from a number of lakes revealed very low levels.

United Kingdom

Recent surveys in England and Wales investigating concentrations of most metals including mercury, arsenic, cadmium, chromium, copper, lead, nickel and zinc, poly-chlorinated biphenyls (PCBs), dichloro-diphenyl-trichloroethanes (DDTs), hexa-chlorocyclo-hexanes (HCHs), and aldrin and endrin ('Drins) found they had decreased substantially in eels from Sussex rivers, 1994–1995 and 2005–2006 (Foster and Block, 2005). The EU regulation limit of 12 pg per g of dioxin-like PCBs in eels was significantly exceeded for the dioxin-like PCB-118 at 100% of sampled sites in 1994–1995 and 2005–2006. Current levels of dioxin-like contaminants in eels in Sussex rivers are higher than those necessary to impair survival of fertilized eel eggs (Palstra *et al.*, 2006). While Northern Ireland has the largest eel fisheries in the UK, no routine contaminant analysis of eels is undertaken. However from 2006, samples of silver and yellow eels caught from Lough Neagh are now routinely monitored for lipid content. No assessments for contaminants in eels have been undertaken in Scotland.

4.4.2 Parasites/pathogens

Ten countries submitted data on pathogens in eel for inclusion in the European Eel Quality Database (EEQD; see Section 4.5).

Belgium

Since last report (Belpaire, 2006), no new information is available on *Anguillicola* in Belgium. *Anguillicola* infection rates were monitored in 1987, 1997, and 2000 in which year 139 of 140 sites had the infection. The wide distribution of *A. crassus* in Flanders is thought to be the result of restocking with glass eel and yellow eel, both of which are susceptible to *A. crassus*. For distribution maps of the parasite, see Belpaire (2006) or Audenaert *et al.* (2003). Previous studies of endoparasitic helminth communities of eel have also been undertaken (Schabuss *et al.*, 1997).

Denmark

The parasite was introduced in the early 1980s and, since 1988, a monitoring programme on the abundance of *A. crassus*, in the eel population in different fresh and brackish water bodies in which it has become established has been continued annually.

Estonia

No information.

France

No information.

Finland

No information.

Germany

Investigations into the health status of eels have been conducted at the River Rhine in North Rhine-Westphalia, while monitoring for *Anguillicola crassus* has been established at the Elbe, Weser, and Ems rivers. For this monitoring, commercial fishers provide eel swimbladders from commercial catches on a weekly basis. As a consequence, no data on length or weight of the fish are available. During the last years, mean annual prevalence was 81.5–90.7% at the River Weser, 83.4–89.1% at the River Elbe, and 69.2–73.7% at the River Ems. At Lake Starnberger, 1022 eels were examined between 1994 and 2005 (Leuner, 2006). The mean prevalence was 80%, and the prevalence appears to decrease slightly (from 88% in 1994 to 71% in 2005). Lehmann *et al.* (2005a) reported infection with *A. crassus* from several rivers in North Rhine-Westphalia: Lippe 52.1%, Ruhr 58.6%, Ems 51.0%, Rhine 62.0%, Sieg 58.1%, Issel 72.7%, Vechte 46.7%, Große Aue 75.0%, and Weser 74.8%.

In several samples from the Rhine and Moselle rivers and from a lake in North Rhine-Westphalia, the occurrence of *anguillaHerpesvirus anguillae* (HVA) was reported by Lehmann *et al.* (2005a, 2005b). A massive eel kill in one lake in summer 2004 was mainly attributed to an HVA infection. Infections with HVA, possibly linked with summer eel kills, have also been reported from 38 waters out of 80 waters investigated in Bavaria (Scheinert and Baath, 2004).

Ireland

Anguillicola crassus was first seen in Irish eels in the Waterford area in 1997. It was subsequently recorded in the Erne (Evans and Matthews, 1999), and this invasion probably occurred between 1997 and 1998, as *A. crassus* was apparently absent in 1996 (Copely and McCarthy, 2005). *Anguillicola* has now also spread to the River Shannon (McCarthy and Cullen, 2000). A summary of the known distribution of *Anguillicola* in Ireland was compiled in 2003 (McCarthy *et al.*, in press) and the database is currently being updated, following discovery of the species in small and reputedly unexploited western Irish catchments. Investigations of parasite assemblages of eels in marine, mixohaline, and fresh-water habitats in the Shannon and other Irish rivers are being undertaken by the National University of Ireland, Galway, as part of a research project funded by the Higher Education Authority (HEA PRTLI- 3).

Italy

Among the sampling and investigations undertaken within specific parasitology research projects, the presence of *A. crassus* has occasionally been examined, but no eel specific monitoring is in place. The infection is widespread throughout Italy, but temporal variations in infection parameters have been noted.

Latvia

No information.

Lithuania

No information.

Netherlands

The market sampling for Lake IJsselmeer collects information on the percentage of eels showing *Anguillicola* infection (based on inspection of the swimbladder by the naked eye). Following the initial outbreak in the late 1980s, infection rates have stabilized between 40% and 60%, while the number of parasites per infected eel fluctuates between 4 and 6.

Norway

No information.

Poland

During recent fishery surveys in the Vistula lagoon, eels were analysed by SFI for stomach fullness and the presence of *A. crassus* in the swimbladder. In 2006, 190 eels were inspected, and infection rate indicated that almost 90% were infected.

Portugal

Anguillicola crassus is present in several regions, but no standard monitoring programmes have been established to examine its distribution.

Spain

Studies into the presence of *A. crassus* in Spanish rivers found that the parasite was widespread. However, there are still some rivers in Asturias and Galicia that have not been colonized, and special measures should be taken to avoid the infection of these basins. It is difficult to follow the sequence of *A. crassus* introduction in Spain, because the first data are from 2000, and the nematode may have arrived before that. However, in the Mediterranean region, the presence of the parasite is lower than in the Atlantic region (lower prevalence, intensity, and abundance).

Sweden

Prevalence of *A. crassus* is a mandatory variable in all coastal sampling of eel in Sweden, including the DCR sampling, and occurs in eels from most sites. All eels dissected at the Swedish Board of Fisheries are analysed macroscopically for the prevalence (at both institutes involved) and intensity (at the Institute of Freshwater Research only) of *Anguillicola* in their swimbladders. The prevalence in coastal waters in 2002–2005 was close to 10% in the marine habitats of RBD 5 and about 60% in the central parts of RBD 4. The prevalence of *A. crassus* in eels from the strait between Sweden and Denmark (Öresund; SD 23) ranged between these levels. The rate of infestation in the pooled data from 2002–2006 was less than 15% in the most marine areas, 47% in Öresund, and close to 60% in the Baltic sites. Between 2000 and 2007, the Institute of Freshwater Research analysed 3545 eels from 41 different fresh-water sites. Infected eels were found at all sites, and the prevalence varied from 37% to 90%.

United Kingdom

Anguillicola crassus is now considered ubiquitous throughout England and Wales (Nigel Hewlett, Environment Agency National Fisheries Laboratory, pers. comm.). Foster and Block (2005) reported infestation levels in eels (~300 mm total length) sampled across the Sussex area in 2005–2006 ranging from 60% to 88% (regional mean 72%). Similar prevalence levels were reported for eels in Kent rivers in 1996–1998 (Cave, 2000; UK country report). In Northern Ireland, the two largest eel fisheries, the Erne and Lough Neagh systems, became infected with *Anguillicola* in 1998 and 2003, respectively (Evans *et al*., 2001; Evans and Rosell, 2006). By 2005, prevalence had reached 100% on Lough Neagh, and this monitoring work is continuing as part of a long-term investigation into all biological aspects of this fishery. In Scotland, *Anguillicola* has been reported at only a single site (Lyndon and Pieters, 2005). A survey is currently being undertaken and, to date, only a single further site of infection has been detected (W. Yeomans, pers. comm.).

4.5 European eel quality database

4.5.1 Introduction

In 2006, WGEEL recommended that further sampling and ongoing monitoring of eel quality was urgently required. It was advised that member countries should set up a national programme on RBD scale to evaluate the quality of emigrating spawners. This should include at least body burden of PCBs, BFRs, and infection parameters of *Anguillicola*, and EVEX. It should be included in the national management plans, while special emphasis should be given to standardization and harmonization of results (units and methods). To this effect the European Eel Quality Database (EEQD) was created in Belgium in 2007 and circulated among members of WGEEL, requesting data on fat composition, contaminant analysis, and infection parameters of *A. crassus*.

4.5.2 Description of the database

The database contains the following information:

Site-specific data

- Country
- Basin
- River/Lake
- Locality
- Coordinate

Data related to sampling

- Sampling year
- Number of eels
- Eel size (cm)
- Eel Stage

Data related to condition

Fat content

- Min (%)
- Max (%)
- Mean (%)

PCB data

- PCB28
- PCB31
- PCB52
- PCB101
- PCB105

- PCB118
- PCB138
- PCB153
- PCB156
- PCB180

Pesticide data

- α-HCH
- γ-HCH (Lindane)
- Dieldrin
- Aldrin
- Endrin
- Hexachlorobenzene (HCB)
- *p,p'*-DDD (TDE)
- *p,p'*-DDT
- *p,p'*-DDE
- trans-nonachlor

Heavy metal data

- Cd
- Hg
- Pb
- Cr
- Ni
- Cu
- Zn
- As
- Se

Data on pathogens

Anguillicola

- N sites
- N sites infected
- Prevalence
- Infection intensity
- Abundance

4.5.3 Preliminary analysis of EEQD

During the working group session, further data were compiled, and the database now contains information from 12 countries, reviewed in Table 4.2. It can be deduced that monitoring of the quality of the eel received increased attention. Countries such as the Netherlands and Belgium (Flanders) continued their monitoring programmes on contaminants, while others countries have initiated eel quality studies. As a result, eel quality in some catchments is well documented, but in many large catchments over Europe, the amount of available information remains scarce. The table illustrates the need for the further development of a wide-ranging and harmonized European Eel Quality Network.

Lipid content in eels seems highly variable between sites (Figure 4.1). Given the importance of fat stores in eels as an energy resource utilized during migration and for the production of gametes, these observations need further investigation.

Data from the EEQD generated Figures 4.2 and 4.3 and provide an overview of the concentration of the Sum PCBs (seven indicator PCBs) and cadmium in eels across Europe. Preliminary interrogation of the database illustrates the wide variability of these contaminants and the presence of black spots (human health risks, environmental monitoring of contaminants within WFD, etc.) over the distribution area of the eel. Such examples merely highlight the benefits of an eel quality database and the need for a harmonized eel quality-monitoring network across Europe to feed such a database.

Table 4.2. Overview of the eel quality data (number of analyses per country) compiled during WGEEL 2007 and incorporated in the European Eel Quality Database.

Country	Fat	PCB	Pesticides	Heavy metals	Anguillicola
Belgium	409	408	373	373	140
Denmark	7	6	6		3
Estonia					
Finland					
France		19		3	
Germany	12	10	9	9	23
Ireland	2	2			6
Italy	18	18	14	7	10
Latvia					
Lithuania					
Norway	8	8	8		
Poland					7
Portugal	1	1		4	3
Spain	18	52	65	83	26
Sweden	25	10	1	179	51
The Netherlands	37	99	99	76	
United Kingdom	1	39	39	39	11

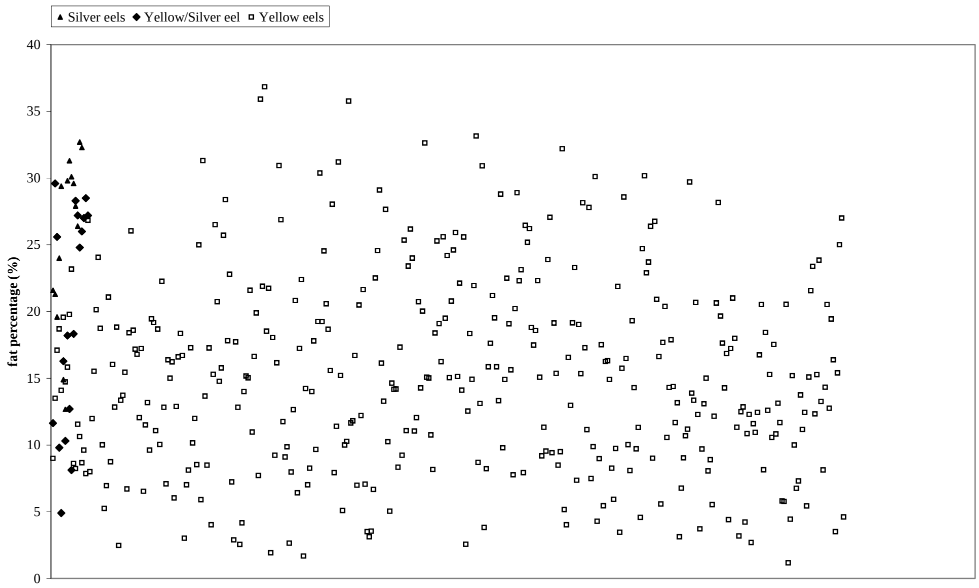

Figure 4.1. Variations in muscle lipid content in yellow end silver eels in Europe. Individual points indicate sampling locations.

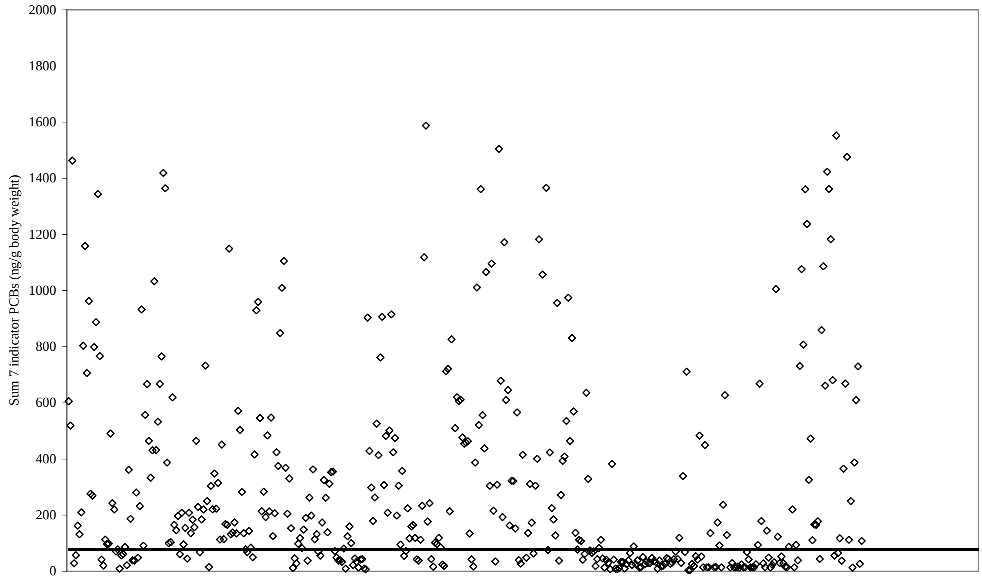

Figure 4.2. Concentration of Sum PCBs (expressed on wet weight basis) in eels in Europe. The line represents the Belgian consumption limit (75 ng per g wet weight). Individual points indicate sampling locations.

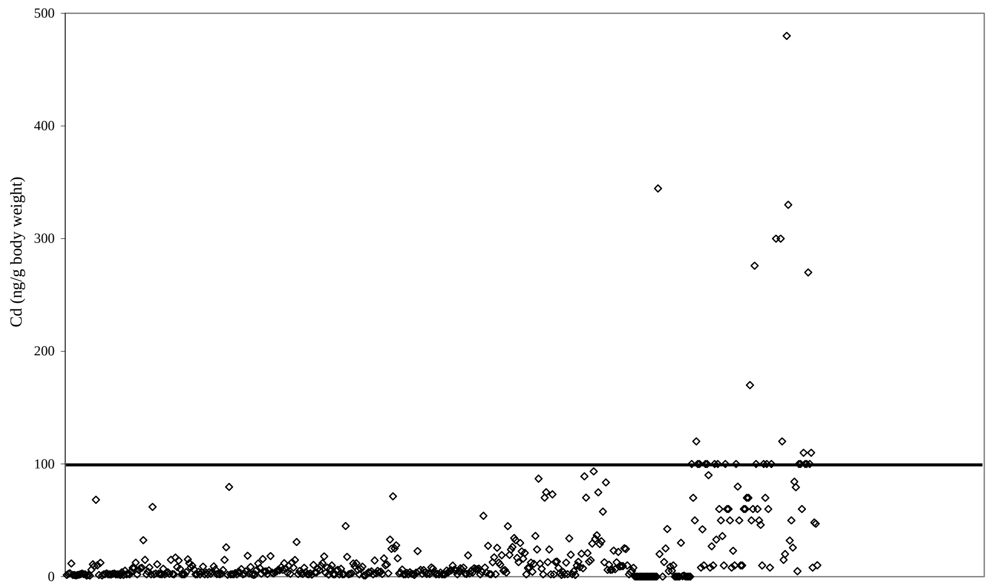

Figure 4.3. Concentration of cadmium (expressed on wet weight basis) in eels in Europe. The line represents the EU consumption limit (100 ng per g wet weight). Individual points indicate sampling locations.

4.5.4 Future development of the eel quality database

The development of a European Eel Quality Database is considered a major and innovative outcome of the working group EEL 2007. Given that the database is in its initial phase and is restricted to a narrow range of quality elements (lipid content, ca. 30 chemicals, and only one disease agent), it is still the first comprehensive, pan-European overview of eel quality data.

Given the proposed eel conservation measures, the database is considered a viable tool within and beyond eel management plans, as it will directly provide data on:

- the quality of spawners, indicating ability for reproduction;
- the distribution of good quality sites where special management measures can be envisaged (special protection of stocks and emigrating spawners, priority places for restocking, etc.);
- quality of restocking material (natural and cultured);
- early warning system for the spread of (new) eel diseases;
- special fishery measures to be taken in relation to human health protection;
- the indication of areas of special concern as to environmental quality (WFD).

4.6 International legal framework

4.6.1 Introduction

Apart from the fact that the quality of eels directly threatens the eel itself by influencing its ability to migrate or by impairing normal reproduction, the contamination level of eels is directly related to two other international legal frameworks.

The quality of the products of eel fisheries is regulated by national and international standards for foodstuffs for the human consumption market. These regulations, influenced by human health considerations, might, in the short term, have a considerable impact on fisheries and stock management (by leading to fisheries closures).

The Water Framework Directive recently (2006) proposed the monitoring of a selection of priority substances and reporting on the chemical status of our water bodies in order to protect aquatic life and human health. The European eel is recognized as a good biomonitor for chemical contaminants with respect to a wide range of those substances.

4.6.2 Legal basis of human health protection: consumption limits and fishery management

4.6.2.1 Introduction

WGEEL recognizes that eel, owing to its high lipid content and various ecological traits, is a species that can bioaccumulate contaminants to very high levels when living in polluted habitats. As such, efforts should be made to monitor the presence and level of bioaccumulating contaminants with particular attention paid to what extent the levels of such contaminants in eels are compliant with (inter)national consumption standards. Strict application of these consumption limits to fisheries may also provide a consequential benefit to the stock, providing protection for the less contaminated eels, which may ultimately migrate to spawn. Compliance with Water Framework Directive guidelines on water quality should reduce contaminants in the environment and also positively benefit eel quality.

4.6.2.2 Eel as a pathway for human exposure to pollutants

A recent study (Bilau *et al*., 2007) assessed the intake of PCBs through eel consumption by recreational fishers and compared it with the intake of a background population. The median estimated intake for recreational fishers in Flanders (Belgium) varies between 18.4 and 237.6 ng Sum PCBs per g bw per day, depending on different consumption scenarios, while the estimated intake of the background population (consumers only) is 4.3 ng Sum PCBs per kg bw per day. Because the levels of intake via eel for two intake scenarios were respectively 50 and 25 times higher than the intake of the background population, the body burden might be proportionately higher and reach levels of toxicological relevance. The intake of PCBs via consumption of self-caught eel in Flanders seems to be at a level of high concern. It was advised to maintain the Flemish catch-and-release obligation for eel, established in 2002, but withdrawn in 2006 (Bilau *et al*., 2007).

On the other hand the Walloon government, aware of the fact that regular eel consumption could pose a threat to human health, prohibited the fishing of eels from 2006 (Walloon Government, 2006).

These data indicate that in some areas (i) eels are polluted in a way that can pose a threat to fisher and consumer health and that (ii) fishery management, in protecting consumers, is not at all consistent even between neighbouring areas.

4.6.2.3 Overview of national and international consumption limits

Maes *et al*. (2007) discussed the existing international framework on maximum residue and contaminant levels in or on food and feed of plant and animal origin, including Regulation (EC) No. 396/2005 of the European Parliament and of the Council (European Commission, 2005). The maximum pesticide residue level (MRL) in foodstuffs is 0.01 mg per kg. This general limit is applicable by default, i.e. in all cases where an MRL has not been specifically set for a product or product type. Definitive tolerances will be listed in Annex II of the regulation, which has yet to be published. Until then, MRLs for pesticides in products of animal origin established by Council Directive 86/363/EEC, as amended, are in force (European Commission, 1986). For cadmium, lead, and mercury, levels have been established by Commission Regulation (EC) No. 466/2001 (European Commission, 2001). In February 2006, the European Commission (2006c) revised the maximum levels for dioxins and dioxin-like PCBs in foodstuffs (Commission Regulation (EC) No. 199/2006).

For the present report, complete information on the relevant national legislation was not available. Some countries have revised their national legislation to comply with these regulations, while some have additional higher national standards for some contaminants.

The quality of eels fished in Member States should therefore be measured and compared with this national and international legislative framework, and the necessary fishery management measures should be taken where appropriate in order to protect fishers and consumers.

4.6.2.4 PCBs

New data on residues of contaminants became available from some countries. Concentrations of the sum of the seven indicator PCBs (Sum PCBs) measured in eel in Flanders are high: in 75% of all sampled localities, the Belgian PCB standard for fish was exceeded. Sum PCBs varies between 3 and 12 455 ng g^{-1} wet weight (2524 eels, Maes *et al*., 2007a). In Wallonia, eels have been sampled from 35 stations between 2001 and 2004 and revealed PCB concentrations (Sum 7 PCBs) between 40 and 1958 ng per g of body weight (Thomé *et al*., 2004). The PCB consumption standard is exceeded at 94% of the sites in Wallonia.

These data clearly indicate that (i) contaminant levels in eel is very variable and can reach very high values; (ii) that in areas considered to be less polluted (e.g. Wallonia) the contamination of eels can be considerable; (iii) that contamination levels can exceed, by several orders of magnitude, the national maximum residue levels in fishery products for human consumption.

4.6.2.5 Dioxins

For dioxins, it was reported from Flanders that 50% of the sites (N = 8) were above the maximum residue levels (Sum of dioxines and dioxin-like PCBs 12 pg WHO-TEQ per g wet weight). In eels collected in 2006 from 22 sites from The Netherlands, total dioxins were above the maximum allowable level in 74% of the analysed samples (Hoogenboom *et al*., 2007), which clearly indicated the need for management measures to be taken.

4.6.2.6 Conclusions on legal framework

In a number of cases, eel contaminant levels are above human consumption standards. New evidence has been given that, in some areas, eels are polluted to such a degree that they pose a threat to the health of consumers. The quality of eels fished in Member States should be monitored and compared with national and international legislative framework, and the necessary fishery management measures should be taken where appropriate in order to protect fishers and consumers. In some areas where consumption levels exceed legal consumption limits, the fishing, trading, and eating of such eels has not been forbidden.

4.6.3 The eel and the evaluation of chemical status within the Water Framework Directive

The usefulness of measuring contaminants in eel for monitoring the chemical status of our water bodies within the Water Framework Directive was discussed recently (Belpaire and Goemans, 2007 a, 2007b). The WFD recently (2006) proposed to monitor a selection of priority substances and to report on the chemical status of our water bodies with the final objective being the protection of aquatic life and human health. The majority of these substances are lipophilic; nevertheless, it is proposed to monitor them in the water phase. As there is serious concern about whether measurements of these lipophilic compounds in water will give satisfying results to guarantee the protection of aquatic life, monitoring in biota seems to be more appropriate. For the time being, the WFD fails to present an appropriate model efficient enough to guarantee this protection.

The advantages of using the eel as a model within the WFD have been described by Belpaire and Goemans (2007a). A wide range of studies over Europe exist and have pinpointed a variety of environmental contamination. Eel contaminant profiles seem to be a fingerprint of the contamination pressure of a specific site. From the Flemish eel pollution database, reference values and quality classes for PCBs, OCPs, and heavy metals in eel were deduced and published by Belpaire and Goemans (2007b).

The creation of a harmonized, Europe-wide chemical monitoring programme for eels (see Section 4.5) would have a triple application: (i) the evaluation of environmental health and chemical status, (ii) the sanitary control of fisheries products within human food-safety regulations, and (iii) the monitoring of eel quality within the requirements of the international eel restoration plan (Figure 4.4). Taking into account the actual high concentration of some contaminants in certain eel subpopulations and the ecotoxicological effects of these substances, achieving good chemical status of EU waters will be directly beneficial for eel stock restoration. By measuring in the eel itself, we are in a better position to protect the eel directly (Belpaire and Goemans, 2007b).

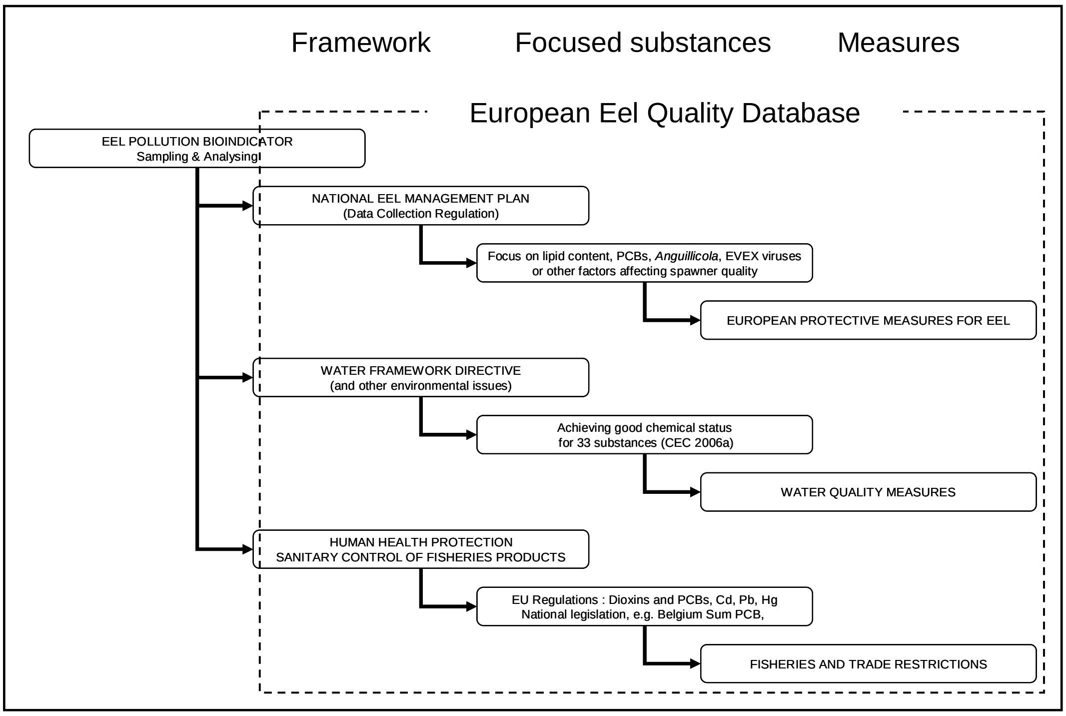

Figure 4.4. Possibilities of combined use of monitoring contaminants in the eel (adapted from Belpaire and Goemans, 2007b).

4.7 Quality assurance

When developing an international monitoring network on quality parameters on eel, there is a requirement to ensure maximal quality of the data. Methodology and quality assurance has, to some extent, been described by France for a national programme (Briand *et al*., 2006). This should be discussed, extended, described, and implemented on an international level within the framework of an international monitoring network.

4.8 Conclusions on eel quality

Considerable advances have been made in the collection of data on contaminants, parasites, and fat levels in eel, with many Member States commencing the monitoring of eel quality. WGEEL has initiated the establishment and development of a European Eel Quality Database (EEQD). The eel quality data are highly variable and indicate the possibility of identifying black spots for low quality eels.

Many Member States have started monitoring eel quality, and 13 of the 17 Member States provided data. This enabled the compilation of a comprehensive overview on the contaminant load in eel over its distribution area.

Results from the EEQD showed that considerable variation in contaminant load exists within river basin districts, according to local anthropogenic pollution, linked with land use.

There is evidence that, on a pan-European scale, large differences in eel quality occurs between catchments. Furthermore black spots with low quality eels were detected.

Lipid content, which is believed to be an important index of fitness, was highly variable between sites.

Anguillicola is now widely distributed throughout Europe.

Taking into account the high concentration of some contaminants in certain eel subpopulations and the ecotoxicological effects of these substances, achieving good chemical status of EU waters, primarily through the implementation of the Water Framework Directive, will be directly beneficial for eel stock restoration.

New evidence was presented on the negative impact of certain contaminants on the fitness of eel (Geeraerts *et al*., 2007) and on the negative impact of *Anguillicola* on behaviour of Swedish silver eels. Viruses are currently not included in eel quality monitoring.

The WG Eel 2007 initiated the development and implementation of the European Eel Quality Database (EEQD).

In some regions eels are polluted to such an extent that they represent a threat to consumers, and consumption limits in some countries currently exceed maximum allowable levels. Fishery management measures to protect consumers are not consistent, even between neighbouring areas, and human health is not protected everywhere.

4.9 Recommendations on eel quality

The working group recommends that the European Eel Quality Database should be further developed and maintained by Member States.

Member States should initiate harmonized monitoring strategies aimed at the development of a European Eel Quality Monitoring Network, to collect the relevant data to be fed into the EEQD. National eel management plans should take account of these data for evaluation of the quality of spawners.

Consideration should be given to extending the range of eel quality parameters monitored.

Where eel fisheries occur, yield and quality should be controlled and compared with maximum allowable human consumption limits. Consistent and immediate fishery management measures (closing fisheries, advice not to eat eels) should be implemented in areas where the contaminant levels in eels exceed human consumption standards.

All efforts to improve water quality and reduce levels of contaminants entering the watercourse should be made, and compliance with Water Framework Directive guidelines on water quality should reduce contaminants in the environment and also positively benefit eel quality.

The working group recommends the inclusion of contaminant monitoring in eel as a tool for measuring the chemical status of our water bodies as defined in the Water Framework Directive.

The impacts that contaminants may have on the reproductive capacity of both females and male eels should be investigated.

We repeat the WGEEL (2006) recommendation that the EVEX virus and *A. crassus* should be added to the list of notifiable fish pathogens.

4.10 Gaps in eel quality knowledge – research needs

There is a need for more information on the impacts of eel quality during the different eel life stages and not just the relationship between contamination and reproduction. An assessment of their impacts on overall eel fitness is needed.

The evaluation of ecotoxicological benchmarks for contaminant effects on eel.

Given that research to date on reproductive capacity has focused on female eels, the impacts that contaminants may have on the reproductive capacity of male eels should now be investigated too.

Further investigation into the incidence of viruses (e.g. EVEX) across Europe.

4.11 Acknowledgements

The Working Group on Eel acknowledges everyone who have provided published and unpublished information on contaminants and diseases for inclusion in the European Eel Quality Database. Complete references of the origin of the data included in the database can be found in Annex 6 of this report.

5 Anthropogenic impacts on migration

5.1 Introduction

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).

In this chapter, we will discuss accessibility to upstream locations, knowing that there must be a balance between the gain in habitat, and therefore eel density, and potential loss in mortality and damage to downstream migrants. Power plants represent clear obstructions for downstream movement and cause a risk for the survival of silver eel. Mortalities and sublethal effects will be described here as well as new results on the behaviour of downstream migrants in the vicinity of obstacles. Finally we will address the issue of by-pass and deflection systems in conjunction with knowledge obtained on the behaviour of eels.

A recent workshop on eel downstream migration was organized by the Swedish Board of Fisheries and the Swedish hydropower industry in May 2007 in Stockholm. Most of the results described here were presented during the workshop.

5.2 Description of the problem

5.2.1 Upstream migration

Man-made obstacles to eel movements take a range of forms, from small weirs and culverts to large hydroelectric dams. Most obstacles are more likely to have greater impacts on upstream than downstream movements, though hydro-schemes with fish passes form a notable exception. The compilation of complete datasets of man-made obstacles in a country is no easy task, and not all states will have exhaustive inventories, while fewer still have detailed information on the extent to which a perceived obstacle actually affects eel migration. Nevertheless, information about obstacles is likely to be crucial in understanding and in attempting to quantify the "pristine" state of eel stocks. The Water Framework Directive should have compiled such an inventory for each river basin district, which could be accessed for this purpose.

A few examples will suffice to illustrate the potential scale of the problem. In Brittany Briand (pers. comm.) estimated that obstacles may have reduced catchment production by 30%. In Scotland, it has been estimated that the up to 35% of river channels (by length) were partially excluded to eels, whereas 6% were completely barred to eels (Godfrey, unpublished data). In New Zealand, Boubee (pers. comm.) has estimated that hydro-dams block access to 35% of the total longfin eel habitat, equating to a lost biomass of about 3614 tons, mostly expected to be in the form of large females.

5.2.2 Obstacles to upstream movement

5.2.2.1 Assessment of the impact of man-made obstacles on eel populations

If density-dependent processes are operating on the colonization patterns of eel stocks throughout the catchment, then obstacles may impact silver eel escapement from the catchment as a whole. Assessing anthropogenic range restriction is therefore an important consideration in the assessment of compliance with the target of 40% of natural spawner-escapement levels, specified in the Council regulation establishing measures for the recovery of the stock of the European eel.

If the whereabouts of all man-made obstacles are known, then the *maximum* magnitude of their impact can be readily calculated. The total surface area of river channels and lakes in a catchment can be measured using techniques in GIS, and the proportion of the area from which eels are excluded can be identified and quantified. This figure can be taken to represent the maximum loss of production caused by the obstacles, effectively based on the simplifying assumptions that: all habitat within a river system is equally productive per unit surface area; eels are totally excluded upstream of man-made obstacles; and that no natural obstacles impede eel passage. Although this kind of estimate is evidently unrealistic, it has the merit of erring on the side of caution, and in practical terms it may be difficult to achieve even so crude an estimate within the time-scale available before the mandatory production of eel management plans.

Greater realism in assumptions about population processes, habitat use, and the actual impact of individual obstacles on eel access should increase the accuracy of the estimate of lost production. A number of refinements to the maximum impact estimate can be incorporated, if time and resources allow:

1) Assessment of eel population density changes with distance from the sea (in the absence of obstacles).
2) Assessment of the impact of preventing the movement of eels upstream on production in the downstream reaches of the river (for a range of different population densities).
3) Assessment of the relative productivity of different habitats represented upstream and downstream of the obstacle (e.g. upland vs. lowland, riverine vs. lacustrine).
4) Assessment of the secondary impact of obstacles on the sex ratios of spawners, via effects on density.
5) Assessment of the true extent to which a man-made obstacle causes disruption of eel movement.
6) Assessment of the impact of other natural obstacles within the system on habitat accessibility.
7) Information about the relative contribution of spawners leaving from different parts of a system (i.e. do spawners originating from high or low in a catchment contribute asymmetrically to the total spawning output?).

It should be recognized that the present state of knowledge is inadequate to make these assessments with confidence. In particular, the role of density-dependence in the functioning of eel populations is so poorly understood (see Section 6.3), and the relationship between habitat and eel production is not well described. Such assessments of the impact of obstacles to upstream movement and the resultant loss of production should be carried out on a case-by-case basis, using locally derived parameters.

However, in the meantime, some general approaches may be possible. For example, the RCM and SMEP models being developed for England and Wales (Ibbotson *et al*., 2002, Aprahamian *et al*., in press) offer an approach to dealing with points 1–3 (and perhaps 4) above. A system for categorizing the severity of individual and cumulative effects of obstacles to upstream eel migration into a single score based on obstacle height, gradient, surface roughness, and bank characteristics has been developed (Leprevost, 2007). Along with density data from electrofishing surveys, these scores were used to model the potential impact of obstacles on spawner production in Brittany, and a reduction of 30% caused by obstacles to upstream migration was identified. This approach offers the potential to deal with points 5 and 6 above.

Mitigation

The need to apply the precautionary principle when making decisions that involve density-dependence, and where its role is not known, is emphasized elsewhere in this document. Here we argue that allowing the eel to re-colonize its natural range by the removal of artificial barriers where there are no concerns about mortality when recrossing those barriers in a downstream direction, is an application of the precautionary principle because, first, it increases the range of habitats from which spawners can be potentially recruited, and second, it must reduce (or at worst leave unchanged) density-dependent pressures on growth and mortality. The likely influence of reduced densities in generating a larger proportion of females has often been regarded as an additional advantage of removing obstacles to upstream movements, because female fecundity is in general more crucial to population increase. However, the lack of knowledge of sex ratios of spawning eels in the Sargasso Sea makes this perhaps controversial.

If there are no concerns regarding significant sources of mortality associated with downstream migration past an obstacle, then amelioration of its impact on upstream migration may be effected with a variety of simple structures (Dahl, 1991; Knights and White, 1998; Solomon and Beach, 2004; Larinier *et al*., 1999). Elvers cannot swim against current velocities of >0.5 m s^{-1}, while yellow eels may ascend at flows of up to 2.0 m s^{-1} (references in Knights and White, 1998). Fish passes designed for salmonids generally operate at somewhat higher velocities than this (Clay, 1995) and so may not aid eels in their upstream movements.

Where significant mortality during downstream passage is anticipated, an attempt to provide upstream access may be misguided. The impact of habitat exclusion on production and the extent of downstream mortality at hydropower turbines should be evaluated, to determine whether allowing upstream access is beneficial or deleterious to spawner escapement and whether or not the option of translocation of upstream migrations to catchments where escapement to the sea by the maturing silver eels is more assured. At present, there is rarely sufficient knowledge of the processes involved to make this kind of cost–benefit analysis in a rigorous way (see also Chapter 3.4).

5.2.3 Downstream migration – hydropower

5.2.3.1 Downstream migration

Mortality and sublethal effects

Hydropower has been recognized as one of several factors contributing to the dramatic decline in the eel population (ICES, 2002), and eels tend to have considerably greater mortality rates from downstream passage at hydropower stations than other fish species (Hadderingh and Baker, 1998). In many European rivers, such as the Rhine and Meuse, numerous hydropower stations have been installed.

Early reports of fish mortality at European hydropower stations were published by Von Raben (1955, 1957) and by Berg (1985, 1986, 1987). In these studies, the average mortality rates for European eel, which is very susceptible to injury of turbine blades, ranged between 15% and 38%. However significant mortality can also occur owing to structures other than the turbines themselves, for example, impingement on trash racks or physical damage from spillway passage may also cause severe mortality (Adam and Bruijs, 2006; Boubee, pers. comm.), such as:

- On dams with heads over 10 m and/or an impact of hard structures in the tailwater region, fish may suffer lethal injuries.
- Screens and trash racks in front of water intakes cause damage when fish are impinged and pressed against the racks by the water velocity.
- Turbines and pumps cause mortality by direct contact with turbine blades, shear stress, cavities, and pressure differences.
- Fish that are entrained through the screens at cooling or potable water intakes die in the following zone.

- Fish that have passed and survived hydraulic structures may be easy prey for predatory fish and fish-eating birds in the tailwater zone.
- Rapid changes in osmotic conditions at flood control sluices in coastal areas provokes high mortality rate among the fish.

Injuries and mortality are generally established directly after collecting the fish; this mortality can be defined as direct mortality. Delayed mortality, for example mortality after 24 hours, cannot be excluded but this has not been investigated in many cases.

Bruijs *et al*. (2003) listed six main types of sublethal effects from downstream passage at hydropower stations:

- Red fins/skin slashes
- Haemorrhaging on the head and abdomen
- Lethargic behaviour
- Complete and partial bisection
- Vertebral damage
- Crushed heads

In addition, Therrien and Bourgeois (2000) recognize internal injuries: eye bulging, internal haemorrhages, rupture of the swimbladder, and gaseous emboli. All these sublethal effects may lead to subsequent death or significant compromise of ability to spawn successfully. Such sublethal effects are rarely quantified.

Mortality rates

Estimations of eel mortality rates are extremely variable depending on the site and the type of structure. Accurate estimations are difficult to obtain owing to the uncertain behaviour of eels during their downstream migration. Estimation mainly involves netting eels at the outlet of turbine. However, this is a difficult procedure and telemetry is often preferred because it yields more detailed and varied results (on behaviour) for example.

A portion of this variation is likely to be caused by inherent differences between individual turbines (smaller turbines are more lethal) and in the structure of particular dams and spillways. Further variation in mortality can be explained by variation in eel length: longer eels are more likely to be damaged in turbine passage (Larinier and Travade, 2002; Bruijs *et al*., 2003). Indeed Boubee (pers. comm.) concluded that the survival of larger eels (>80 cm) passing downstream through turbines in New Zealand was likely to be nil. River flow conditions may also affect mortality rates, because they influence the availability of alternative passage routes through/over a dam.

The types of turbine used in European rivers are Kaplan, Straflo, or Francis turbines. Bruijs and Durif (in press) reviewed reported eel mortalities for Kaplan turbines: they are quite similar, ranging from 20% at Obernau, Germany (Von Raben, 1957), 22% at Dettelbach, Germany (Holzner, 1999), and 24% at Beauharnois, Canada (Desrochers, 1995), 16–26% on the Meuse (Winter *et al*., 2006), up to 37% at Raymondville, USA (Franke *et al*., 1997), and 38% at Neckarzimmern, Germany (Berg, 1986).

Of special importance for silver eel is the cumulative mortality caused by passage of a series of hydroelectric power stations. If 20% is a typical average mortality rate, the total mortality rate of downstream migrating silver eel after the passage of five hydroelectric power stations reaches approximately 70%. Dönni *et al*. (2001) made a calculation of the cumulative mortality of downstream migrating silver eel for the River Rhine between Lake Constance and Basel. The cumulative mortality of downstream migrating silver eel, passing maximal 11 hydroelectric power stations in this stretch of river, amounted to 93%.

5.2.4 Other forms of mortality

Other types of barriers such as pumping stations, cooling water intakes, and tidal power plants also represent potentially harmful and lethal structures for downstream migrants. We have, however, no knowledge of the impact of these facilities on eel migration. Reports have also been made of eels being injured and killed by propellers of ships on the Rhine. Again no data were available.

5.3 Downstream migration

5.3.1 Behaviour

5.3.1.1 Knowledge of migratory behaviour

The behaviour of downstream migrating silver eels has been investigated mainly using tagging of eels and telemetry. The use of tagging methods is particularly well adapted to these types of studies. Winter *et al*. (2006) showed that surgically implanted eels did not present greater mortality. The behaviour of tagged eels was slightly reduced in terms of locomotor activity level; however, the timing of activity (i.e. locomotor activity) was the same in the control and experimental groups.

All behavioural studies tend to show identical patterns in the way individuals approach power stations. In France, Gosset *et al*. (2005) observed the behaviour of 74 eels using radio-telemetry. Close to half of the radio-tagged eels returned up the headrace after their release. Most of them were evidently reluctant to pass the turbines and made several incursions (Durif *et al*., 2003). The same behaviour was observed by Watene *et al*. (2003) in New Zealand. Winter *et al*. (2006) indicate that eels showing hesitation to pass probably seek alternative routes to pass the power station. In the study by Bruijs *et al*. (2003), 50% of the tagged individuals (approximately 300 individuals) showed clear hesitation and 25% turned upstream.

The upstream-orientated escaping movements of eels in front trash racks were observed in flume tank experiments and described by Adam *et al*. (1999). They found that an eel that comes in direct physical contact with the trash rack reacts by turning and swimming upstream.

Eels may remain in the headrace for quite a long time, up to two months according to Durif (2003), if they haven't found passage within the appropriate environmental window. They generally find a low-velocity area and remain motionless in natural shelters, until the right environmental conditions arise again (Boubée, Durif, pers. comm.).

On the Moses-Saunders Power Dam on the St Lawrence River in Canada, McGrath and collaborators observed that eels use the entire water column in search of means of passage. Eels display undulating vertical movement patterns in front of the intakes and do not appear to privilege any bottom over surface during this searching behaviour.

The main conclusions from the May 2007 workshop on Downstream Migration were that eels have an active behaviour as opposed to floating passively towards the intakes. They show reluctance to enter the turbines and search for other means of passage. They are able to swim away from the intakes and return upstream if the velocity is below 0.5 m s^{-1} (Adam pers. comm.). Between attempts to pass the facility, eels rest in sheltered and low-velocity areas. According to experts, these may be designated as suitable areas for installing bypasses, as long as proper deflection mechanisms (bar-racks and louvers) are installed in front, or upstream, of the intakes.

5.3.2 Bypass and deflection

5.3.2.1 Mitigation measures

Bypasses

Bypass systems may consist of holes drilled through the dam and fitted with pipes (Boubée, pers. comm.), existing discharge sluices at the outlet of which a reception pool must be installed to cushion the fall of the fish. The latter system was used by Gosset *et al*. (2005). They compared the efficiencies of a surface and a bottom sluice installed on the spillway of a small hydroelectric power plant in France. Total efficiency for both bypasses, evaluated on the basis of downstream movement of radio-tagged eels, ranged from 56% to 64%. However, preferred passage through the bottom bypass for both tagged and untagged eels was confirmed by telemetry, as three to four times as many eels transited through the bottom bypass compared with the surface one. These results showed that eels were more attracted by passage near the river bottom, but nevertheless did use the surface bypass.

Spillways can also be used as bypass systems. However, the discharge must be designed to avoid contact with fish and to ensure that turbulence is minimized (Therrien and Bourgeois, 2000). Fish leave the headrace with surface flow and therefore do not seem at first hand adapted to silver eel migration. Other details and descriptions of types of spillways used for several species of fish can be found in Therrien and Bourgeois (2000). Boubée in New Zealand tested survival of long-fin eels after spillway opening and concluded that they constitute a reliable means of getting downstream migrants safely over dams.

Deflection systems

The extent to which migrating silver eels can be directed away from hazards, such as cooling water intakes, pumps, and hydropower turbines, and towards safer downstream routes has been the subject of increasing review recently. Knowledge of eel migratory behaviour and of the environmental determinants of the timing (diel cycles, seasonality, etc.) is required. Likewise, detailed information on the hydrological conditions, anthropogenic structures, and plant operating protocols that apply to a particular local situation is also essential. Mitigation measures involving deflection technologies inevitably have strong site specificity and reflect local eel management objectives.

In addition to their use in directing silver eels away from hazards, to safe migratory routes, deflection technologies can also be important in increasing the effectiveness of mitigation measures that involve trap/transport operations. In such cases, the objective will be to increase capture efficiency at fishing sites by focusing silver eels towards net or trap entrances in order to increase capture rates, and render such operations more cost-effective and/or feasible in other ways must underpin research and development in this area.

Although the protection of the migratory European eel, in the context of the EU eel restoration plan and the WFD, is one of the principal objectives of this report, it is important to recognize that many of the anthropogenic structures and industrial activities that adversely affect eels are also impacting on other species. These can include other long-distance migrants such as Atlantic salmon and other species such as cyprinids that are undergoing local movements. Thus, the search for multispecific solutions can also be important considerations of the various alternative systems used to attract or repulse migrating fish with a view to reducing anthropogenic mortalities. Appreciation of the different sensitivities of fish species, with respect to light spectral frequencies, intensity, etc., and to similar interspecific variations in respect of other sensory modalities, as well as differences in natural behavioural responses to stimuli generated by alternative deflection technologies will be of assistance in selection of single vs. multispecific screens.

5.3.3 Mechanical barriers

Mechanical barriers, such as trash racks at turbine intakes and similar structures that may be located at spillways or other hazardous locations for eels migrating downstream at power plants, are only effective if bar intervals are rather small, and this has implications for power generation potential and may result in excessive accumulations of plant matter and other trash. Available information suggests that eel avoidance is only possible at relatively low flow rates (e.g. <0.2 m per sec). Experimental studies show that male silver eels, being smaller, require bar intervals <9 mm whereas females may be prevented by bar intervals of <15 mm. A 20 mm bar interval may allow eels as large as 70 cm to pass though at 0.5 m per sec (Beate, pers. comm.). These constraints limit the extent to which mechanical barriers alone may be effective in limiting eel mortality and sublethal impacts at larger hydropower stations. However, in slow-flowing conditions and many small privately owned hydrogenation units, they will be of value. When combined with use of behavioural deflection technologies, mechanical barriers may also be of value in eel protection at other sites. Further research on multibarrier approaches to eel deflection would be helpful. Mechanical barriers are also often an essential part of the structures that may be used to capture eels for trap and transport mitigation of the effects of hydropower stations on eels. Leader nets of differing mesh sizes in large fykenets or coghill nets and metal or wood wattle screens that direct eels to nets in eel fishing weirs, are examples of the use of such mechanical systems.

Mechanical barriers to eel migration may also include regulating weirs, canal gates, etc., and their design criteria may also have to be reviewed in development of eel protection systems for power plants and other industrial water intake points.

5.3.4 Electrical barriers

Electrical barriers are sometimes used on a small scale to limit fish movements during mechanical disturbance (e.g. bridge construction) to riverine habitats and for other reasons. Exclusion of unwanted species, such as invasive non-indigenous species, can also sometimes be achieved by such a behavioural system. The best-known and most extensive use of electrical barriers involves exclusion of non-seagoing sea lampreys inhabiting the Laurentian Great Lakes in North America from potential stream spawning sites for population control reasons. Application of electrical barriers at experimental sites in French hydropower stations, on a limited scale, and some other research suggests that there may be opportunities to use electrical barriers more widely in deflection systems for silver eels.

5.3.5 Light screens

Historical records of the use of river bank fires by silver eel fishers and observations on eel deflection by lights at commercial fishing weirs indicate the potential use of light screens in improved efficiency of eel capture systems used for capture and transport methods of mitigating anthropogenic effects, such as those occurring at hydropower stations. A variety of laboratory and field experiments have demonstrated the potential use of light screens at power stations in Europe and North America. Experiments have involved use of lights of various intensities, spectral properties, as well as strobe lighting. Commercial applications have involved use of light alone or in combination with either mechanical guidance systems or other behavioural technologies using sound, bubble screens, etc. Large-scale experiments undertaken at the Moses Saunders Dam on the St Lawrence River, by EPRI, showed that powerful light arrays did affect eel swimming behaviour (Dixon, pers. comm.). It seems that in general light deflection systems are, like most other behavioural barriers, in high-flow conditions due to the speed at which the relatively slow maximum swimming abilities of eel species. However, in low-flowing rivers such as those used for "run of the river" sorts of turbines now more widely used, or for other situations where eels can potentially be diverted to safe temporary refugia during generation periods, such technologies still have considerable potential as silver eel protection measures.

5.3.6 Bubble screens

Bubble screens have been proven to be particularly effective when used to accommodate an evanescent (non-propagating) sound field. The sound field being largely contained within such a bubble curtain can produce demonstrable diversions of various species, including eels; commercially available systems have been produced in UK for several years. Like other behavioural systems, this approach is often most effective when combined with the use of physical screens or other technologies. In contrast to mechanical systems, which typically have high diversion efficiencies but high recurrent costs (trash rack cleaning, repairs, etc.), the relatively higher capital costs of such systems may in the longer term justify more widespread use in fish protection at hydropower stations and assist in silver eel conservation measures.

5.3.7 Sound and infrasound

Observations on responses of eels to natural (waterfalls, etc.) and anthropogenic sound production (such as may occur at hydropower dams and industrial plants) have led to attempts to develop deflection systems involving noise as an eel deterrent. However, such effects seem to be also important in other behavioural technologies, such as those involving bubble screens and water jets.

Deflection of eels using infrasound induced startle and avoidance behaviour, though not commercially applied at hydropower plant intakes, etc., appears to offer new opportunities to reduce mortalities in migrating and locally dispersing eels (Sand *et al*., 2000; Sonny, pers. comm.). This can be undertaken through creation of multispecies barriers or through actions that specifically target eels. Improved knowledge of the sensory systems of the numerically dominant fish and of those having high conservation status, including eels, will help in the research, and development work can assist in the development of this new approach to eel deflection. Likewise, further field trials, involving different hydrometric systems and reflecting the diversity of environmental conditions under which downstream migrating eels approach hazards or trap sites. Infrasound (10–20Hz), attributable to fish-swimming activities, may provide important natural signals allowing predatory fish to detect potential prey and also allowing the latter to detect potential predators, and to initiate appropriate avoidance response behaviour. Such natural escape reactions, if they can be effectively elicited by generation of infrasound in appropriate river or lake sites, may provide effective protection for eels in otherwise difficult locations.

5.4 Recommendations for anthropogenic impacts

- Increase upstream access to habitats from which successful downstream migration is possible.
- Install appropriate bypass systems where technically possible and biologically beneficial, or alternatively initiate trap and transport measures.
- Develop cost–benefit analyses of management strategies for mitigation of anthropogenic impacts, which should include both biological and economical parameters.

6 The restoration process: concepts, methodologies, research needs

6.1 Introduction

A review of the available information on the status of recruitment, stock, and fisheries of the European eel supports the view that the population as a whole has declined in most of the distribution area, that the stock is outside safe biological limits, and that current fisheries are not sustainable. Recruitment is at a historical minimum, and most recent observations do not indicate recovery. The European Union has accepted a regulation establishing measures for the recovery of the stock of European eel (Commission of the European Communities 2007 Council Regulation establishing measures for the recovery of the stock of European Eel. Council Regulation No. 007). This chapter will discuss the concepts, methodologies, and research needs involved in the restoration process.

The objective of the EU regulation is protection and sustainable use of the eel stock. To this end, Member States will develop eel management plans for their river basins, achieving a reduction in anthropogenic mortalities so as to permit the escapement to the sea of at least 40% of the biomass of silver eel relative to the best estimate of escapement that would have existed if no anthropogenic influences had impacted the stock. The anthropogenic influences encompass fishing, migration barriers, habitat destruction, pollution, etc., but also trap and transport of eels within river basins, stocking of recruits from the core of the distribution area to the outer regions or outside the natural distribution area, pre-growing glass eel in indoor facilities before releasing them into the wild, combating natural predators, and other artificial measures; that is: both positive and negative impacts occur.

There are strong indications that the production of recruits might be impaired by the low spawning stock. Because of the low recruitment, it is unlikely that sufficient glass eel can be captured in areas of abundance and used for stocking all relevant surface waters elsewhere. There are indications that recruitment is declining faster than the stock due to depensatory processes in the reproductive phase, which may eventually lead to an extinction vortex (Dekker, 2004; see also Section 2.1.3; Figure 2.6). Consequently, ICES (2004) has suggested considering stocking as a potential measure, to enhance the stock in a short time frame. Other positive actions in addition to stocking may also be required to be evaluated and implemented, such as mitigation of barriers to upstream and downstream migration.

The discussion in this chapter will be based on the assumption that the goal of the EU Regulation is to restore the natural stock by restoration of the natural conditions, that is, restricting negative anthropogenic impacts. Additionally, positive anthropogenic impacts are being considered as mitigation for negative impacts, or might be selected to speed up the restoration process and to escape from the potential depensation trap. It will be consistent with the risk-averse strategy of the precautionary approach, to prioritize restrictions on the negative impacts, while not relying on the positive actions. The discussions below will set priorities accordingly.

6.2 Stock–recruitment relation

Data on abundance of glass eel recruitment, of yellow eel stocks, and on fishing yields are presented in Chapter 2. Recruitment is in decline since 1980, and is below 5% of the historical level since 2000. Landings have shown a gradual decline since the 1960s, down to approximately 25% of the former level. The causes of the decline in recruitment are not well known, but might well be related to a low spawning stock; see Figure 6.1 for a graphical representation of the relationship between spawning stock size and subsequent recruitment. The ecology of eels makes it difficult to demonstrate a stock–recruitment relationship. However, the precautionary approach requires that such a relationship should be assumed to exist (ICES, 2002). Therefore, ICES (2002) advised to restrict fisheries and other anthropogenic impacts, in order to ensure that the spawning stock returns to and then remains above the critical level B_{lim}, above which recruitment is not impaired by the size of the spawning stock. In the absence of pertinent knowledge of eel, ICES (2001, 2002, 2003) advice was based on a default B_{lim} of 30% of the SSB occurring under pristine conditions. However, this default advice is derived from other fish species, such as cod, herring, and plaice, whose biology is fundamentally different from the eel's. The European eel constitutes a panmictic stock, whose continental distribution area is scattered over thousands of rivers (Dekker, 2000a), and each eel spawns only once in its lifetime (semelparous), at a relatively high age (longevity). Consequently, ICES advise on eel took an arbitrary extra safety margin of 20% above the default level of 30%, coming to B_{lim} equal to 50% of the pristine SSB. Note, however, that some confusion arose on the precise level advised (ICES 2006), in the sense that the limit reference point B_{lim} of 50% has been interpreted as a target reference point B_{pa}, accommodating uncertainty in the assessment of the current status of the stock, rather than the uncertainty in the biological processes. A target reference level for the SSB of the eel should be higher than the B_{lim} advised at 50%; given our poor knowledge of the status of the stock; a considerable gap between B_{lim} and B_{pa} will be required. However, in the absence of a stock-wide assessment of the European eel stock (other than the Procrustean assessment of Dekker, 2000b), no precision level or B_{pa} can be specified.

As an alternative strategy to setting B_{lim} at an uncertain percentage of the notional pristine SSB, another approach might be the following: In the 1970s, recruitment of glass eel was still at historically high levels. This indicates that SSB was not limiting the production of recruits at that time. Quantification of the 1970s spawner escapement therefore is the simplest derivation of the reference level. Note that in this case, the full escapement of the silver eels in the 1970s (given the anthropogenic mortality of that time) corresponds to the escapement level advised by ICES (2002a). That is, one should set the reference point either at 100% of the 1970s silver eel escapement, or at a percentage of the notional pristine state.

There is some evidence to suggest distinct regional subpopulations (Daemen *et al*., 2001; Wirth and Bernatchez, 2001, 2003; Maes and Volckaert, 2002), but more recently Dannewitz *et al*., 2005 described the small variation due to a temporal pattern as opposed to spatial, confirming that eel are a panmictic species. Two complementary studies further highlighted the importance of temporal variation in genetic composition (Maes *et al*., 2006; Pujolar *et al*., 2006). They suggested the following scenario for spatio-temporal genetic structure of the European eel. The protracted asynchronous spawning window of European eels in the Sargasso Sea is induced by differential departure times for the spawning migration and is compounded by differential migrational distances of geographically distinct groups (Tesch, 2003; Kettle and Haines, 2006). Once at the Sargasso Sea, only a subset of the adults spawn successfully and contribute to the next generation by a lottery matching of reproductive activity with oceanic conditions (Pujolar *et al*., 2006). Considering these data, there is now reasonably spread consensus that the stock is indeed panmictic, using the available samples and genetic markers. However, for the European eel, there is no biological material available from the reproductive areas for genetic research. The continental populations constitute mixed feeding aggregations, complicating interpretation of patterns of genetic structure and thus a reliable conclusion about panmixia (Dannewitz *et al*., 2005; Maes *et al*., 2006; Pujolar *et al*., 2006). Future research could focus on the effective population size and potential loss of genetic variability (and thus evolutionary potential). This may have possible implications, for example, if large-scale stocking or translocations occur in the future (Maes and Volckaert, 2007).

In contrast, the continental stock and fisheries are scattered over thousands of river basins in Europe (Dekker, 2000a). Though objectives and targets are set at the level of the EC, management of local stock and fisheries can only be achieved effectively at a regional scale (Dekker, in press). However, the (assumed) panmictic status of the stock has serious consequences for the regional management: restrictions on anthropogenic impacts in a river basin may lead to an increase in the production of silver eels returning to the sea from this river, but will in itself not lead to a substantial increase in the overall escapement of silver eels from the whole continent.

There is no information on what part or parts of the continental stock contribute to the actual spawning population. Hypotheses include: primarily the Baltic production of large females contributes effectively to the spawning stock (Svardson, 1976); the Biscay area is the prime distribution area for recruitment, and therefore likely to make the major contribution to the spawning stock (Dekker, 2000b); the Mediterranean, producing about half the commercial yield at optimal water temperatures, is probably the evolutionary origin of the European eel stock (Dekker, 2003a). In the absence of evidence, a risk-averse strategy to protect the stock must assume that each spatial part of the continental distribution might prove to be essential to the spawning population, and thus should be protected. In the absence of conclusive evidence, a combined effort in all river basins where eels occur is required to recover the stock (see also Section 6.6, discussing the area where protection must be achieved).

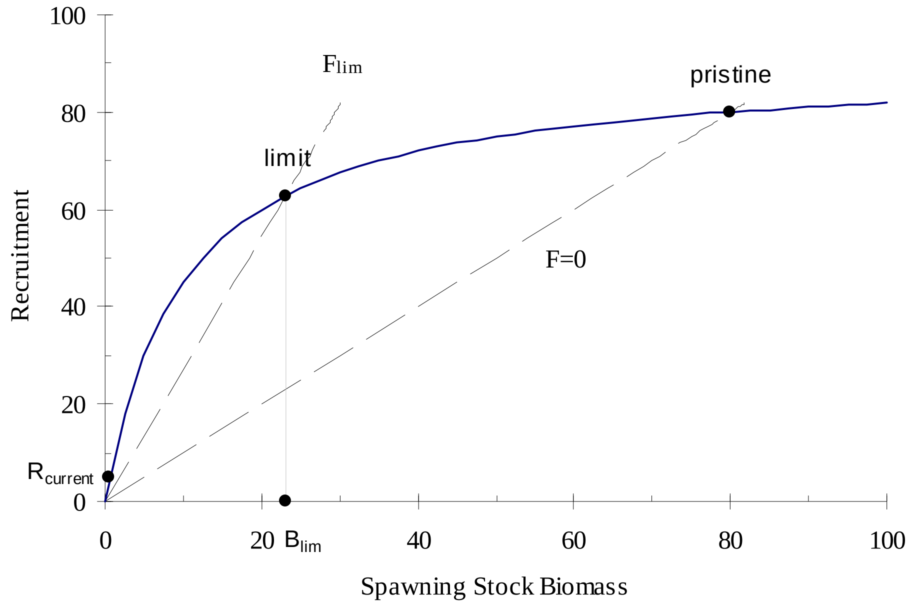

Figure 6.1. Hypothetical stock–recruitment relationship, showing a Beverton–Holt-type relationship. The blue line indicates what recruitment is produced at what spawning stock size; the dashed lines indicate what spawning stock can be derived from a given recruitment, at no fishery (F = 0) or at maximal, just sustainable fishery (F_{lim}).

ICES advice for 2002 was based on considerations of fish-stock dynamics in general. Subsequently, a tentative analysis of eel-specific data on trends in recruitment and stock abundance was presented by Dekker (2004a) and recently updated by Dekker (in prep.); Figure 6.2 presents the updated results; landings have been used as approximate for SSB, which is estimated at approximately 10% of all landings. This tentative analysis gives strong indications of a depensatory relation between SSB and recruitment in eel. Alternatively, other factors, such as adverse oceanic climatic factors (Friedman *et al.*, 2007) might have induced the decline in recruitment. Recent data updates (Dekker, in prep.) fit the depensatory hypothesis well (Figure 6.2), while the mismatch to the oceanographic data increases. In the absence of evidence and a plausible mechanism for an oceanic effect, the prudent assumption is that observed trends were caused by a depensatory stock–recruitment relation (Dekker, in press).

The conventional stock–recruitment relationship of Figure 6.1 assumes that per capita reproduction increases as the spawning stock declines. The net decline of recruitment is the sole effect of the declining spawning stock, which is only partly compensated by the increase in net reproductive rate. In the depensatory case (Figure 6.2), however, the per capita reproduction *decreases* at low spawning stock size. Both the declining number of spawners and the declining reproductive rate then contribute to the sudden collapse of a stock. In the conventional case, any reduction in mortality will restore the stock (though the magnitude of the mortality reduction determines to what extent recovery occurs). In the depensatory case, however, the depletion of the spawning stock leads to a low per capita reproduction, which in itself might prevent a recovery of the stock; this is called the depensation trap. To escape from the depensation trap, the spawning stock must be restored to levels above which the depensation is unlikely to occur. Given the low recruitment, this will be difficult to achieve. ICES (2004) therefore recommended using all possible means to increase the spawning stock, including both restrictions on negative anthropogenic impacts, as well as immediate application of positive impacts, such as stocking. Figure 6.2 indicates that the current spawning-stock biomass might be on the order of 1000 t, while depensation started to occur at 3000 t. A threefold increase would therefore be required.

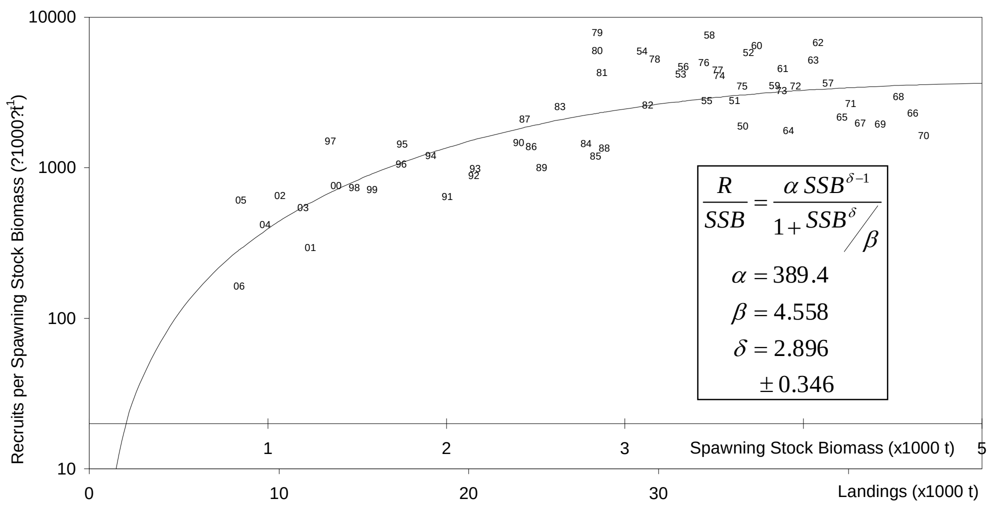

Figure 6.2. Tentative relationship between the effective per capita reproduction rate and the spawning stock size for the European eel, based on the assumption that the trend in landings is indicative of the trend in the spawning stock. Two-digit labels indicate the years of recruitment 1950–2006. (Source: Dekker, 2004; data updates from Dekker, in prep.). Note the logarithmic scale of the vertical axis.

6.3 Density-dependent factors in eel population dynamics

Understanding the density-dependent processes is fundamental to any conservation plan, because it determines the resilience of the stock. Biological processes, such as reproductive success, natural mortality, body growth, silvering processes, upstream migration, and sex ratio might be influenced by individual or biomass density.

For the continental phase, low densities are supposed to lead to a lower natural mortality (Vøllestad and Jonsson, 1986, 1988; de Leo and Gatto, 1996; Bevacqua *et al.*, 2007), reduce upstream dispersal (Lambert and Rochard, 2007), and skew sex ratio in female favour (Rossi *et al.*, 1987; Krueger and Oliveira, 1999; Rosell *et al.*, 2005; Lambert and Rochard, 2007); see WGEEL 2002 report for further details. These processes might aid the population to compensate for environmental changes, but alternatively might well be maladaptive.

Presented below are three examples of possible density-dependent effects, one for Lake Rangsdofer (Figure 6.3), one related to the impact of additional stocking of eel into the Lough Neagh fishery (Figure 6.4; see also Figure 3.1), and for the change in sex ratio and female silver eel size in the Burrishoole catchment (Poole *et al.*, 1990; Figure 6.5).

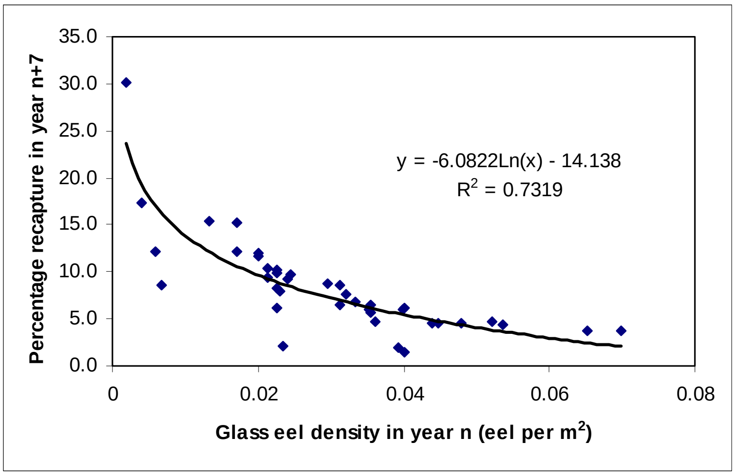

Figure 6.3. Evidence of natural mortality density-dependent. Percentage of eel recaptured in the Lake Rangsdorfer fishery against density of glass eel stocked seven years before. From ICES Working Group 2002.

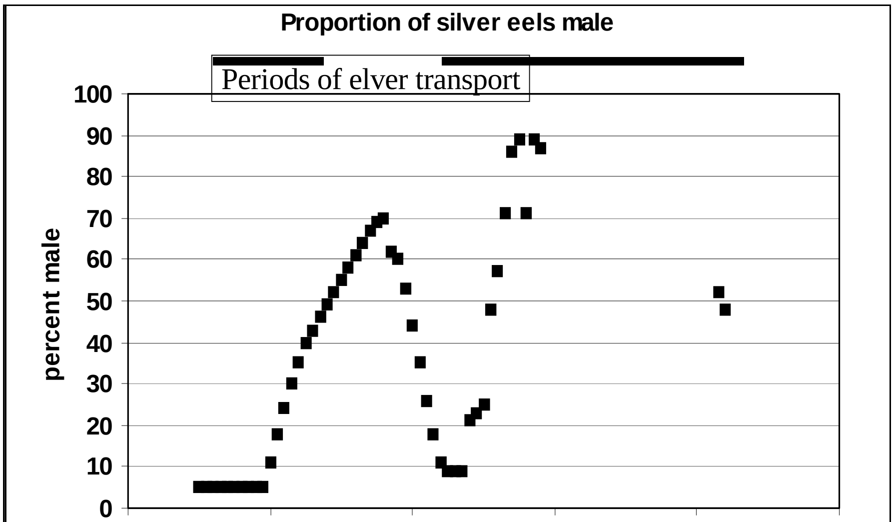

Figure 6.4. Evidence of sex ratio density-dependent. Sex ratio in silver eel catches in Lough Neagh in relation to elver trap and transport operations (solid horizontal bars for periods of active transport). From Rosell *et al.* (2005).

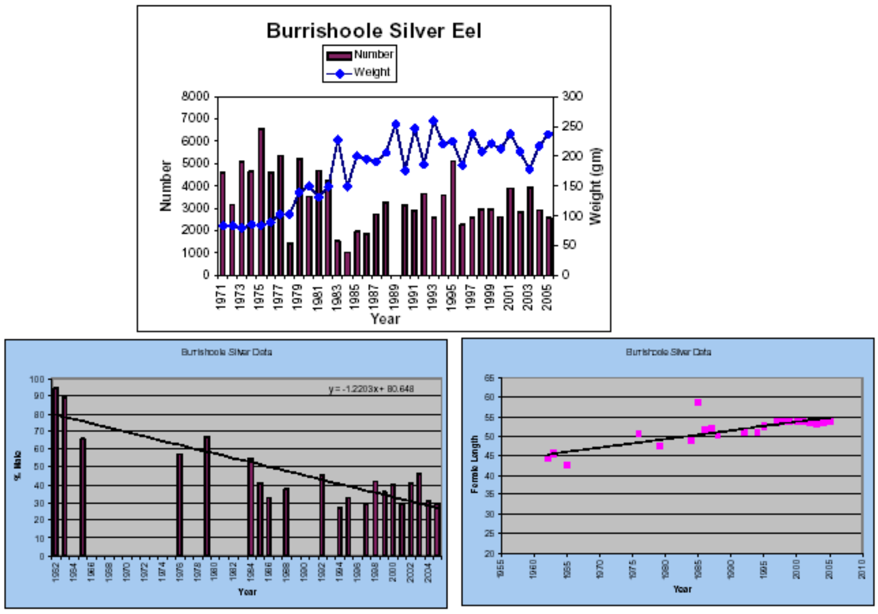

Figure 4. The annual numbers and size of downstream migrating silver eel along with the % males and size of females in the run.

Figure 6.5. Evidence of sex ratio and body growth density-dependent. From Slime report (Burrishoole case study) and Poole *et al.*, (1990).

For the oceanic phase, Dekker (2004a), suggested a depensatory stock–recruitment relationship (Figure 2.6) that is that, for low densities, small spawning–stock decline causes sharp recruitment decline. The reason can be the disruption of social mating processes at low spawning stock densities (Dekker, 2004a), leaving only few spawning aggregations successful in finding a large enough group for social courtship. Recent analyses of spatial and temporal genetic patterns in oceanic recruitment (Maes *et al.*, 2006; Pujolar *et al.*, 2006; Andrello *et al.*, in prep.) indeed shows that reproductive success varies at very short time intervals, which might reflect separate "social events". It must be emphasized that the depensation hypothesis remains valid, even if ocean climate change is included as an additional explanatory variable (Dekker, 2004a), although last years data seem to confirm the depensation hypothesis and not support climate change effects (Dekker, in prep.).

Although the potential existence of density-dependent processes in the continental phase is generally deemed as likely, their unquantified status, at a global scale, make them no argument against precautionary protective measures until possible the relationship among density, food availability, and components of eel life cycle history will be explicitly tested by means of suitable field experiments.

Historically, density-dependence in the continent has been the central argument to justify the intensive fishery on glass eel around the Bay of Biscay (Moriarty and Dekker, 1997), and similarly the impact of exploiting yellows was underestimated and often neglected, assuming strong compensatory density-dependent effects (ICES, 2005). But, while compensatory effects caused by the high densities in the Bay of Biscay were assumed in the past, today they are questioned owing to the low level of recruitment. Figure 6.6 suggests that little or no compensatory effect is acting in the last years in the French Atlantic coast.

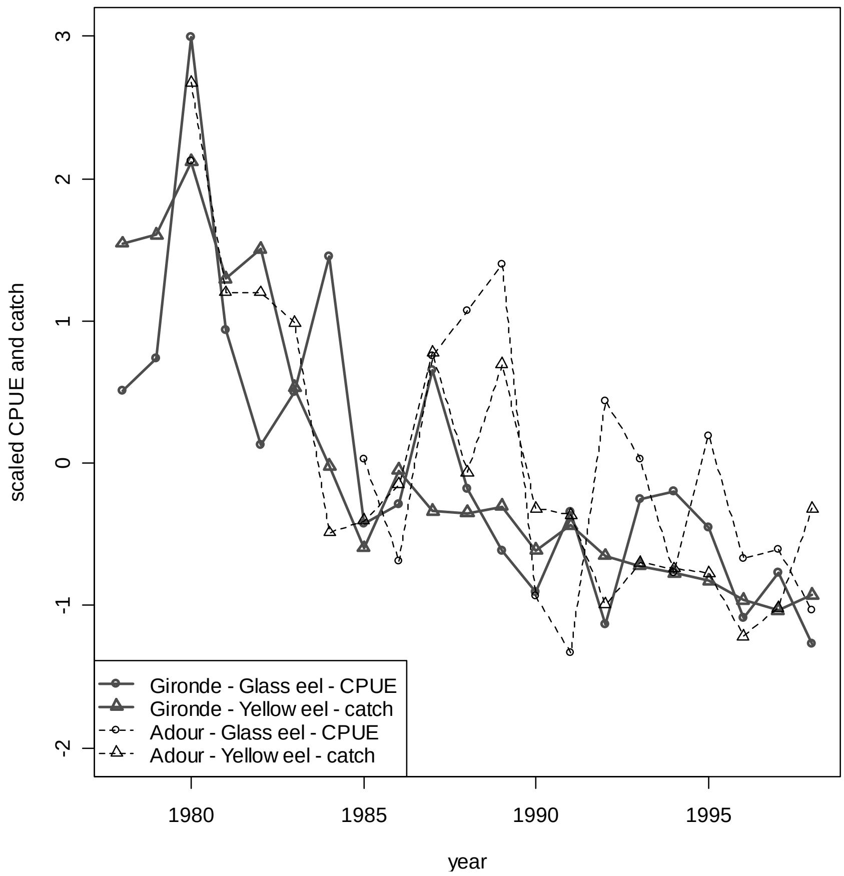

Figure 6.6. Trend of glass eel cpue and catch of yellow eel by the eel pot fishery six year later in two French estuaries (source CEMAGREF, IFREMER).

On the contrary, if today we were facing any compensatory effect, we would expect it to be related to lower densities as suggested by absence of males in the northern population (WG 2007 Sweden; Svardson, 1976) and decreasing upstream migration in inland Atlantic waters (Lasne and Laffaille, 2007).

Quantitative assessment of density-dependence effects is crucial to optimizing the effectiveness of any conservation plan. However, while waiting for more scientific evidence at broader scale, the precautionary approach would suggest consideration of the depensation hypothesis at oceanic level and to disregard compensatory effect at a continental level (Dekker, 2006). Depensation hypothesis at oceanic level implies that protection and recovery of the eel can only be achieved if spawner escapement is restored to pre-1980 levels, which will be difficult to achieve at the current (poor) recruitment level. ICES (2005) therefore considered extensive use of glass eel stocking as a potential means to escape from the depensation trap (Dekker, 2006 AFS). However such a practice will be effective only if final destination sites can provide a larger numbers of spawner per recruitment than the original sites. Today there is no proof that one site is producing more effective spawners per recruitment. Then it would be precautionary to deal with uncertainty and to guarantee, even through, stocking a minimum level of spawners from each natural eel habitat. A post-evaluation programme could assess juvenile mortality dependence on individual density and looking for carrying capacity of each system. Although it is widely accepted that sex ratio is somehow linked to density, the quantitative relationship is not known enough, and the consequences of a skewed sex ratio on the population dynamics are poorly known. If on one hand one could argue that more large females guarantee more eggs and thus more recruitment, on the other hand data said that, in the "old good times", sex ratio was skewed in male favour, and natural recruitment was abundant all over the natural distribution area. The population dynamics consequences of marked sexual dimorphism and a highly variable sex ratio need to be further investigated to assess the effectiveness of any conservation plan.

6.4 Time schedules

In perspective of the very long period of consistent decline in eel recruitment that has been observed, an analysis of possible recovery times in response to mortality reductions is about to be published (Åström and Dekker, 2007); the first attempt of this work was presented as Annex 2 in ICES (2006). The need of mortality reduction was quantified, indicating that no long-term recovery can be expected if fishery mortality is kept above 15% of current level. This breakpoint for recovery corresponds to around 60% of currently achievable spawner escapement (60% SPR); see ICES 2006 WGEEL Report.

Figure 6.7 (from Åström and Dekker, 2007) gives a broader picture of the relation between time until full recruitment recovery and proportional fishery mortality rate still allowed after fishery reductions (multiplying the x-scale by $F = 0.54$). It is evident that even if the fishery is completely closed, recruitment is anticipated to recover fully first after about 80 years. Retaining any fishery rapidly increases the recovery time, finally approaching infinity as 15% of the current fishery pressure is retained. Parameter values regarding the fishery pressure and lifespan represent an approximate average of the whole European eel population (mostly derived from Dekker, 2000a).

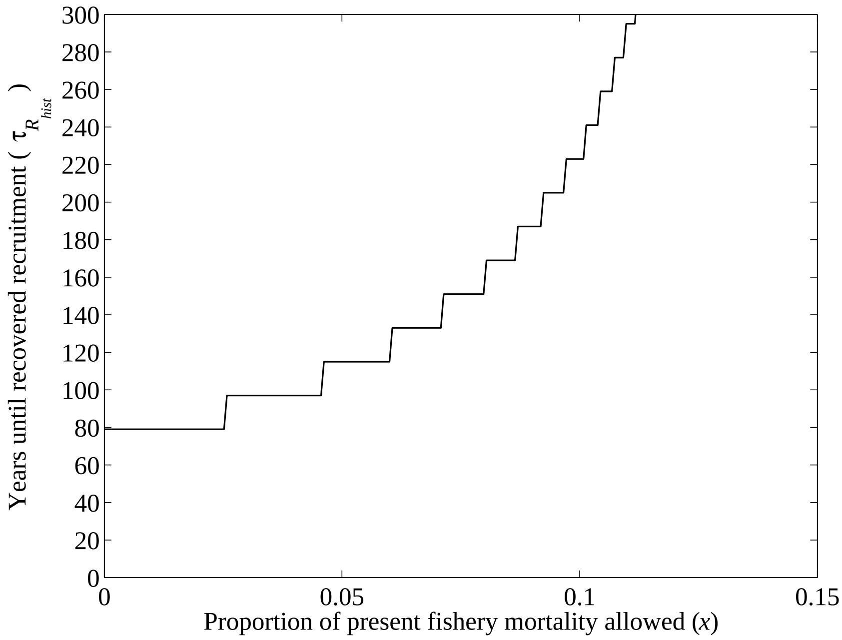

Figure 6.7. The time required for full recruitment recovery at the population level as a consequence of the proportion of current fishing mortality still in practice after fishery reductions. Parameter values used represent an approximate average for the fishery pressures and lifespan of the whole eel population (mainly from Dekker, 2000a). From Åström and Dekker (2007).

In order to broaden the perspective and take into account the possibility that the actual spawning population might mainly be originating in only part of the continental distribution area, rough and tentative analyses were carried out during the working group meeting in Bordeaux, France. Two scenarios were created (Figures 6.8 and 6.9), one approximating lifespans and exploitation patterns as if the northern part of the continental eel population were the main contributors to the spawning, and one scenario where the southern part of the continental population dominated the spawning. The two different scenarios where parameterized either retaining the total lifetime fishery pressure for northern conditions and southern conditions respectively as estimated by Dekker (2000a), or using the annual mortality rates from the same source. The respective time spans for the total lifespan and the exploitation time span were 20 and 10 years for the northern conditions and 3 and 1.5 years when resembling southern conditions, thereby trying to illustrate the possible extremes, between which the actual population contributing to spawning would likely be.

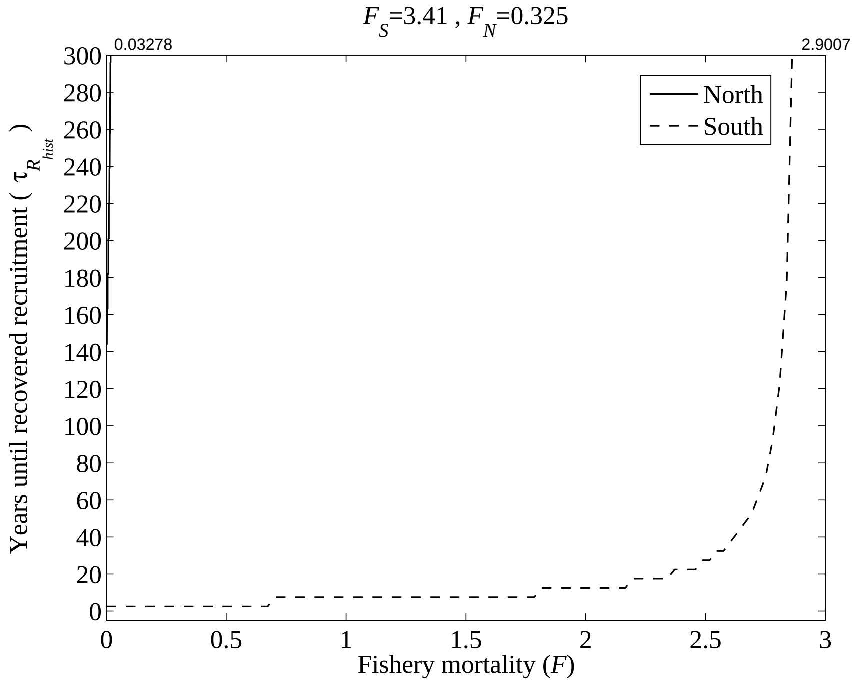

Figure 6.8. Time required for full recruitment recovery as a function of the instantaneous rate of fishery mortality (*F*). Fishing mortality was parameterized to retain lifetime fishery pressure as estimated by Dekker (2000a). Note the solid line in the upper left corner for the northern scenario. See text for an explanation of the two scenarios shown.

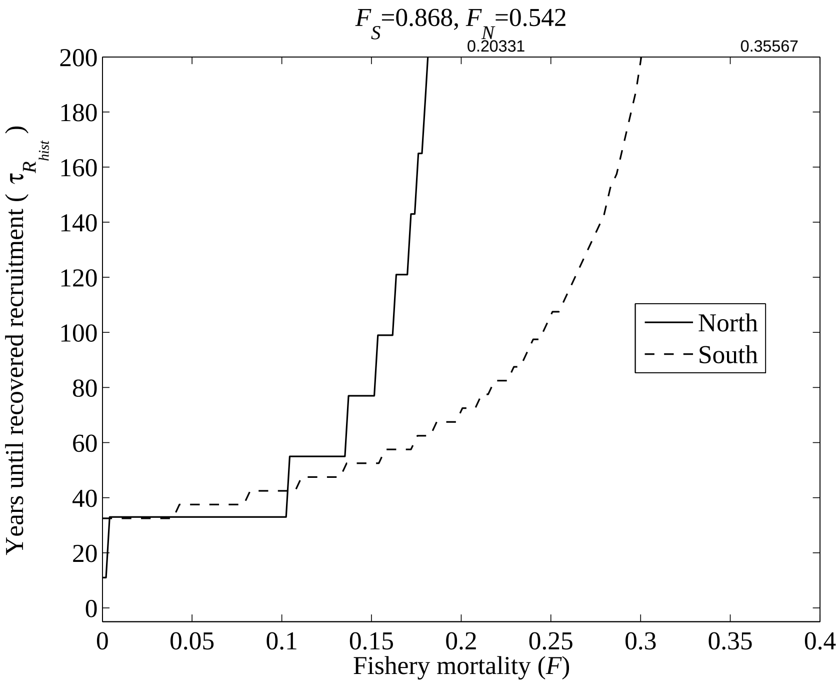

Figure 6.9. Time required for full recruitment recovery as a function of the instantaneous rate of fishery mortality (*F*). Fishing mortality was parameterized to retain annaul fishery pressure as estimated by Dekker (2000). Note the solid line in the upper left corner for the northern scenario. See text for an explanation of the two scenarios shown.

The broadening of these analyses emphasizes the sensitivity to the parameter values. Being unable to tell whether instantaneous rate of fishery mortality (*F*) has to be kept below 2.9 or 0.03 (which are the two most extreme results shown here) in order to safeguard long-term recruitment, the only option remaining is to apply the precautionary principle and recommend complete closure of all fisheries. Because this alone might not suffice, reductions of other anthropogenic factors will be required.

Åström and Dekker (2007) also numerically calculated the possible development of the recruitment over time after restricting fishery. Figure 6.10 illustrates the anticipated recruitment for two different levels of fishery restrictions; complete fishery closure and reducing the fishery by 85%, the latter representing the breakpoint between long-term recovery and continued long-term decline. Three years after restrictions were applied, the two lines hardly differ at all. The recruitment has increased from 0.025 to 0.047 and 0.040, respectively. The possibility to differentiate between the recruitment increase representing long-term recovery and the one representing failure is of course impossible. It is unlikely that such small increases can be detected at all considering the normal variability of such type of data. Note that the wavelike pattern in Figure 6.10. is largely the result of simplifying assumptions in the model. Nevertheless, the clear answer whether or not long-term recovery will be reached cannot be determined until more than one eel generation time has passed.

Given the very long time-scale of recovery, and the small recruitment increases anticipated, other measurements need to be gathered (covered in depth elsewhere; see Section 6.7.3) to be able to judge whether sufficient measures have been taken. Such measurements then have to be compared with short-term goals, ensuring the effectiveness of the management. Preferably measuring and comparing with short-term goals should be combined with fast adjustments of the management measures in order to speed and ensure recovery, i.e. the use of adaptive management should be considered.

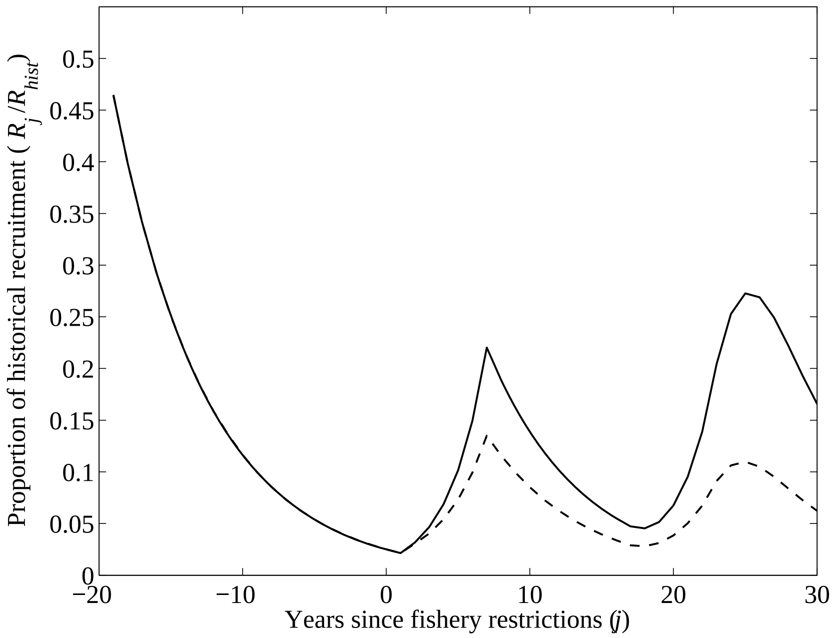

Figure 6.10. Expected recruitment (expressed as a proportion of historical recruitment) after a complete fishery closure at *j* = 0 (solid line) or only restricting fishery to the breakpoint (15% of current fishery pressure), where no long-term recovery occur (dashed line). Modified from Åström and Dekker (2007).

6.5 Data rich poor extrapolation

The patchy distribution of the eel population makes it practically impossible to sample all water bodies where a fishery occurs (Dekker, 2007). Similarly, it is impossible to conduct an analysis of the level of mortality occurring in the turbines of all dams in Europe. However, as in the previous paragraphs, the need for assessing the level of anthropogenic mortality using a short-term target has arisen, and it will be necessary to get an idea of the level of anthropogenic pressure occurring at every site in Europe. For this reason, the development of proximate criteria derived from the analysis of data rich places is urgently needed.

As the management plans will have to be delivered within 16 month, in the coming six month there is an urgent need to set up a concerted action whose task will be to derive proximate criteria for anthropogenic mortality. The idea is to relate the level of mortality measured in the largest possible set of data with a wide gamut of characteristics that could be collected locally.

Several examples can be provided:

- Fykenet fishing mortalities at multiple sites will be related with gear characteristics, number of gears per ha, and factors characterizing the productivity of the hydro-systems using regression methods. To widen the dataset, the total level of mortality will be derived from size structures (Lambert *et al.*, 2007).
- Glass eel mortalities can be analysed using the filtration rate and compared using the same model as in the Gironde and the Vilaine estuaries. The filtration rates at various rates will be used as a proxy for fishing pressure (Beaulaton and Briand, 2007).
- Mortality measured at dams can be assessed using models built for salmons, and relating the level of mortality nominal discharge, height, wheel diameter, number of blades, rotation speed.

The quicker this project is set up, the earlier results can be used by Member States to establish management plans.

6.6 Spatial coverage and transboundary management

In the workshop on including eel into the EU-DCR (Dekker, 2005), the spatial coverage of sampling the eel landings all over Europe was addressed. For this purpose, the exemption criteria for biological sampling were estimated to be inappropriate with regard to eel. Therefore, it was suggested to include under the DCR all countries (sorted by size of their landings with respect to weight or numbers) that contribute to 95% of all reported landings in order to get a better spatial representation of catches. It was concluded that the exemption rule for sampling should be applied to a sum of all European (reported and estimates of unreported) landings, which would increase the number of countries where data sampling under the DCR will be required at the actual status from 8 to 11.

This paragraph raises the question of how many Member States will have not only to prepare but to carry out an eel management plan to achieve a sufficient spatial coverage of the European eel stock (in order to reach an effective level of management measures for the recovery of the European eel stock as a whole). Following the line of thinking from the workshop on DCR, it is concluded that the same rule should be followed as well. Whether this should be the 95% limit or any other percentage should be considered and decided.

But in addition to the DCR dealing with landings, this rule should apply to a best estimate available of the potential contribution of individual Member States to the (pristine) European eel stock. This implies that all countries should contribute to the initial estimation of the total pristine stock. This is to avoid neglecting those countries where the former stock is already highly depleted or where data on landings are very incomplete. After submission of the relevant data, an assessment and the cumulative distribution of the European eel stock (by weight as well as numbers) for all Member States within the historical range of eel could be calculated in order to draw the line of cumulative distribution (see Figures 6.11 and 6.12 with the cumulative distribution of landings by weight as well as numbers for comparison). The European eel stock can be managed even if the range of the pristine eel stock will not be recovered to 100% (see Section 2.3 for the information on the eel population in the Black Sea).

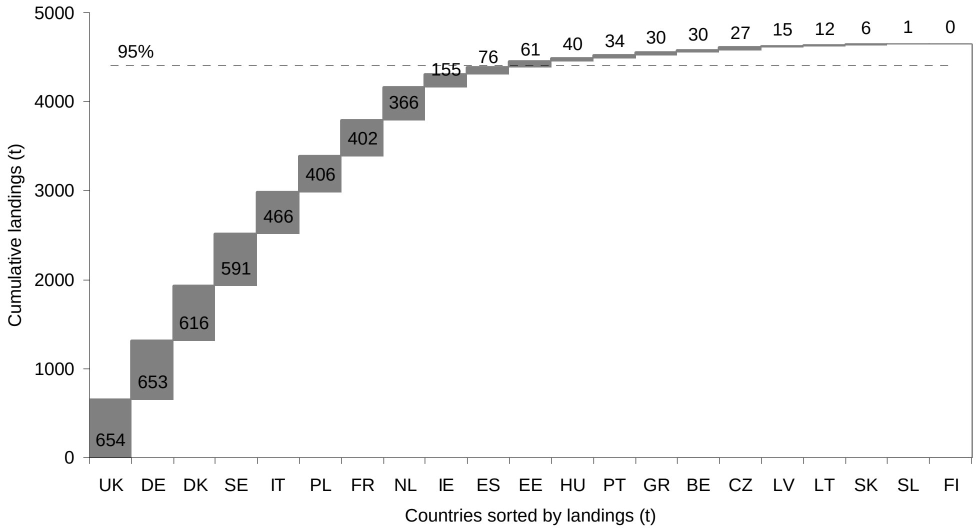

Figure 6.11. Cumulative distribution of eel landings by country, in weight, all life stages combined. Yellow and silver eel catches dominate these results. Source: Sanga Saby Report, 2005. For several countries, coverage is still incomplete.

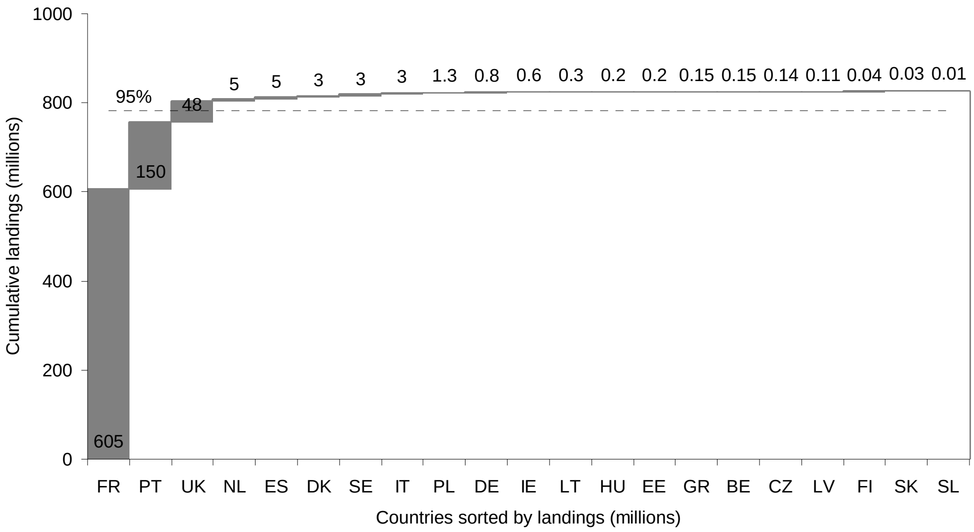

Figure 6.12. Cumulative distribution of eel landings by country, in numbers, all life stages combined. Glass eel catches dominate these results. Source: Sanga Saby Report 2005. For several countries, coverage is still incomplete.

6.7 Transboundary coordination especially in Community waters

According to the regulation each member state operating an eel fishery in Community waters has to reduce its fishing effort at least to 50% (relative to the average effort from 2004–2006) or to ensure a reduction of eel catches at least of 50% (relative to average catch 2004–2006). But the extent of reduction of eel fishery in community waters has taken into account the management efforts in adjacent river basin districts where spawner escapement has to achieve 40% in the long term. Reaching this target may be compromised by catches of silver eels leaving the river basin and migrating through Community waters. This implicates a further coordination effort between eel management in RBD's and the regulation in related Community waters. The same need of coordination is expected to take place where member states first draw a management plan for the national territory of an international river basin. While achieving a certain target of spawner escapement inscribed in the management plan, a silver eel fishery and other anthropogenic mortalities take place in the downstream area of the same basin being part of the territory of a another member state or a state outside EU.

6.8 Assessment procedures

The terms of reference given to the 2007 group include to "review available methodology for assessment of the status of the eel population, the impact of fisheries and other anthropogenic impacts and of implemented management measures (that is: results of FP6 project Slime Dekker *et al.*, 2006), and consider options for stock assessment at the population level".

6.8.1 Assessment of the status of the eel population

6.8.1.1 Assessment of eel escapement at the global scale

Lack in spatial coverage of the monitoring, difficulty to understand some processes (dispersal, sex determinism, juvenile mortality) currently jeopardize attempts to run a full assessment of the stock. The present estimate at the European scale is mainly based on analysis of European catches (Dekker *et al.*, 2000) or on the knowledge of the trend in recruitment and an average of the life-history traits for eel (Åström and Dekker, 2007). Precise evaluation in some data rich system is available, and more are expected to be in the coming years.

Therefore the calibration of the first measures in the management plan will have to be based on the rough idea of the Fpa. Evaluation of mortality in data poor contexts will be done by extrapolation from data rich systems using the methodology that will be proposed in Concerted Action.

Article 9.1 of the E. U. requires tri-annual reports per Member state on the status of the stock, the impact of fishing and other anthropogenic mortalities, and the progress towards the management target. Since this assessment will only be required by 2012, this topic might be postponed for some time, though in-between monitoring and research will have to be tuned to the global assessment needs. By that time, a full evaluation of the status of the eel stock will be required.

6.8.1.2 Population assessment at the local scale

The SLIME project was initiated to collate separate initiatives developing eel modelling tools, to apply these tools to real data and to compare and contrast approaches and results. Most of these models were initiated in recent years in response to the scientific advice to protect and restore the stock on a catchment basis. But none of the models presented in SLIME is currently used in support of actual management actions and further development (in particular validation of the current models and understanding of the basic biological processes) will be required.

The Regulation explicitly lists three options to determine the target level of escapement for each river basin (a.) use of locally historical collected data. (b) assessment of potential production based on habitat (c) comparison to other, similar systems.

An other approach is to define process-based models or statistical models that estimate present production of silver eel and extrapolate the target level by simulating with historical recruitment and without any anthropogenic impact. This approach was adopted by Åström and Dekker (2007) in their simulation model of eel stock recovery or by LePrevost (2007) in her first evaluation of habitat productivity in Brittany rivers.

In the near future, stock assessment methods should be based less on hypotheses concerning biological processes and more on numerous data from the monitoring in order to focus on stock status evaluation rather than improvement of eel ecology and knowledge of local population estimates. Although where data are rare or unavailable, a combination of both approaches will be required.

6.8.2 Assessment of the effect of implemented management measures on the local population

The principle of this assessment is to measure the direct output of the process targeted by the management measure. For instance, monitoring the elver stock will help assessing management measures for glass eels. But the benefit expected from a management measures (such as in Figure 6.13), might in many cases be too low to be detected in the short term.

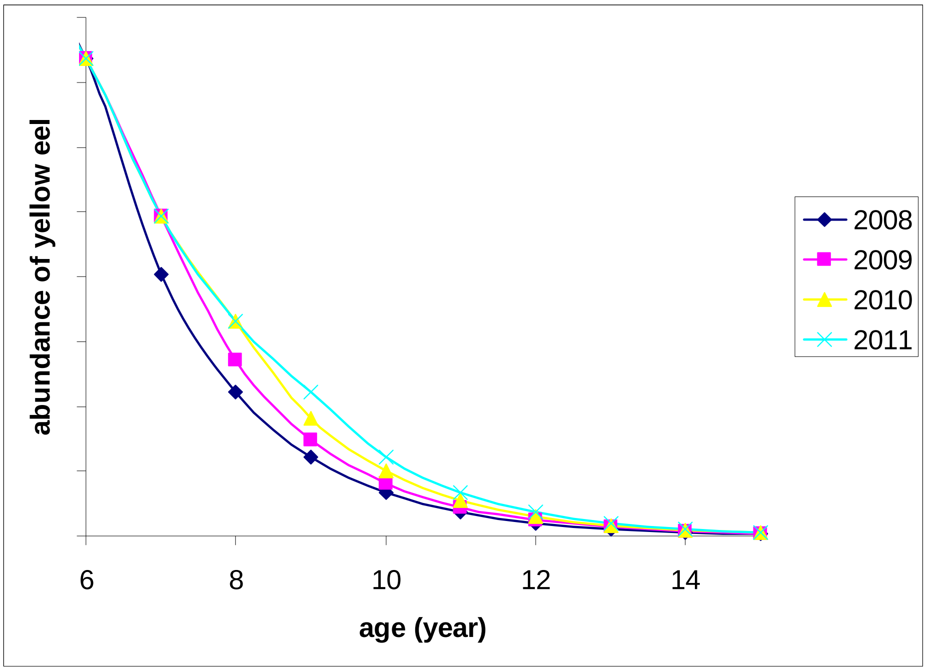

Figure 6.13. Yellow eel age structures from 2008 to 2011 with a reduction of anthropogenic mortality in 2009 (natural mortality is constant to 0.14, and anthropegic mortality affecting eel older the 7 years decreases from 0.40 to 0.20 in 2008 and remains thereafter).

6.8.3 Need for intermediate and proximate criteria

The recovery of the stock will last several decades (Åström and Dekker, 2007). This time schedule is too long compared with the expectations and lifetime of local managers. Therefore reference variables and values must be calculated to judge in the short term whether a local stock is under sustainable management and the Eel Management Plan is adequate. The choice of these reference variables will have to be made cautiously since they will provide the momentum for the initial steps of local management. It will not be possible to achieve this risky task before the end of 2008 but these reference variables should be provided, if available, for the second reporting of EMPs.

6.8.4 Monitoring guidelines

Cleary, the assessment of effective recovery of the stock only will be possible if present recruitment time-series are continued since the goal is the restoration of recruitment to its full level. Fishery-independent monitoring should also be developed to guaranty continuity in the assessment process.

At the local scale, monitoring of yellow and silver eel should also be continued and enhanced.

6.8.5 Stocking assessment

The effect of stocking on the eel population, including up to silver eel escapement, will have to be tracked in the assessment procedure. There is no conceptual possibility to integrate stocking so long as the assessment is separated geographically (at least the donor and destination catchments). Probably specific life-history traits (mortality, migration ability, growth) should be specified in order to increase the reliability of the evaluation.

6.9 Conclusions and recommendations on concepts, methodologies and research needs

This chapter has provided a conceptual overview of the restoration process, has identified fundamental lacks in our knowledge, and has sketched the steps that will be required in implementing the EU Regulation.

Based upon the information presented, the following recommendations are provided:

The EU Regulation for the eel aims primarily at the restoration of the spawning stock, leading to a recovery of recruitment. It is therefore of utmost importance, that existing recruitment monitoring is continued, improved (e.g. releasing the dependence on commercial fisheries), and extended where inadequate.

An assessment of the current state of the stock, including an assessment of the impact of anthropogenic mortalities, is urgently needed. In most river basins, this assessment will not be achievable from available data, while for some rivers, adequate datasets exist. It is therefore proposed, to initiate concerted research as soon as possible, to compile datasets, to develop regression models of the relation between the impacts and widely available data, in order to inter/extrapolate to the data poor situations.

Following the compilation and implementation of Eel Management Plans in 2009, the first post-evaluation of the EU Regulation is foreseen at the end of 2012. Timely development of assessment procedures is required, geared to the data becoming available, while indicating the progress towards recovery of the stock.

Though density-dependence has been demonstrated in several life stages by means of various mechanisms, it is not well understood, and knowledge is certainly inadequate to predict where it will occur. This affects both the calculation of restoration targets, and the assessment of the impact of fisheries and other anthropogenic factors. Fundamental research will be required.

7 Sampling methodologies

7.1 Introduction

The draft EU Eel Recovery Plan Regulation requires for each Eel Management Plan a description of the extant eel population, as a first step to assessing the status of the population relative to the historical reference status (see Chapter 6).

Further, the EMP should provide a description of the eel-producing habitat, and a quantification of the impacts of anthropogenic (mortality) factors on the population, to inform and guide the selection of management measures intended to increase the escapement of silver eels. This chapter considers the sampling methods available to provide the data for these population status and management action assessments.

This chapter draws on information from the EU INDICANG programme, previous working group reports, published scientific literature and the knowledge of the working group members. We have considered a pragmatic approach given that there are 18 months left to develop the EMPs, but also that these and other/additional methods will be used later as the further improvement of EMPs and the post-evaluation of the effectiveness of the management measures, as required by the Regulation.

The chapter concludes with recommendations for the use of particular methods for various eel stage and habitat type combinations, the standardization of methodological approaches where appropriate, and identifies areas of further research and development, or future technical support, required to inform this topic.

The methods used to analyse the data collected using these methods, and the assessment of population status, are considered in Chapter 6.

7.2 Methods to describe the current local eel population

7.2.1 Introduction, main objectives

For the description of an eel population, several basic aspects need to be considered during the development of the sampling strategy. An eel population consists of several life stages with very different characteristics (glass eel, elver, yellow, and silver eel). Eel use a broad range of different habitats (marine, coastal, fresh-water; lakes, rivers, streams, channels). They can be sampled with different types of fishing gears, which differ in suitability for sampling purposes depending on life stage and habitat. There are also seasonal aspects, which need to be taken into consideration.

It is necessary to determine, which parameters are needed to describe the population or to describe some special characteristics of the population (e.g. silver eel escapement). This may include e.g. densities, growth rates, sex ratio, proportion of silver eel or data on eel quality (condition, lipid content, contaminants, diseases and parasites). A clear identification of the parameters is crucial, because this will determine the sampling strategy. It has to be noted that the selection of the parameters can differ between catchments according to the conditions and the availability of data in the respective waters.

If the parameters have been identified, the sampling strategy has to be developed. *(It will be very useful to check, which data are already available for a system.)* The entire strategy may contain monitoring but also special studies e.g. to develop indicators.

According to the EU Council Regulation, the main goal of the EMPs is to guarantee an escapement rate of silver eels of 40% compared with a situation without anthropogenic impacts. Consequently, the reference level as well as the present situation should be assessed with priority based on available direct measurements of escapement. The direct measurement or determination of escapement rates is thus one approach to meet the requirements of the Council Regulation. However, such data may only be available for a limited number of river basins. Consequently, as a second basic approach, escapement may be estimated based on population parameters of the yellow eel stock in the respective catchment.

There are several aspects, which need to be addressed for the choice of one of the two approaches. It might be difficult to measure escapement directly in large estuaries. On one hand, measuring of escapement in the lowest reaches or estuaries of whole river basin districts would reduce the number of sampling stations considerably. On the other hand, this approach would not provide any information on mortality factors in the river systems and consequently would not allow the determination of the management measures that will bring the highest effect on escapement. This limitation of the approach could, however, be compensated for by studies on special mortality factors in the river system (e.g. hydropower mortality, studies on mortality caused by predators, etc).

If the escapement rates shall be determined based on parameters of the yellow eel stock, this will presumably require an assessment of the eel stocks in many waters (in particular if the natural conditions and anthropogenic impacts are heterogeneous) and hence, a very high sampling effort. Models or indices need to be developed, which relate characteristics of the yellow eel stock to silver eel escapement. If there is no direct estimation or index for silver eel escapement, the parameters of the yellow eel stock will have to be analysed with a rather high spatial resolution continuously. For this approach, it will also be necessary to update the effect of all relevant mortality factors continuously.

Since conditions may differ strongly between countries and river basins, no recommendation of one of the approaches is possible at the moment. However, the responsible decision makers in the countries or river basins have to consider these aspects in there choice of an approach for each river basin district.

INDICANG (Annex 5) was the first network with participants spreading from Cornwall in the UK to Northern Portugal. Its aim was to obtain a synoptic view of the status of the species by setting up an information and action network. The project tried demonstrate to the European Community and decision makers at all levels through examples, that the eel remains part of our social, economic and biological heritage. It also tried to explain the need to start a policy to restore habitats as soon as possible. Without this policy the species is potentially doomed to extinction. The recruitment levels of European eel along the Atlantic coast decreased 15 to 20 times since 70s. Considering that local/regional plans for restoration have to take account many factors like water quality, habitat access, direct mortality and several participants, the main objectives of INDICANG project were to register the wide heterogeneity of the available data, in quality and quantity, and of the technical tools to achieve initial diagnosis and monitoring; to transfer the available technical and scientific knowledge concerning the different biological stages; to forecast the duration of the restoration process; to present the different resource management objectives within a catchment, leading to appropriate indicators built with a collection of particular descriptors; to inform about some of these indicators (Table 7.1).

Useful descriptors and indicators (Table 7.1) for a local plan have to specify the main natural characteristics of the catchment area, to identify the human pressures, to monitor their temporal and spatial evolution and to evaluate the impact of the various pressures on the dynamics local eel population. One the most important phase of the project was to publish different methodological guides with the objective to produce scientific and technical basis to estimate, from the descriptors chosen by the project, the relevant indicators to follow and evaluate the status of the eel resources and its environment.

Table 7.1. Summary of results from INDICANG programme to consider practical indicators of eel populations across continental life stages and the variety of gross habitat categories found from estuary to fresh-water source.

	Absolute quantifications (flux and production)	Point abundant indices (relative evolution)
Total recruitment of the river basin (glass eels in tidal area)	Quantification of the glass eel flux	Catch per unit of effort (if fisheries exist)
Fluvial recruitment (elvers and young yellow eels)	Counting if a dam near the tidal is equipped with a specific ladder	Counting on dams more upstream Front of colonization (<15 cm and 15–30 cm)
Growing stage (yellow eels)		Catch per unit of effort (if fishery or permanent electrofishing networks) Observations of the size structure and of the sex-ratios
Silvering and downstream migration	Flux quantification by: Trapping (small catchments) Marking-recapture methods (if several fisheries along the main axis) Electronic fish counters	Links with the observations about the yellow eels

7.2.2 Methods to sample glass eel and elver

At present monitoring of true glass eel at sea or close to the sea is performed by eight European countries (Figure 7.2). Abundance indices are also derived from commercial landings in three countries bordering the Bay of Biscay. In most countries the methods used has a long history with time-series updated annually within the EIFAC/ICES WG on eel. As the primary objective is to follow up long-term changes on a relative basis, the type of method chosen was not important as long as it is representative. Most methods are described and discussed in Dekker (2002) and given the potential for changes in the future these should be reviewed and improved.

Recruitment in upstream rivers from primary target areas for glass eel settlement in estuaries and lagoons is one of them and gives information on overall trends in recruitment to upstream parts of the catchment. It could also provide information on total densities of recruits upstream. Trapping ascending young eels in fish passes is the most common method and long time-series exist from Denmark and Sweden.

As the results of a local EMP will depend of all other EMPs in the total area of distribution, the value of primary glass eel recruitment indices is more general than local. In a long-term perspective though, a local recruitment index could, in theory, be related to the potential silver eel production of a specific catchment.

At present most indices of recruitment indices are based on human activities as construction of dams, fishing or industrial activities. This puts consistency at risk! Dams may be removed, fishing stopped or industries may close. This situation urges for alternative and independent methods to quantify recruitment. Drop traps were successfully used in Sweden (Westerberg *et al*., 1993) and in Australia, habitat traps efficiently caught glass eel (*A. australis and A. reinhardtii*) (Silberschneider, 2005). A more thorough review is recommended.

Table 7.2. Methods used in glass eel and elver recruitment monitoring, as reported to joint EIFAC/ICES WGEEL 2007.

	Fishery-dependent methods		Fishery-independent methods				
Country	Marketing stats	Catch stats	Stow nets (in tidal areas)	Scientific trawling	Lift netting (at sluices)	Fixed nets at nuclear power station	Fish ladder counting
BE					Y		Y
D							Y
DK							Y
F		Y		Y			Y
IT			Y				
IR							Y
LV							
N							
NL					Y		
PL							
PT		Y	Y				
SE				Y		Y	Y
SP	Y	Y		Y			Y
UK	Y	Y					

7.2.3 Methods to sample yellow eel

Measuring relative or absolute densities of yellow eel within catchment gradients will most probably play an important part in future eel management. The main objectives are to describe the actual status of stock and how it changes over time and to provide data for modelling silver eel escapement. To meet the demands of both objectives the information obtained from any method should be representative for the entire catchment area. The relative potential for different parts of a catchment for silver eel production is normally not known. This speaks in favour of monitoring all parts of the gradient from estuaries upriver to the most remote habitats. The outcome of the INDICANG project will probably provide practical and conceptual input for the future design of monitoring methods aiming at yellow eel stock characteristics.

The methods for sampling of yellow eel stocks should have a low degree of size selectivity and the season should be identified when catchability for the whole population is optimal. Few or no methods for fish capture meet the objective of no selectivity. Four different methods for measuring yellow eel density were reported in the country reports to EIFAC/ICES WGEEL in 2007 (Figure 7.5).

Electrofishing is used in many countries. This method is probably the best available technique in shallow fresh water in smaller lakes and streams. To guarantee validity of results, the number of sampling stations must be sufficient. According to DIN/EN 14011: 2003 (CEN/DIN Standard Water-Quality Sampling of Fish with Electricity), it depends on spatial variation between sampling stations. This is expressed as variation coefficient *CV* (= standard deviation between sampling stations / mean of population) for abundance (number per sampling station). For comparisons between populations, Table 7.3 gives the minimum number of sampling stations (n) for different values of *CV*.

The sampling stations themselves must be representative for habitats in the river basin body and a minimum size or length of the sampling stations is required (Table 7.4; DIN/EN 14011: 2003).

Table 7.3. Minimum number of sampling stations (DIN / EN 14011: 2003).

VARIATION COEFFICIENT (CV)	MINIMUM NUMBER OF SAMPLING STATIONS REQUIRED
0.2	3
0.4	4
0.6	9
0.8	16

Table 7.4: Minimum sizes of sampling stations in relation to size of the water body.

SIZE OF WATER BODY	MINIMUM LENGTH OF SAMPLING STATION/AREA
Small stream, width <5 m	20 m
Small river, width 5–15 m	50 m
Large river, channel, width >15 m	>50 m, bank of one or on both sides of river
Large areas of shallow water, depth <70 cm	200 m²
Large water bodies (e. g. lakes)	>50 m of littoral area

For physical reasons, electrofishing cannot be applied in brackish or marine water bodies. Therefore, to cover all parts of the area of distribution electrofishing will have to be combined with other methods. The sampling design and type of electrical current used might have to be adapted to eel as a target species and the possibility of an international standard should be considered (if it one doesn't already exist). Figure 7.1 shows that the density of eel assessed, at the same site, was substantially lower when all species were targeted as opposed to when only eel was the target species. In fact what appears to be the case is that there is an upper limit of eel recorded at a site irrespective of the actual density of eel.

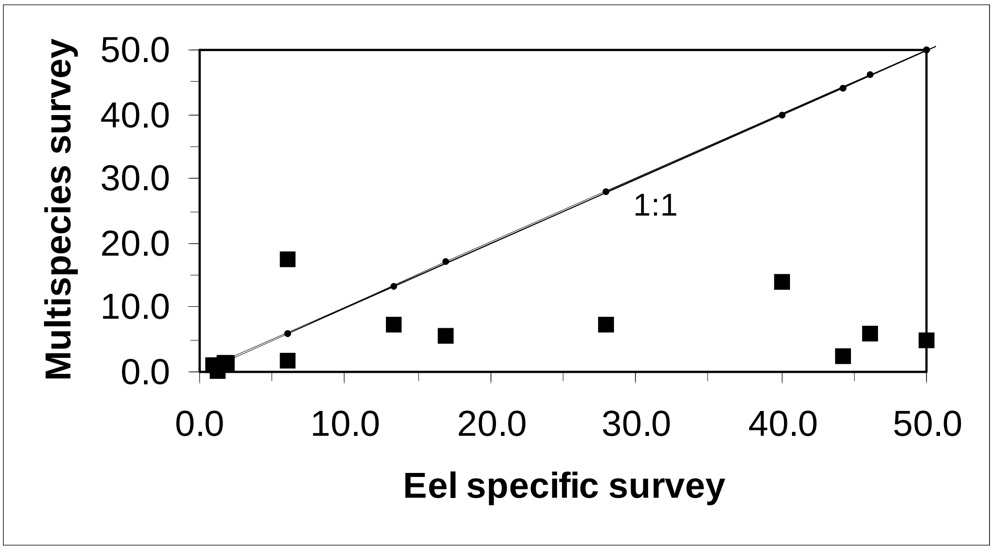

Figure 7.1. Comparison of eel density (# 100 m–2) in multispecies surveys and in eel specific surveys (Knights *et al.*, 2000).

7.2.3.1 Shallow, flowing waters

The cryptic behaviour of eels during daylight, especially by smaller eels, means that 3 or even 4 pass electric fishing surveys may be required to effectively sample the population, as evidenced by decreasing modal length of successive catches reported by Aprahamian (1986). However, other studies have reported high capture efficiencies after 2 or even 1 pass (Glova *et al.*, 2001). Furthermore, variability in capture efficiency between sweeps often leads to greater catch numbers in subsequent sweeps, thereby making the data unsuitable for population estimates based on depletion methods (e.g. Carle and Strub, 1978).

By contrast, the Point Abundance Sampling by Electrofishing (PASE) technique (Nelva *et al*., 1979 cited by Lafaille *et al*., 2005), based on 30s sampling of 1 m^2 areas is a much quicker and therefore cheaper sampling method than standard sweep electric fishing. Given that time and resource limits will inevitably constrain the available sampling effort, this may be a useful alternative to multi-pass electrofishing. Lafaille *et al*. (2005) showed that the PASE method provided similar estimates of eel population density and size structure when compared with a 2-pass depletion method across 35 * 120 m^2 sections of tributaries of the Vilaine River, France, though the survey sites chosen by Lafaille *et al*. (2005) were from relatively small (mean width 3.7 m), shallow (mean depth 0.26 m) and slow-flowing streams. The suitability and applicability of this method to larger rivers remains to be tested.

In a model used to explain variations in eel densities according to habitat factors and the method used to fish, the ratio between values expected for two different methods was calculated (Briand, *unpublished results*). The difference fishing on foot and by boat was 1.9. The ratio between two-pass electrofishing aimed at catching eel where the anode must remain at 30 s at each point (Briand *et al*., 2005) and standard two pass electrofishing was 11.8. However, the electrofishing stations used with the eel method were also a habitat favourable for eel, and this might explain at least part of the difference.

7.2.3.2 Deeper waters (e.g. lakes, canals, rivers, estuaries)

Fykenet surveys are reported from Belgium, Ireland, the Netherlands and Sweden. In Ireland, fykenets are sometimes used in combination with baited longlines. In Sweden test fishing with small fykenets is practised within national and local environmental monitoring since the late 1970-ties, providing the only fishery-independent data on relative abundance and size distribution of yellow eel in coastal areas. The surveys are primarily designed for temporal analyses and for comparing sites. When spatial distribution is prioritized, random selection of sampling sites should be used. The Irish methods are presented in (Poole, 1994). A study of Jellyman and Graynoth (2005) indicated some potential for depletion netting using fykenets as an effective method of estimating population size in eels in riverine habitats, where electrofishing is not possible.

There are several models of fykenets on the market and the need for standards is considered irrelevant with the possible exception of mesh size in codends. There is though a strong demand for consistency over time for each local monitoring system. Fishing with fykenets provides cpue data and estimates of length-, sex- and age distributions along with density estimates. Size selectivity is estimated to be within an acceptable range. Dependence of catchability/locomotive activity may induce bias to the density estimate. This could at least partly be handled by mandatory records of water temperature at the gears. No international standards are available for fykenet surveys. Basic principles could be adopted from standards concerning multi mesh-size gillnets (Appelberg *et al*., 1995). Anyhow sampling design should be based on the local situation, taking into account habitat characteristics, eel density, etc.

Other gears used to collect yellow eel density estimates are an electrified trawl used in the Netherlands. These gear types (probably) meet the same demands on technical pros and cons as do fykenets. They are though probably more restricted to specific habitats.

7.2.4 Population measures

An estimate of absolute density is desired but hard to get information. An EMP though, will demand total density estimates to be related to the carrying capacity of the management unit. Mark recapture experiments can be used in closed areas, with no (or negligible) exchange with surrounding habitats. Total yellow eel density was estimated to 1.1 kg/ha in a Baltic Sea archipelago area in Sweden (Adill and Andersson, 2006). The possibility to relate relative abundance (cpue) to total biomass should be considered in future eel research.

Mathematical models are the most common tools to estimate total fish densities. Tentative models to estimate eel density were produced within the SLIME project (Dekker *et al.*, 2006).

7.2.4.1 Size, sex and age structure

Estimates of size, sex and age structure are essential to modelling silver eel escapement from yellow eel data. This kind of information can be achieved from surveys as well as from sampling commercial catches. Methods for this type of sampling are common practice for most fish technicians and biologists. Differences in details though, might exist between laboratories and a common practice manual should be concerned.

7.2.5 Fishery dependent methods

Good catch statistics should provide information on landed quantity from the individual fisher and on the fishing effort that was used to obtain a certain amount of fish. This provides a value on catch per unit of effort (cpue), which is used as an estimate of relative fish density. Every management unit should target this kind of information. If it meets the demand of high quality, it provides a cost-effective method, giving to some degree the same information as surveys do. In reality officially collected catch statistics rarely meet the demands of good monitoring and management.

An alternative method to collect catch statistics is reported from Poland and Sweden where contracted fishers report both catch and effort on a daily bases from single poundnets and/or sets of fykenets. Another method to collect catch and effort data is reported from France, for glass, yellow and silver eel in some basins. The data are provided by a group of co-operative fishers through personal contacts, in order to ensure confidence and accuracy of the data collected. The only reliable time-series from both countries are based on this kind of information. The collection of data is confidential and based on trust between parties. There is no guarantee though for long time consistency.

7.2.5.1 Size, sex and age structure of commercial landings

Sampling commercial landings from marine waters for size and age is regulated in the Data Collection Regulations. The sampling technique in most aspects does not differ from sampling fishery-independent catches (see 7.5). As eel fishery even within possible management units might cross borders between marine and fresh-water habitats sampling landings should be concerned in all habitats with considerable landings.

Table 7.5. Methods used in yellow eel monitoring as reported in country reports to joint EIFAC/ICES WGEEL 2007.

	Fishery dependent methods		Fishery-independent methods			
Country	Length/age composition of landings	Detailed catch statistics	Electro fishing	Electrified trawl	Fykenets	Longlines
BE			Y		Y	
DE			Y			
DK	Y		Y			
F			Y			
IT			Y			
IR	Y	Y	Y		Y	Y
LV	Y		Y			
N			Y			
NL	Y		Y	Y	Y	
PL	Y	Y	Y			
PT			Y			
SE	Y	Y	Y		Y	
SP			Y			
UK	Y		Y		Y	

7.2.6 Methods to sample silver eels

Measuring or estimating the numbers of silver eels leaving RBDs may be the most difficult part of the data collection process required for the development and continuation of Eel Management Plans. Silver eels are often descending rivers when fishing/sampling is difficult to perform due to high water velocities, low temperatures, and large amounts as debris, which clog the fishing gears. However, the enumeration of silver eel escapement is key since the management target is to be based on an assessment of silver eel escapement relative to a historical reference level.

Around Europe, silver eels are sampled using both fishery and fishery-independent methods, primarily based on intercepting/trapping the eels, but also in some cases by electrofishing, during their downstream migration (Table 7.6). The most robust data derive from direct counts at river-width trapping operations, but of necessity these operations are limited to sites with dams or weirs. However, even these facilities may not provide total counts of escapement since they may not be sited at the downstream limits of the rivers for practical and operational reasons (availability of existing structures-weirs, barrages, etc., dimensions of rivers) and therefore, attempts to count/estimate the silver eel escapement may underestimate total escapement by missing out potential production from parts of the river further downstream from the fishery/sample site. Of course, this problem also extends to the estuary, and even perhaps to coastal waters, but in terms of the Eel Management Plans, this will only need to be considered in the circumstances where the RBD definition includes the estuary or estuary and coastal waters.

The next level of approach is to estimate run size based on measures of catch and estimates of trap efficiency, based on mark-recapture experiments. This approach can be applied to fishery and fishery-independent sampling programmers, but the estimates introduce a degree of uncertainty. Sampling must be representative across the size range of fish and the migratory period. Commercial fishing gears may be limited by size limits imposed as conservation/management measures. Furthermore, commercial fishing operations may be targeted towards those periods (nights) that are expected to be most productive in terms of size of the catch relative to fishing effort. Where such selective fisheries operate, they should be augmented with random operation and sampling of the fishery, or with another method which is independent of the fishery operation. The gears used during fishery-independent sampling can be designed to ensure little or no size selection of the catch, but smaller meshes or gaps will clog up with debris more quickly and therefore are likely to require even more intensive monitoring to ensure the continued and efficient operation of the gear.

The variety of tags and marks that can be applied to silver eels was considered by a previous EIFAC Working Group (Nielsen, 1988). Trap efficiency is estimated based on the proportion of marked/tagged fish that are recaptured after (i) being released upstream of a single trap site or (ii) in a second trap farther downstream.

Statistical packages are available to inform experimental design and can be used to determine that a sufficient numbers of eels are marked in order to estimate trap efficiency and hence escapement at the desired level of statistical precision, though these may require some amount of prior knowledge or assumptions about the numbers of fish susceptible to the sampling method on any sampling occasion. It is important to establish such levels of precision in order to understand the degree of uncertainty surrounding the escapement size estimate. Knowledge of this uncertainty is required for the informed comparison between escapement of different RBDs, and also for models, which include stochastic mechanisms.

The third level, with the greatest degree of uncertainty, is to derive estimates based on marking of pre-migrant, putative silver eels. In addition to the uncertainty of estimates because of that associated with estimates of trap efficiency, additional uncertainties arise from i) the difficulties in marking a representative sample of putative silver eel across all habitat types across the basin (upstream of the trap site), ii) the difficulties in accurately identifying those eels that will become silver eels in the same year, and iii) the potential for mortalities between the marking and recaptures.

The biological sampling should include sizes, sex ratios, and length-, and age-distributions, in order to characterize the run.

Table 7.6. Methods used in silver eel monitoring as reported in country reports to joint EI-FAC/ICES WGEEL 2007.

	FISHERY DEPENDENT METHODS			FISHERY-INDEPENDENT METHODS		
COUNTRY	Length/age composition of landings	Detailed catch statistics	Stownets	Mark recapture	River traps	Stownets
BE						
D			Y	Y		Y
DK	Y			Y		
F				Y		
IT						
IR	Y	Y			Y	Y
LV	Y					
N					Y	
NL				Y		
PL	Y	Y		Y		
PT						
SE	Y	Y		Y		
SP						
UK					Y	

7.3 Methods to quantify fishing pressure

Fishing pressure is defined here as the capacity of the fishery to exploit the stock and quantification of the fishing pressure requires information on the numbers of gears, their efficiency and selectivity, and their seasonal and spatial deployment (i.e. the effort expended in catching the fish). Data on catch and fishing pressure can be used, in conjunction with estimates of the population size and that component which is susceptible to the fishery, in order to calculate the impact of the fishery on the population and therefore the escapement of silver eels, as must be described in the Eel Management Plans. In addition, these data can be used to calculate the catch per unit of effort (cpue) as an index of abundance (see Chapter 6).

In order to maximize the value of these fishery data, they should be stratified, as appropriate, according to the life stage exploited, the fishing sector, the gear type and the fishing métier. Data on fishing effort should include those to describe number of fishing rights or licenses, which are very often different from the absolute number of fishers per categories in activity (e.g. part-time or full time fishers, numbers of gear per licence); the type of fishing gears and their associated capture profiles (e.g. filter volume of nets), temporal aspects of fishing operation (season, days per season, time per fishing event). For eel specifically, a pragmatic approach is to collect glass eel catch data as weight (but with subsampling to allow the extrapolation from catch weight to numbers), whereas ideally, yellow and silver eel catch data could include both weight and number, though as with glass eel, subsampling of catches can provide an estimate of one statistic if for practical reasons the catch data are limited to weight, or even to boxes of graded eels: Lough Neagh catch data are collected as catch weight and also as numbers of boxes of small or large eels, and the size dichotomy between male and female silver eels allows an estimate of the catches of male vs. female silver eels.

The data on catch and effort per gear type are collected directly from the fishers themselves, and the status of fishers (i.e. licence rights, number of fishers) is collected from the fishery management organizations. The primary fish market (dealers) is another potential source of data, at least of catch, but often this provides a reduced level of data since it may not provide such detail as the catch per gear or the associated fishing effort.

Any fishery sampling programme should incorporate the appropriate tools and the methods designed to provide a statistical monitoring system which ensures the collection of data that are accurate and representative of the entire fishery (i.e. are not selective). The appropriate statistical monitoring systems and the fisheries indicators, fishing effort, captures (cpue) with their units, are common to all fisheries and well known; efficient guides exists from the Food and Agriculture Organization (Holden and Rait ,1994; FAO, 1999; Evans AND Grainger, 2002*)* and a specific guide for eel has been developed as part of the methodological guide of the EU-Project Title INDICANG Project (Castelnaud, 2007; http://www.ifremer.fr/indicang).

However, the development of an effective statistical monitoring system typically requires prior knowledge of the functioning of the fisheries, which is very often limited (Neis *et al*., 1999; Hilborn, 1985; Brethes, 1990). Such limited knowledge often leads to uncertainties on the descriptors that would be required to select the appropriate dataseries. However, most eel fisheries around Europe are well established and the creation of new fishery monitoring procedures or the improvement of existing, but limited procedures can draw upon a large body of knowledge.

However, during the short period available to establish the impact of existing fisheries on eel populations, there may be insufficient time to implement new procedures for the fishery data collection and those tasked with developing EMPs may have to use proxies of the fishery indicators defined above, assessing their reliability through the description and analysis of the data and the data collection method.

In conclusion, the quantification of the impact of fisheries on the eel population depends on the deployment of a robust and statistical fishery monitoring system that provides catch and effort data that are reliable and representative of the entire fishery (FAO, 1996; FAO, 2002; FAO, 2003).

Normally, with the controls of fishers, fishing effort and sale of eel requested by CITES (but does not apply to sales within EU), these indicators of fishing pressure will be available at the international level, but these obligations will not replace the interest and justification of efficient local statistical monitoring systems which are necessary to produce abundance indices accurate enough to monitor the trends in stock abundance.

7.4 Methods to describe the condition of the habitat and the impact of non-fishery mortality factors

7.4.1 General

Relevant elements of natural eel habitat have been described in ICES (2004) and are listed in Table 7.7.

Table 7.7. Habitat variables relevant to eels in waters according to WFD (yes = relevant, no = not relevant). After ICES (2004).

	Variable name	Lakes	Rivers	Artificial waters	Trans. waters	Sea
v1	Distance RBD from Sargasso Sea	yes	yes	yes	yes	yes
v2	Distance inland migration to sea	yes	yes	yes	no	no
v3	Obstructions for migration	yes	yes	yes	yes	no
v4	Dissolved oxygen	yes	yes	yes	yes	yes
v5	pH	yes	yes	yes	no	no
v6	Summer temperature	yes	yes	yes	yes	yes
v7	Duration of growing season	yes	yes	yes	yes	yes
v8	Trophic status	yes	yes	yes	yes	yes
v9	"Instream" cover	yes	yes	yes	yes	yes
v10	Pesticides	yes	yes	yes	yes	yes
v11	Flood plains and tidal area	yes	yes	yes	yes	yes
v12	Anguillicola crassus	yes	yes	yes	yes	no
v13	PCB's/Endocrine disruptors eel content	yes	yes	yes	yes	yes
v14	Gradient	yes	yes	yes	no	no

These habitat variables may influence individual eels and hence the population in different parts of the River Basin District and during different phases of the life cycle. The Water Framework Directive makes a clear distinction between lakes, rivers, transitional waters, the sea and artificial waters. These types of water habitat also seem to be inhabited by eels differentially (Tesch, 1999), so the same distinction is to be made for the description of eel habitat. For example, in stratified and deep lakes, the eels do not occur in the deeper parts that seem to be unsuitable habitat.

Some areas are characterized by temporarily flooding, like tidal areas and floodplains. These may provide foraging areas for eels in times of flooding during the growing season and contribute additionally to the growth of the eels, depending on the frequency and duration of flooding. The same applies to the areas that run dry during periods of droughts, or during periods of water abstraction: the frequency and duration of higher water levels during the growing season will add to the production potential, provided that the low water levels are not linked directly or indirectly to mortalities.

Both the quantity and quality of the habitat are important and should be measured for an EMP. The quantity of habitat (wetted surface area) should be determined for the different water habitats (Table 7.7), but varying water levels will result in varying surface areas. In these situations it is recommended to measure the minimum-, maximum and average area and if possible the respective P_5 or P_{95} values. Because these areas are important mainly for growth, these should be determined in the growing season (see also variable V7).

7.4.2 Influences of habitat on growth of yellow eels

Eel is a very tolerant species and will be able to occur in practically each water area within its distribution range. The exceptions are water bodies with pH <3 or dissolved oxygen concentrations lower than 3 mg/l (ICES, 2004; Tesch, 1999).

A number of habitat variables in Table 7.7 affect the growth of eels. Distance from the sea (V2) is the most important structuring parameter for eel densities, size and age distributions and sex ratios (e.g. Naismith and Knights, 1993; Lobon-Cervia *et al.*, 1995; Ibbotson *et* *al*., 2002). Obstacles to migration (V3) may result in higher densities of eels in downstream areas, possibly leading to decreased production in the local population by density-dependent limits on growth (Klein Breteler *et al*., 1990). Low oxygen levels (V4), if not leading to mortalities, may result in reduced food consumption and retardation of growth. In very acid waters with low pH (V5) the eel will not occur, but nothing is known about the effect of low pH on the growth of eel.

Growth of fish in general and of (yellow) eels in particular, is largely dependent on temperature, food consumption and activity (Hewitt and Johnson, 1992). As yellow eels beyond 30 cm are considered to be relatively sedentary (Baras *et al*., 1998), temperature (V6) and food are the main factors that determine the possibilities for these eels to grow, and therefore also the possibilities for yellow eels to exist and ultimately to contribute to escapement of silver eels. Eels grow at temperatures between 10 and 35˚C (ICES, 2004). Thus, the number of days per year with water temperatures between 10 and 35˚C (V7) are relevant and should be measured.

Food consumption by eels not only depends on temperature, but also on the productivity of the water. ICES (2004) indicates that the trophic status (V8) determines eel production, but also that instream cover (macrophytes, etc., V9) may play a role. ICES (2004) also suggests that pesticides may reduce growth by influencing the forage base for eels. However, data supporting the suggested relations between suitability of eel habitat and trophic status, instream cover and pesticides are lacking. A complicating factor is that many eels forage on invertebrates that are linked to or associated with terrestrial production, and that part of that terrestrial production takes place on the interface between land and water, on the flood plains and tidal areas (V11).

7.4.3 Migration obstacles

7.4.3.1 Natural migration obstacles

One key element of the quality of natural eel habitat for migrating eels is the distance of the RBD concerned to the Sargasso Sea (V1 in Table 7.7) or to the edge of the continental shelf (ICES, 2004). Distance of a RBD to the Sargasso Sea therefore acts as a gradual natural obstruction in the migration routes. This applies primarily to the glass eel (and younger stages), but also to the silver eels that return to the spawning places.

Distance of the inland habitat to the sea (V2) and elevation (V14) are other natural habitat variables that affect the local eel inland population just by dilution (Knights *et al*., 2001; Ibbotson *et al*., 2002). The distance functions will result in effects on numbers, but also may imply effects on growth by density-dependent sex development and growth.

In many RBD's also natural obstructions (V3) occur that prevent glass eels or migrating yellow eels from migrating upstream to potentially productive areas. The distance of these obstructions to the sea and their impact on upstream migration must be documented effectiveness of these obstructions in blocking further migration are items recommended to be measured.

7.4.3.2 Man-induced migration obstacles

Man-made migration obstacles for upstream migration may limit the potential habitat to be colonized. They also may increase the surface of suitable habitat, because of water retention by dams and increase of water surface upstream from these obstacles. In situations with limited colonization of upstream areas due to obstacles in the migration routes, the resulting higher densities of eels in downstream areas possibly result in decreased production in the local population by density-dependent growth (Klein Breteler *et al*., 1990).

Migration obstructions for downstream migration might affect the condition of the eels with regard to spawner quality or eventually may prevent them to migrate to the sea and spawning places. In cases of hydropower (or pumping stations in lowland waters) they may result in mortalities.

As with natural obstacles, the important information required regarding anthropogenic obstacles to migration are the distance of the obstruction to the sea and the effect the obstruction has in reducing the numbers that pass in a good condition. Useful information for the latter with regard to upstream migration concerns the height, slope and roughness of the dam or weir and the possibilities for the eels to migrate along the obstruction using banks or fish passes. Generally site-specific information is needed.

An indication of the year of construction of the obstruction may help in determining the natural status of the habitat. Useful information for determining the mortalities or injuries at hydropower stations concerns the position of the turbine in the river bed (eels migrate in the main current), the working regime (switching off the turbine during the main migration period reduces the damages), the efficacy of the protection screen, the turbine type, the water flow rate, the turbine type and the characteristics of the turbine (ICES, 2003). Also the lengths of the eels passing by and the construction and functioning of the bypasses are important. These data also are highly site specific.

7.5 Conclusions and recommendations on sampling methodologies

7.5.1 Methods to sample eels

Glass eel and elver recruitment monitoring has a general interest for the entire area of distribution. Existing methods should be maintained, but alternative and independent methods should be explored and adopted to secure long-term data collection. Alternative techniques to obtain fishery-independent data on glass eel abundance should be explored and tested.

Monitoring abundance and structure of yellow eel populations is expected to be an important tool for estimation of status and development of silver eel escapement. This requires surveys and sampling of commercial and recreational landings, in all eel habitats within management units.

Quantifying the abundance and biomass of eels in a waterbody is not easy. Other than in shallow rivers where depletion electrofishing survey estimates are possible, methods available today do not allow for the quantification of yellow eel population abundance in other habitats, such as deeper areas of rivers, lakes, estuaries and coastal waters.

Clearly, direct counts and even estimates of silver eel escapement will be very hard or indeed impossible to achieve in many RBDs. Practically, therefore, silver eel escapement in many river basins will have to be estimated using proxy indicators from earlier life stages and models.

In order to provide a description and an analysis of the present situation of the eel population/stock in each river basin the existing monitoring methods for spawner escapement and glass/yellow eel immigration have to be improved leading to cost-efficient methods which can be transferred from data-rich to data-poor river basins.

7.5.2 Methods to sample anthropogenic and natural impacts

Fishery-independent monitoring is proposed as an option for EMPs, considering relative density, distribution, and size/sex/age structure of yellow eel stocks, if the level of silver eel escapement cannot be obtained by other methods.

7.5.3 Methods to sample habitats

Habitat data can be used to describe the actual potential of RBD's for settlement, colonization, growth and production of eels. Habitats-important parts of the habitat data needed may be obtained from the information made available by the WFD.

The habitat data to be sampled for developing an EMP should comply with the data requirements in Table 7.7.

8 Predation

8.1 Introduction

Natural mortality of eels is a major, but relatively unknown, factor in the population dynamics of the species. Mortality caused by predation is but one of the factors contributing to natural mortality (and may be compounded by other issues such as disease and parasitism). The new EU Regulation lists reducing predation as a possible management option that could be employed when attempting to reach escapement targets. As a result, predation on eel and potential mitigation measures to reduce it are considered here. No systematic review of eel predators is available and so, rather than merely list the predatory birds, mammals and fish of eels, this chapter summarizes information for some species likely to be 'representative' of the diversity of eel predators in non-marine habitats, covering both birds and mammals, and both common and less abundant species.

At a national-international spatial scale, predation on European eel as a form of natural mortality is not well represented in the published literature (see Tesch, 2003). At this continental scale a number of piscivorous predators are known to consume eels, including birds such as the Great Cormorant (*Phalacrocorax carbo*, hereafter cormorant), several species of herons and egrets, two species of sawbill ducks (*Mergus* spp), and mammals such as the Otter (*Lutra lutra*) and the mink (*Mustela* spp). It is not possible to synthesize here all available information on eel predation, rather the focus is on one of the most abundant avian predators (the cormorant) with some comments on other species (the Grey Heron *Ardea cinerea*), Goosander (*Mergus merganser* and the Red-breasted Merganser *M. serrator*), and on one of the more widely studied mammalian predators (the Otter). This is not to be taken as an indication that these are necessarily the most 'important' predators of eels, merely that more dietary information is available for them than for many of the other predatory species. In this respect, predation on eel by harbour seal (*Phoca vitulina*), grey seal (*Halichoerus grypus*) and the harbour porpoise (*Phocoena phocoena*) are mentioned in the WGEEL Nantes report (ICES, 2003, p37). Here, estimates of annual eel consumption by the latter species in waters close to the shore are given as 4.400 tonnes.

Specific mention is also made here to both methodology (in relation to assessing piscivorous diet) and mitigation measures (specifically in relation to the cormorant).

8.2 Methods of assessing predator diet

Assessing the diet of fish-eating predators relies on the identification and measurement of hard (i.e. undigested) remains found in oral pellets, regurgitations, and stomach contents. Commonly, these undigested remains include otoliths, skeletal bones (particularly vertebrae) and scales. Numerous biases, mostly relating to the differential digestion (and hence differential recovery) of undigested remains, occur in such dietary analysis, influencing both estimates of the diversity of prey taken and the size of individual fish eaten. For piscivorous birds, these biases have been comprehensively assessed and reviewed (Carss *et al*., 1997, Carss and Marquiss, 1999).

Most commonly, assessing the diet of mammalian predators relies on analysis of undigested prey remains in faecal material. As this material has experienced the complete digestion process, there are considerable biases associated with faecal analysis. Otter faecal (i.e. spraint) analysis has been comprehensively assessed in relation to the errors associated with the methodology for two important aspects. First, the usefulness of using otter spraints to estimate general diet (i.e. diversity and proportions of prey species eaten) was examined by Carss and Parkinson (1996) and Carss and Nelson (1998). Second, the accuracy of prey size distribution estimates based on bones recovered from otter spraints was examined by Carss and Elston (1996) and Carss, Elston and Morley (1998).

Given the demonstrable biases associated with assessing the diet of these piscivorous predators, particular care must be taken when interpreting the results of dietary studies and interested parties are urged to consult the reviews mentioned here.

8.3 Mitigation measures

As with all species of wild birds the cormorant is covered by the general scheme of protection of the Birds Directive (79/409/EEC) and its deliberate capture and killing, disturbance, destruction of its nest or taking of its eggs can only be allowed by Member States in accordance with the derogation system of the directive. Three species of Cormorants that naturally occur in the EU, Great Cormorant (*Phalacrocorax carbo*), Shag (*P. aristotelis*) and Pygmy Cormorant (*P pygmaeus*) are given this protection under the Directive. Thus all members of the fish-eating bird community are protected under European legislation (i.e. the Birds Directive). However, some local management measures may be permitted under derogation.

In relation to cormorants, there is also an "*Action Plan for the Management of the Great Cormorant in the African-Eurasian Region*" produced under the auspices of the Bonn Convention (Conservation of Migratory Species of Wild Animals). The appropriate legislation is discussed in Carss (2003, pp24–25).

Management of cormorants in Europe has been discussed for decades: potential mitigation techniques to reduce fish consumption varying from a diverse range of site-specific measures to some form of continental population control. The issue of the necessity (or not) of managing cormorants and how best to do it has received considerable attention. On a national level, (A) the effectiveness, practicability, acceptability, and costs of site-specific measures for a variety of habitats/fishery types, (B) general information about management actions taken in relation to cormorants, and (C) relevant national management plans and legal regulations are reviewed for a total of 24 European countries by Carss (2003, pp103–130). Furthermore, complete information on a country-by-country basis for all 24 Member States is given in Carss and Marzano (2005). Cormorant management on a continental level is discussed fully in van Dam and Asbirk (1997) and Carss (2003, pp103–105, 127–129) while the ecological considerations in relation to cormorant-fishery conflicts are synthesized in Carss (2003, pp 78–102).

Summarizing the above briefly, all fish-eating birds likely to be predators of eels are protected under EC legislation, specifically the Birds Directive but also under the Bonn Convention (in relation to cormorants). Numerous potential site-specific measures are available to mitigate against cormorant predation at fisheries, although these are of variable effectiveness, practicability, and cost-effectiveness. Under current legislation, killing cormorants to reduce their population numbers is not an option. Even if it were, available ecological information suggests strongly that population reduction may not reduce the most pressing conflicts with fisheries because cormorants are attracted to the most profitable or 'optimal' food sources-often where they are most likely to conflict with human interests.

It is likely that the same (or very similar) issues would be applicable to potential mitigation measures taken against any other avian predators. Furthermore, there would be similar issues in relation to mammalian predators such as the otter. This species has extremely high conservation status in Europe with specific European and national legislation to protect it. The European subspecies of the otter is listed as "globally threatened" on the IUCN/WCMC Red Data list: for details see:

http://www.iucnredlist.org/search/details/php/12419/all

The otter is also listed on Appendix I of CITES and Appendix II of the Bern Convention. It is also listed on Annexes II and IV of the Habitats Directive (92/43/EEC), the former means that otter conservation requires the designation of Special Areas of Conservation across

Europe, the latter means that the species "is in need of strict protection": for further details see:

http//ec.europa.eu/environment/nature_conservation/eu_nature_legislation/habitats_directive/index_en.htm

8.4 European estimate of eel consumption by cormorants

The geographical ranges of eels and cormorants overlap almost completely. Moreover, across Europe, these birds (a) have increased substantially in recent years, and (b) are widely reported to eat large eels, many of which are likely to be female (Carss and Ekins, 2002). Such predation has not, to date, been included in eel population dynamic studies (e.g. Dekker, 2000). However, while Carss and Ekins (2002) suggested that cormorant predation on eel could be important on the continental scale and should be considered in future European investigations of eel population dynamics, they provided information only from one cormorant colony in the UK. This chapter takes a broad-brush approach and, using mostly published data, makes an attempt to quantify the scale of cormorant consumption of eel across Europe. Data presented here, for 19 European countries, include estimated annual consumption (tonnes) and estimates of the size (length) of predated eels.

8.5 Methods for estimating of eel consumption by cormorants

At the pan-European level, cormorant consumption of eels was determined either by extrapolating from published studies (usually restricted to particular colonies) to the national level, or by applying the method employed by Carss and Ekins (2002) and, again, extrapolating to larger areas. In essence, these calculations of consumption require information on the number of cormorants, their daily food intake, the proportion of this that comprises eel, and the period under consideration. Many of the potential limitations of such general calculations are discussed in Carss *et al*. (1997) and Marquiss *et al*. (1999).

For this chapter, cormorant consumption of eel was determined separately for 19 countries (Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Spain, Sweden, United Kingdom). Moreover, separate calculations were made for (a) the cormorant breeding period (for brevity, assumed to be 60 days), and (b) the rest of the year. For cormorant numbers (of both races/subspecies) and the proportion of the diet comprising eel in most countries, baseline data for 'breeding period' calculations were generally obtained from the literature (van Eerden *et al*., 1995, Gromadzki and Gromadzka, 1997, Baccetti and Cherubini, 1997, Keller and Carss, 2003, Cowx, 2003, Carss and Marzano, 2005). For these data, the values used by Carss and Ekins (2002) for daily food intake and breeding period were used. In some cases (i.e. United Kingdom, Ireland, Poland), calculations were done separately for different habitats where proportions of eels were shown to differ greatly and then summed. Eel consumption by birds in Norway, Denmark, Netherlands, Estonia, and Italy were taken directly from specific publications or from unpublished data.

Calculations of eel consumption in the non-breeding period were even more simplistic than those for the breeding period. Wintering cormorant numbers (of both races/subspecies) for 14 countries were taken directly from the literature (mostly Carss and Marzano, 2005, but also van Dam and Asbirk, 1997). A best guess was used for wintering numbers in Denmark, Estonia and Ireland and the assumption was made that no birds wintered in Finland or Sweden. It was then assumed that these birds were distributed in a 50: 50 ratio between two age classes: adults and immatures. Cormorant body mass data (for both races/subspecies and for both age classes) were taken from Carss *et al*. (1997). Daily food intake for individual birds was taken to be 25% of body mass, following Marquiss *et al*. (1999). Finally, the (biomass) proportion on eel in the diet of non-breeding birds was based on informed guesswork. Both intuitively and with some published evidence, the proportions of eel in the diet of cormorants are likely to be lower in winter-when eels in many European waters are in torpor and presumably less 'available' to predators. Thus two values for the proportion of eel in cormorant's 'winter' diet were used: 6% (being half of the average breeding (i.e. 'summer') value, and 3% (being 25% of it).

Figures for the lengths of individual eels consumed by cormorants were taken from the literature (see above) or unpublished studies.

8.6 Results of estimates of eel consumption by cormorants

Eels were scarce, very rare or not present in fish communities, or had not been recorded in the diet of breeding cormorants in Belgium, Spain, Portugal, Finland, Latvia, Lithuania, Czech Republic, and Greece. For the 11 remaining countries (or regions within them), a total of 169 000 pairs of cormorants (plus their nestlings in some instances) were estimated to consume 1300 tonnes of eels during the 60-day breeding season.

For the rest of the year, in all 460 000 cormorants (31% being of the nominate race *Phalacrocorax carbo carbo*) were estimated to be present in the 19 countries included here. Given both the race/subspecies and age-class proportions discussed above, and assuming that eel comprised 6% of the cormorant diet (by mass) across Europe, produced a 'winter' consumption figure of 5000 tonnes. The corresponding figure for an assumed eel contribution to the diet of 3% (by mass) was 2500 tonnes.

Combining the single estimate of consumption during the breeding period with the two derived for the rest of the year gave figures of 4000–6000 tonnes of eel consumed by cormorants annually across Europe (at least, for the 19 countries considered here).

Eel length data were available (though often samples were very small) for 8 countries. Data were restricted to the 'summer' breeding period in all cases. In many instances, considerable proportions of individual eels were estimated to be >35 cm in long (Table 8.1).

8.7 Discussion

The calculations of annual eel consumption by cormorants across Europe undertaken here are very 'rough and ready' and they are of unknown accuracy. Furthermore, there are a number of important caveats. These include:

1) Many of the figures for cormorant numbers, cormorant diet, and eel catches are several years old-breeding cormorant numbers range from the mid-1990s to 2005; wintering cormorant numbers are mostly the best estimates available in 1995, though some are earlier; cormorant dietary studies range from the 1960s and 1970s (1 study each), the 1980s (2 studies), the 1990s (7 studies) and the 2000s (4 studies); eel catch data were from 1993.
2) In some instances, the cormorant diet data used were restricted to a small number of colonies (or sometimes a single one) and were then extrapolated to a wider area.
3) The cormorant numbers used in such calculations were thus not necessarily the absolute numbers estimated at the national scale but, instead, were the likely numbers using the same region (or habitat) as those birds for which dietary information were available.
4) As discussed above, there are sometimes considerable methodological biases associated with estimates of cormorant diet.
5) Similarly, a variety of methods have been used to derive published figures for fish consumption by cormorants (e.g. using different estimates of cormorant body mass and daily food intake, breeding period, nestling birds requiring food).

6) In many cases, such extrapolations were based on cormorant dietary data obtained in one period and information on cormorant numbers obtained in a different period.

Nevertheless, these calculations may offer an insight into the order of magnitude of eel mortality caused by the cormorant-a top aquatic predator in relatively shallow salt, brackish and fresh waters. Taken at face value, these preliminary, crude estimates suggest that cormorants may consume some 4–6000 tonnes of eel each year (in the 19 countries covered here). A similarly crude calculation (albeit using a different methodological approach to the one undertaken here) estimated annual eel consumption of a similar order of magnitude, at some 1800–9000 tonnes (WGEEL Nantes report (ICES, 2002, p37).

Here, the value of this consumption estimation is unknown. However, when compared with estimates for the (commercial) captive fishery (1993/94) for the countries covered here (excluding glass eels and those produced from aquaculture-see Table 10 in Moriarty, 1996), estimated cormorant predation is perhaps ca. 30–50% of these commercial catches. Furthermore, the brief review of sparse data on eel length again supports the contention that cormorant predation falls disproportionately on larger, mostly female, eels. In conclusion, data presented here add further weight to the suggestion of Carss and Ekins (2002) that, at the international scale, predation might be considered in future investigations of eel population dynamics.

Finally, no attempt to estimate the 'impact' of cormorant predation on eels was made-this is because of the extreme difficulties in quantifying cormorant predation on fish stocks generally (see Wires *et al*., 2003 for review).

Table 8.1. Estimated lengths of individual eels consumed by great Cormorants during the breeding period. See source citations for detailed methodologies.

COUNTRY	EEL LENGTH INFORMATION	SOURCE
Northern Ireland	70% of eels eaten by cormorants were greater than 40 cm	Finlay (2006)
Ireland	ca. 80% of eels seen eaten by cormorants were greater than 35 cm	Figure 4, Doherty and McCarthy (1997)
England – inland colonies	40, 40, 43, 44, 49, 55 cm	Carss and Ekins (2002)
England - Abberton Reservoir	Mean eel length (total N = 131) in 3 breeding seasons = 46, 41, 43 cm	Carss and Ekins (2002)
Norway	Median eel length from cormorant pellets (n = 78) = 33 cm, from nestling regurgitations (n = 57) = 44 cm	Unpublished data from Thesis, Målfrid Skarperud, Institute for Biology and Nature Management, Norges Landbrukshøgskole.
Sweden	4 eels recorded 42–50 cm	Engström (2001)
Denmark	Average eel length from studies at 22 colonies = 33 cm. At 12 (54%) of these colonies, colony-average eel size >35 cm.	Hald-Mortensen (1995)
Netherlands	Mean length of 145 eels = 26 cm, 15% of eels were >35 cm	van Rijn and van Eerden (RIZA) unpublished data
NW Poland	Mean length of 10 eels = 49 cm	Wziatek *et al*. (2003)
Katy Rybackie colony - Poland	N = 159 eels recorded over 3 breeding seasons from either cormorant pellets or regurgitated prey. In each of 6 cases (year x diet assessment method) average eel length was >35 cm	Table 5.2, Stempniewicz *et al*. (2003)
Italy	96% of eels recorded in breeding period (n = 54) were >35 cm	Volponi (Univ. Ravenna) unpublished data.

8.8 Eel predation by other fish-eating birds

The cormorant in Europe is probably the most abundant avian predator of eels and also one of the most intensively studied birds in the region (see Preface to Keller and Carss, 2003). Even so, as discussed above, estimating the species' predation on eel is extremely difficult and only very crude estimates are possible. Thus, for other fish-eating species it is not possible to derive even crude estimates of eel consumption. Nevertheless, it is possible to say something about eel predation by other birds. Grey herons (*Ardea cinerea*) are also a common eel predator. Their foraging behaviour has been reviewed (Hughest *et al*., 1999): although more restricted in foraging habitat than the cormorant (i.e. to shallower water), grey herons undoubtedly take eels. However, evidence suggests (e.g. Feunteun and Marion 1994) that the majority of eels taken are 16–30 cm in length (i.e. generally smaller than those consumed by cormorants). Similarly, sawbill duck diet in Europe and North America has been reviewed (see Marquiss *et al*., 1999) and although certainly not the most commonly taken prey species, eels are frequently recorded in dietary studies. As with grey herons, data suggest that the eels taken by sawbills will be generally smaller than those consumed by cormorants. Furthermore, sawbill diet studies show that the proportion of eels in the diet varies in both time (e.g. seasonally, and between-years) and space (e.g. both between and within catchments): the same is likely to be true for other predatory birds. Other fish-eating birds (e.g. osprey *Pandion haleatus*) are recorded taking eels on occasion but the fish is certainly not a 'common' prey item.

8.9 Eel predation by otters

Potential consumption of eels by otters is perhaps best explored in relation to site-specific studies. Eels are frequently recorded in otter diet where this predator occurs across Europe (e.g. Mason and Macdonald, 1986, Kruuk, 2006) and, in regional localities such as those in northeast Scotland, may even be the most commonly taken prey item-in freshwater habitats (lakes and streams, see Carss *et al*., 1998). Here, proportions of eel in the diet vary both seasonally (being highest in summer, followed by spring, autumn, winter) and within the catchment (being highest in the lower reaches, lowest in the highest reaches and intermediate in the middle reaches). Although there is no evidence here that otters select particular prey species, there is a suggestion that they might do so indirectly, through choosing to forage in particular habitats. Data (Carss, *unpublished*) suggest that otters foraging in a small, shallow Scottish lake may disproportionately select the largest eels from the population: mostly eating eels larger than 35–40 cm in length.

Compared with the cormorant, the relative paucity of data on (a) the proportions by mass of eel in otter diet, (b) the size of eels taken by otters, (c) the daily food requirements of the species, and (d) the numbers of otters at regional, national, and international scales, it is not possible to derive even a crude estimate of overall eel consumption by otters at the European level.

As mentioned above, mitigation of otter predation on fisheries is likely to be very difficult given the species' high conservation status and also its behavioural and foraging ecology

8.10 Conclusions and recommendations on predation

Natural mortality of eels is a major, but relatively unknown, factor in the population dynamics of the species. Although predation is just one of several factors contributing to natural mortality, the new EU Regulation lists reducing predation as a possible management option that could be employed to when attempting to reach escapement targets. Studies suggest that a number of birds, mammals and fish prey on eels, although this has seldom been quantified and potential impacts on stocks are unknown. All bird and many mammalian predators of eels are the subject of national and international protective legislation across Europe. In the case of the cormorant, perhaps the commonest eel predator at the time of writing, attempts to mitigate against the species would involve formal requests to the relevant authorities and require compliance with the Birds Directive (often through national authorities). Other predators such as the otter have very high conservation status and it is likely to be extremely difficult to obtain permission for potential mitigation activities.

9 Research needs

The Working Group identified a number of key research needs urgently required to support the implementation the EU Regulation for recovery of the eel stock, including the development of a) methods to effectively sample and describe eel populations in all habitat types, b) coherent local stock assessment procedures, including proxies for mortality rates and other impacts, and c) the improvement of population models, in order to assess compliance with the recovery target and to focus and evaluate management actions.

In addition, we require research on fundamental aspects of eel biology and production. The priorities include evaluating the potential net benefit of stocking, and exploring and quantifying the possible density-dependence effects on various processes (mortality, growth, movement, maturation and sex differentiation).

In light of these research needs, several fundamental programmes emerge:

9.1 Support for stock assessment in data-rich and data-poor river basins

The patchy distribution of the eel population makes it practically impossible to sample all water bodies where they occur. Similarly, it is impossible to conduct an analysis of the level of mortality occurring in the turbines of all dams in Europe. However, with the deadline for submitting Eel Management Plans (EMPs) less than 16 months from the publication of this report, there is an immediate need to be able to assess the level of anthropogenic mortalities in the development of EMPs across Europe. For this reason, the development of proximate criteria for anthropogenic mortality derived from the analysis of data rich places is urgently needed.

However, assessing the stock is not sufficient to allow managers to discriminate between changes to the stock, which might result from natural fluctuations in recruitment vs. improvements brought about by management actions. Thus, monitoring programmes should be developed to provide data on the status of population and also on changes in anthropogenic mortalities/impacts.

Other than in shallow rivers where depletion electro-fishing surveys are possible, sampling methods available today do not allow for the direct quantification and characterization of local eel populations in other habitats, such as deeper areas of rivers, lakes, estuaries and coastal waters. Thus, the description and analysis of the present situation of the eel stock in each river basin, requires the improvement of existing methods, and development of new methods to monitor glass, yellow and silver eel stock components. Such methods must be cost-effective and facilitate the transport of knowledge and assessments developed for data-rich river basins across to data-poor river basins. Research topics in this area include:

- The rapid collation and assessment of data from data-rich river basins, and the development of proxy criteria for anthropogenic mortalities;
- The development and testing of methods to characterize and quantify eel stocks in deeper areas of rivers, lakes, estuaries and coastal waters;
- The development of methods to obtain abundance estimates based on extrapolating from indices of relative abundance (e.g. cpue);
- The testing of relationships between habitat characteristics and eel production as indicators of the relative production potential of different habitats;
- The development of best practice guides on the spatial and temporal resolution of sampling/monitoring programmes for data-rich and data-poor river basins and for different habitat types.

9.2 Stock enhancement and the effects of density-dependence

There is a clear need for the production of quantified guidelines adding to existing conceptual decision frameworks (see ICES, 2006) for the stocking of European eel as an aid to stock recovery. This will require new research consisting of stocking experiments with effective post evaluation programmes addressing the question of whether or not stocking supports the spawning stock. Experimental stocking programmes will also provide the opportunity to test for the effects of density-dependence on various eel life-history processes. To evaluate and monitor the effect of restocking measures it is necessary to develop methods making it possible to identify stocked eels in a mixture of eels of different origins. By that there is a need for methods to batch mark and/or tag large quantities of young eels as small as glass eels. Research topics in this area include:

- Time of stocking
- Frequency of stocking
- Stocking densities
- Which life stage to stock
- Assess methods to identify stocked origin, either by recruitment patterns, or natural or artificial marks;
- Yields from stocking in different habitat types
- Effects of stocking on sex ratios

9.3 Anthropogenic impacts on various life stages

Mortality of eels is caused by both human activity and natural predation. All the recent studies show that pollution, hydroelectric facilities, and parasites have a disastrous effect on eel immediate mortality and survival. Depending on the type of risk (*i.e.* turbine entrainment, natural predation) certain life stages (resident, migratory) or size classes may be more targeted than others, thus creating a shift in the size distribution of eels and possibly in the sex ratio. A more rigorous assessment of these effects and development of ways to mitigate them might be considered in future investigations at the international scale. Research topics in this area include:

- The quantification of the mortality rates caused by various turbines etc, and their non-lethal effects (i.e. the subsequent survival of those that survive the passage);
- Research on the swimming behaviour and orientation mechanisms of migratory eels to facilitate development of mitigation measures (trap and transport, bypass channels);
- Development of novel downstream passage technologies (fish friendly turbines, efficient guidance systems: louvers and bar racks);
- Methods to quantify and assess the impacts of predators on all stages of eel;
- Further research on the impacts of eel 'quality' on production and survival of different eel stages, and reproductive fitness of silver eel, and the development of standard ecotoxicological benchmarks for eel 'quality';
- Evaluation of the relative impact of the chemicals/parasites on the stock

Other research needs

In addition to the three research themes outlined above, the WG recognized the need for the further research and the continued development of methods to track migrating eels in fresh, coastal and oceanic waters, incorporating comparisons between stocked and naturally produced eels, and eels of varying 'quality'.

Furthermore, the WG recognized that due to similarity between the species and a shared need for stock recovery, further research should include collaboration between eel scientists working on *A. rostrata* and *A. anguilla*.

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Annex 2: Agenda

Agenda for Joint EIFAC/ICES WGEEL 2007-Bordeaux, France

Monday 3 September

9.00	Get organized
9.30–10.00	Welcome RP
	Welcome Dr Hugues Ayphassorho – CEMAGREF
	Local Information: Francoise
10.00–10.30	Intro to Working Group, ToR, etc.
10.30	Coffee
10.45–11.15	Restocking – introduced by R. Rosell and N. Sjöberg
11.15–11.45	Spawner Quality – introduced by C. Belpaire
11.45–12.15	INDICANG – introduced by E. Diaz (for P. Prouzet)
12.15–12.45	SLIME achievements and concepts for modelling-W. Dekker
13.00	Lunch
14.00–14.30	N. America/Canadian Management Plans-intro by G. Verreault
14.30–15.30	OSPAR, CITES and EU Regulation-introduced by R. Poole
15.30	Coffee
16.00–16.30	Open Session on EU documents, subgroups, thoughts, etc.
16.30–17.00	Predation-introduced by Dave Carss
17.00–17.45	Subgroup breakout to get organized, rapporteurs, approaches, etc

NOTE: Depending on the status of the proposed EU Guidelines document, etc, I may seek to hold a short evening session on Monday in order to facilitate a complete discussion on this.

Evening sessions may also be held for discussions of Research proposals, Workshops (i.e. eel age, standardization).

Tuesday-Subgroups breakout

10.00–11.00	Plenary

Wednesday-Subgroups breakout

9.00–10.00	Plenary
10.00–10.15	Upstream migration issues and obstacles-C. Briand

Thursday morning-subgroups breakout

12.00–15.00	Plenary
14.00 deadline	produce conclusions and recommendations draft 1.
16.00	DEADLINE for draft report
16.30–17.30	(while report is being printed for circulation) Discussion on EU guidelines/ Research proposals, etc

Friday-Go through and agree report

Any loose ends on documents/research proposals, etc.

Finish at 14.00 approx.

Annex 3: ICES ASC September 2006; Theme Session J

SUBMITTED TITLES, AUTHORSHIP AND ABSTRACTS FOR ACCEPTED EEL SESSION PAPERS, TO BE PUBLISHED IN ISSUE 7 OF THE *ICES JOURNAL OF MARINE SCIENCE*, 64 (2007)

1. Is there more to eels than slime? An introduction to papers presented at the ICES Theme Session in September 2006

Willem Dekker, Mike G. Pawson, and Håkan Wickström

No abstract

2. Current status and temporal trends in stocks of the European eel in England and Wales

A. Bark, B. Williams, and B. Knights

An extensive four-year programme of catchment surveys, data collection, and model development for eels was undertaken in order to establish the status of the stocks in England and Wales, so that appropriate management action can be taken. Nine test catchments representing different geographical areas and catchment types were studied, covering 14 rivers, two estuaries, and a fresh-water lagoon. Data were collected via electric fishing, fykenetting, fixed eel racks, and elver traps. In all, 13 500 eels were caught, weighed and measured, and the sex and age of a subsample of 1400 determined. despite declining recruitment, eel stocks in some, perhaps many, west coast rivers are probably still at or near to carrying capacity, with male-dominated populations. In other rivers, particularly those towards the southeast of England, current and historical data indicate declining female-dominated stocks. For rivers where recruitment is not limiting, there appears to be a direct relationship between the standing stock of eels and the mean nitrate level. This relationship potentially facilitates the application of a biomass-based biological reference point for eels for application to individual catchments. The data also suggest that it may be possible to develop reference points based on mean eel length or sex ratio.

3. Status of New Zealand fresh-water eel stocks and management initiatives

Don J. Jellyman

New Zealand has two main species of fresh-water eel, shortfin (*Anguilla australis*), which is shared with Southeast Australia, and the endemic longfin eel (*Anguilla dieffenbachii*). Both species are subject to extensive commercial and customary fishing. The shortfin is the smaller and shorter lived, with typical generation times for females ranging from 15 to 30 years; generation times for longfin females are double this. The distribution and the abundance of both species have been compromised by habitat modifications, shortfins, the more lowland species, being affected by wetland loss, and longfins by weirs and dams. Although there are few concerns about the status of shortfins, there is increasing evidence of overexploitation of longfins, including reduced recruitment, reduction in catch rates, reduction in abundance and average size, and a regional reduction in the proportion of females. Eels are managed under the Quota Management System, although individual and regional quotas are set from catch histories because biological parameters are inadequate. Maori, New Zealand's indigenous people, have been allocated 20% of commercial quota, with additional quota set for customary take. The annual commercial catch of eels has halved over the past decade, and is now about 700–800 t, shortfins comprising 66% of catches. Recent management developments have included enhancement of upstream waters with juvenile eels, consolidation of processing into fewer but larger units, setting aside of additional reserve areas to increase escapement of silver eels, increased management involvement of Maori, and development of regional management strategies.

4. Effect of *El Niño* on migration and larval transport of the Japanese eel (*Anguilla japonica*)

Heeyong Kim, Shingo Kimura, Akira Shinoda, Takashi Kitagawa, Yoshikazu Sasai, and Hideharu Sasaki

To clarify the effect of an *El Niño* on the migration of Japanese eels (*Anguilla japonica*) in the western North Pacific, differences in migration patterns of eel larvae (*leptocephali*) in *El Niño* and non-*El Niño* years were compared qualitatively through a numerical particle-tracking model. Depending on interannual meridional displacements of the salinity front and bifurcation of the North Equatorial Current, transport of Japanese eel larvae to the Kuroshio was much less than to the Mindanao Current in an *El Niño* year, and recruitment to coastal habitats in Japan decreased in those years. In non-*El Niño* years, transport to the Kuroshio was twice as high, and recruitment to coastal habitats increased. If the spawning area of eels was independent of *El Niño*, transport differences between the two currents were not clear. In the western North Pacific, mesoscale eddies also played a significant role in dispersing eel larvae and prolonging their migration. Consequently, the changing oceanic conditions associated with climate change have resulted in decreased recruitment of Japanese eels, and the eddy effect on migration of the Japanese eel larvae needs to be added into the NEC-Kuroshio system.

5. Experimental field study on the migratory behaviours of glass eels (*Anguilla anguilla*) at the interface of fresh and salt water

Tammo P. Bult and Willem Dekker

European eels (*Anguilla anguilla*) in the glass eel phase migrate using ocean currents and Selective Tidal Stream Transport. Conventional fish ladders installed at the interface of marine and fresh water, however, require the fish to swim upstream actively. We question the efficiency of these fish ladders for glass eel immigration, and propose a simple siphon over migration barriers, restoring the original Selective Tidal Stream Transport. A conventional trap and our siphon were tested concurrently at two sluice complexes in The Netherlands (Tholen, Nieuwe Statenzijl) in spring 2005. In all but one case, the siphon caught more glass eels than the trap, as well as more sticklebacks and other species. Clearly, the natural immigration process can be restored fairly easily and at low cost and with low intrusion levels of salt. Follow-up studies should focus on optimization, and the effect of a passage on the hinterland stock.

6. Effect of management measures on glass eel escapement

Laurent Beaulaton and Cédric Briand

Stocks of European eel (*Anguilla anguilla*) have declined continuously and steadily since 1980. A model, GEMAC, Glass Eel Model to Assess Compliance, has been developed with the objective of assessing anthropogenic impacts on glass eels in estuaries and evaluating the effects of management measures, to support initiatives aimed at helping the eel stocks recover. The model is described and applied to two estuaries with contrasting anthropogenic pressures: the Vilaine and the Garonne. It assesses the proportion of settled glass eels relative to a non-impacted situation with current (%S/R) or pristine recruitment (%S/R_0). The estimated %S/R (%S/R_0) are 5.5% (1.1%) for the Vilaine and 78% (19%) for the Garonne, in accord with the different levels of anthropogenic pressure in these two estuaries. A sensitivity analysis shows that the assessment of %S/R is accurate, and that in a data-poor context, the %S/R is under-assessed, as required by the precautionary approach. Seven management scenarios are explored, all aiming to halve the anthropogenic pressure, but in fact leading to different levels of glass eel escapement, from almost zero to a 13-fold increase. This variation emphasizes the need for the estuarine context of eel stock management to be carefully evaluated for effectiveness when implementing management measures.

7. Age, growth, and condition of European eel (*Anguilla anguilla*) from six lakes in the River Havel system (Germany)

Janek Simon

In all 199 female yellow European eels (*Anguilla anguilla*), 21.6–66.2 cm long and 3–14 years old, was collected by electro-fishing from six lakes in the River Havel system (Germany) in spring 2001. The condition and the growth rate, estimated by means of otolith increments, varied between eels within single lakes and between lakes. Fulton's condition factor ranged from 0.10 to 0.24 and the gross energy content varied between 4.3 and 15.3 MJ kg^{-1}. There were no significant differences in mean condition factor (0.16–0.18) or gross energy content (6.5–9.3 MJ kg^{-1}) between lakes. Fastest growth was in Blankensee (mean 5.3 cm $year^{-1}$), and the slowest in Lake Sacrow (mean 4.0 cm $year^{-1}$). For all lakes combined, the overall mean annual increment was estimated to be 4.5 cm $year^{-1}$. The biggest annual increment on the otoliths was generally laid down during the first and second years in fresh water, when the growth rate was 6.1–8.5 cm $year^{-1}$. Then, in the subsequent 12 years, the annual increment remained almost constant or decreased slightly (with lake-dependent values of between 1.6 and 6.8 cm $year^{-1}$). In the River Havel system, the time between stocking of the lakes with glass eels and the recapture of eels at 45 cm body length was 7–10 years. The physiologically possible maximum length (L_∞ values) of eels lay in the range 50–130 cm. Compared with previous investigations (between the 1950s and the 1970s), the only difference observed was a trend towards slower growth.

8. Eels: contaminant cocktails pinpointing environmental contamination

C. Belpaire and G. Goemans

There is growing concern that insufficient somatic and health conditions of silver European eels (*Anguilla anguilla)* emigrating from European waters to oceanic spawning areas might be a key causative factor in the decline of the stock. One factor that could contribute to deterioration in the status of eels is high contaminant accumulation in their body. Contaminants may affect lipid metabolism and result in lower energy stores. A high body burden of contaminants and low energy stores might be responsible for failure of migration and/or impairment of successful reproduction. During a 12-year study on a relatively small area within the river basins of IJzer, Scheldt, and Meuse (ca. 13 500 km^2), 2613 eels were sampled covering a dense monitoring network of 357 stations. Eels were analysed for ca. 100 chemicals. These included PCBs, organochlorine pesticides, heavy metals, brominated flame-retardants, volatile organic pollutants (VOCs), endocrine disruptors, dioxins, perfluorooctane sulphonic acids (PFOSs), metallothioneins, and polycyclic aromatic compounds. This series represents only a very small fraction (<0.5%) of the >30 000 chemicals currently marketed and used in Europe. The biomonitoring value of eels as a tool for monitoring environmental contamination is illustrated. Two major conclusions were drawn: (i) eel is a highly suitable biomonitor for environmental contaminants, for both local and international purposes, e.g. to evaluate the chemical status for the Water Framework Directive, and (ii) dependent on the degree of pollution in their habitat, the levels of certain contaminants reported in yellow eels can be high, and might affect their potential for reproduction.

9. Just go with the flow? Route selection and mortality during downstream migration of silver eels in relation to river discharge

Henrice M. Jansen, Hendrik. V. Winter, Maarten C. M. Bruijs and Harry J. G. Polman

The European eel (*Anguilla anguilla*) has been in steep decline for several decades. Fisheries and hydropower-induced mortality presumably play an important role during the downstream migration of silver eels, and downstream-migrating silver eels must make various navigation and route-selection decisions in order to reach the sea. We examined the influence of river discharge on route selection of silver eels. To quantify the impact of hydropower and fisheries on silver eel mortality, radio-telemetry experiments were performed in the River Meuse in 2002 and 2004, surgically implanting 300 silver eels with Nedap-transponders. Route selection and passage behaviour near detection stations was assessed. Silver eels were distributed over the alternative migration routes in the river in proportion to the discharge until the silver eels reached the entrance to the turbines. The eels altered their behaviour when approaching the turbines of hydropower plants and showed stationary and recurrent behaviour. We discuss the consequences of this on route selection and mortality rates caused by hydropower facilities and fisheries.

10. Silver eel mortality during downstream migration in the River Meuse, from a population perspective

Hendrik V. Winter, Henrice M. Jansen, and André W. Breukelaar

The European eel (*Anguilla Anguilla*) population has decreased sharply over the past few decades owing to a combination of many factors. To determine the impact of hydropower and fisheries during the downstream migration of silver eel in the River Meuse, telemetry experiments were performed during the years 2002–2006, using 18 detection stations (NedapTrail-System®) in the river and two at the entrance to the hydropower turbines. Recaptures in fisheries were used to assess fisheries mortality. In all, 300 silver eels were surgically implanted with Nedap-transponders. For each stretch between subsequent stations, mortality rates were assessed and related to the different factors. However, to determine the overall effect on the escapement of silver eels from the River Meuse, insight into the distribution of silver eels in the entire catchment of the River Meuse is required. At two locations, mark-recapture experiments in 2002 revealed that the estimated number of migrating silver eels increased strongly in a downstream direction, suggesting that a large proportion of silver eels start their migration from the downstream stretches and tributaries of the River Meuse. Approaches and monitoring requirements that can be used to determine the impact on silver eel populations in a river basin are discussed.

11. Assessment of population size and migration routes of silver eel in the River Rhine based on a two-year combined mark-recapture and telemetry study

Jan Klein Breteler, Tim Vriese, Jost Borcherding, André Breukelaar, Lothar Jörgensen, Stefan Staas, Gerard de Laak, and Detlev Ingendahl

More than 3000 female silver eels >50 cm were marked and released in the River Rhine at Cologne in 2004 and 2005 and more than 4000 and 6000 per year, respectively, were checked for marks in the different Rhine branches close to the sea. Migration pathways of downstream-migrating eels were also tracked by telemetry from the point of release (300–350 km from the sea, depending on the migration route) through the three main branches of the Rhine (Waal, Nederrijn + Lek, IJssel + Lake IJsselmeer) to the sea. Downstream migration to the sea took from <2 d to more than a year, but was generally in October and November of the year of release. Most successful migrators seemed to find their way to the sea via the Nieuwe Waterweg rather than via Lake IJsselmeer or Haringvliet. Some 23% of released eels of the 2004 cohort and 15% of the 2005 cohort made it to the sea in less than two years The telemetry data suggest that the Nederrijn + Lek watercourse, the only location where hydropower stations have been built in the lower Rhine system, might be important for downstream migration of eels only in the years with greater discharges, suggesting that management measures should concentrate on the Waal and downstream sections in order to improve spawning escapement of the silver eel population of the Rhine system.

12. Silver eel migration behaviour in the Baltic

Håkan Westerberg, Ingvar Lagenfelt, and Henrik Svedäng

Female silver eels (*Anguilla anguilla* L.) were tagged with data storage tags and released in the Baltic Sea at the same time at a single site on the east coast of Sweden. Data on temperature, light, and depth were obtained from six eels, continuous records for 71 days at sea. The swimming behaviour was similar for all fish, almost stereotyped: swimming activity was between dusk and dawn, starting at a light level corresponding to civic twilight and ending in the morning at generally the same light level. During daylight, the eels rested on the seabed at depths of 2–36 m. Swimming depth was typically close to the surface: up to 95% of swimming time was spent within 0.5 m of the surface. Short dives at irregular intervals (some 1–2 h^{-1}) were made down to the thermocline depth, or occasionally, to the seabed. The duration of such dives was typically 5–10 min. Although only a few days at liberty, the eels had migrated a considerable distance between recapture and release sites, indicating a mean rate of travel of ~16 km d^{-1}. The recapture positions suggested unidirectional movements towards the southwestern Baltic Sea, i.e. close to the straits leading to the ocean, supporting a belief that the recorded movements were related to eel spawning migratory behaviour.

13. Challenges for genetic research in European eel management

Gregory E. Maes and Filip A. M. Volckaert

Marine organisms experience a broad range of intrinsic and extrinsic influences during their lives, which impact their population dynamics and genetic structure. Subtle inter-population differences reflect the continuity of the marine environment, but also pose challenges to those wishing to define management units. The catadromous European eel (*Anguilla anguilla*) is no exception. Its spawning habitat in the Sargasso Sea and long migration across the North Atlantic qualify it as marine. However, the synergy between hydrographic variability, changing climate and the impacts of habitat degradation and overfishing in continental waters has negatively affected stock sizes. Its protracted spawning period, variance in age-at-maturity, parental contribution and reproductive success, and the difficulty in sampling the spawning region together may mask a weak geographical genetic differentiation. Recent molecular data report evidence for spatial as well as temporal differences between populations, with the temporal heterogeneity between intra-annual recruitment and annual cohorts exceeding the spatial differences. Despite its common name of “fresh-water eel”, the European eel should really be managed on a North Atlantic scale. The fishery may have to be curtailed, migration routes kept open and water quality restored if it is to survive. Eel aquaculture has to focus on efficient rearing in the short term and controlled breeding in the long term. Future research on eel genetics should focus on (i) sampling and analysing spawning populations and recruitment waves to detect spatio-temporally discrete groups, and establishing a biological baseline from pre-decline historical collections for critical long-term monitoring and modelling of its genetic composition; (ii) the analysis of adaptive genetic polymorphism (genes under selection) to detect adaptive divergence between populations, perhaps requiring separate management strategies, and (iii) improving artificial reproduction to protect natural stocks from heavy exploitation, especially now the species has been categorized as endangered.

14. On the application of models of European eel (*Anguilla anguilla*) production and escapement to the development of Eel Management Plans: the River Severn

M. W. Aprahamian, A. M. Walker, B. Williams, A. Bark, and B. Knights

The European eel stock has declined significantly since the 1980s, and the Eel Recovery Plan of the European Commission requires Member States to develop river basin Eel Management Plans that will achieve an escapement of silver eels that equals or exceeds 40% of the escapement biomass that would be produced in the absence of human activities. However, because silver eel escapement is not quantified within the United Kingdom, a modelling approach is required to estimate potential and actual escapement, and to assess the likely effects of management measures. We focus on two approaches developed in the UK, the Reference Condition Model (RCM) and the Scenario-based Model for Eel Populations (SMEP), and illustrate how such approaches can be used in Eel Management Plans using selected data from the River Severn. The RCM results indicate that the yellow eel population in the River Severn basin may be just 30–40% of the potential density indicated by reference conditions derived from a selection of reference rivers between the late 1970s and the early 1980s. The challenges of applying a model designed to be as realistic of eel production as possible, and the limited data on natural eel habitat and eel production in the Severn, preclude a SMEP analysis similar to that of the RCM, but simulations based on a simplified basin description and eel survey data from the early 1980s illustrate the potential of this model to assess compliance and test management scenarios.

15. Multi-objective assessment of conservation measures for the European eel (*Anguilla anguilla*): an application to the Camargue lagoons

Daniele Bevacqua, Paco Melià, Alain J. Crivelli, Marino Gatto, and Giulio A. De Leo

The European eel (*Anguilla anguilla*) stock has declined since the early 1970s and is currently considered to be outside safe biological limits. The European Commission has proposed a regulation (COM 2005/472 final) to establish measures for the recovery of the stock, with the aim of achieving an escapement to the sea of 40% of the adult eel biomass (with respect to undisturbed conditions) from each river basin. The proposed regulation imposes an effective reduction of fishing activities until implementation of an approved eel management plan. We use a demographic model, explicitly accounting for age, length, and sex structure, and important features of the continental phase of eel life cycle, to assess the effectiveness of the proposed regulation. We explore alternative management options with reference to the Camargue (southern France) eel population. Using multicriteria methods, we compare different fishing policies with respect to two potentially conflicting objectives: preserving a sufficient spawner escapement and guaranteeing an acceptable harvest to fishers. We show that the current fishery is inefficient and that appropriate management policies (such as limiting the fishing season and increasing the mesh size of fishing gear) are likely to have a doubly positive effect, by achieving the conservation target of the regulation and increasing fisher revenues.

16. When will the eel recover? A full life cycle model

Mårten Åström and Willem Dekker

The European eel population has declined over the past decades in most of its distribution area, and the stock is outside safe biological limits. The EU has taken up the challenge to design a management system that ensures the escapement of 40% of spawning-stock biomass, relative to unexploited, unpolluted circumstances in unobstructed rivers. This ultimately aims of restoring the spawning stock to a level at which glass eel production is not impaired, i.e. to restore the stock to full historical glass eel recruitment. In order to explore the trajectory from the current depleted state to full recruitment recovery, we developed a simple model of stock dynamics, based on a simplified stock–recruitment relationship and the conventional dynamic pool assumptions. Recruitment trajectories under different future fishery regimes are explored, for the medium (one generation time) and long timespan (until full recruitment recovery). Reducing fisheries to zero, recovery is expected within about 80 years, whereas under an ultimately sustainable fishing regime of just 10% of the current rate of fishing mortality, recovery may take more than 200 years. Moreover, management regimes, apparently leading to slight recovery of the stock in the coming 5–15 years, might still be unsustainable in the long run.

Annex 4: WGEEL Advice to OSPAR

Joint EIFAC/ICES Working Group on Eel

Chair: Dr Russell Poole

Term of Reference (d) '07: Provide fast-track advice, by correspondence, to OSPAR on new species and habitats to be potentially listed on their "Threatened and Declining list"

In autumn 2006, the joint EIFAC/ICES Working Group on Eel have reviewed the two proposals for the nomination of Eel, *Anguilla anguilla,* to the OSPAR list of threatened and/or declining species; one by the WWF and the other by Germany. The nomination by WWF would appear to be the more up to date although both appear weak, unbalanced and lacking in supporting arguments. Despite the weaknesses of the proposals as indicated, their factual basis is sound and they make the case that eels should be afforded the best possible management and protection. The recent reports from the EIFAC/ICES Working Group on Eel, 2004 (Galway) and 2006 (Rome) provide the most complete and up to date reviews of the expert judgment on the decline of eel recruitment and stock status, including potential factors implicated in the decline of eel. The scientific advice on the need to protect eel has been almost exclusively based on the analysis of historical time-trends, which are poorly reflected in the nominations.

The Nomination presented by the WWF: *Anguilla anguilla*, European Eel

The figures used in the WWF nomination have not been referenced and are mostly taken from Working Group reports or publications.

Geographical extent. Not sure of the relevance of the RBD map as it implies the range of the eel, or the decline/threat to eel, is limited to this area. Dekker, 2003, which is referenced in the document, provides a more detailed plot.

Decline-*Known distribution/Range*. The genetic isolation by distance scenario has now become somewhat outdated. Reference to www.fishbase.org is not a sufficient reference. The most recent research has shown that the European eel is still believed to be panmictic and the genetic variation found is mainly temporal and not spatial (Albert *et al*.2006, Dannewitz *et al*., 2005, Maes *et al*., 2006 a, b; Pujolar *et al*., 2006).

However, despite the apparent genetic similarity with distance, it should be noted that the stock is not biologically homogeneous over its range and there are considerable geographical differences in recruitment patterns, population dynamics (i.e. growth rates, sex ratios, rates of survival, and productivity of the habitat) and consequently in fisheries. This has implications for fishery management and stock recovery times across the continent.

Where relevant, specify evidence. It is not clear where figures 9.4.9.1 and 9.4.9.1 originate in and the source of the Glass Eel Time-series figure is not acknowledged.

Threat-*Where relevant, specify evidence*. The factors responsible for the decline in the eels stock and recruitment have not been fully elucidated and remain a list of probable factors. There is no reason to single out *Anguillicola* in this section as a factor on its own. The EIFAC/ICES WGEEL has discussed many of the factors influencing spawner escapement and spawner quality in its most recent reports, of which *Anguillicola* is one. The impact of *Anguillicola* on the overall stock has not been evaluated.

Changes in relation to Natural Variability. The 5–10 factor drop in recruitment quoted here is not consistent with the 1–5% quoted earlier in the document. Dekker (2004) not in reference list-presumably "Slipping Through Our Hands-PhD Thesis". The implication given from this paragraph is that climatological or oceanic factors were the over-riding cause of the decline, as there is no evident change in known factors. Whether ocean and climate caused the decline in recruitment has not been proven, and there is mounting evidence that many of the factors listed earlier probably also impact on the stock or on spawning and recruitment. Dekker (2004) demonstrated that the Knights (2003) hypothesis was not in agreement with the available data.

Expert judgement This section should at least review the latest WGEEL documents from the 2004 Galway and 2006 Rome meetings, and should probably also review the report from the September 2005 Workshop on National Data Collection-European Eel, Sanga Saby, Sweden.

Required further management. References to ICES 2001, 2003 and WGEEL 2005 are not consistent with the ***Useful references*** section.

Useful References. Not Complete-see above.

Additional references for WWF proposal

Albert, V., Jónsson, B., and Bernatchez, L. 2006. Natural hybrids in the Atlantic eels (*Anguilla anguilla*, *A. rostrata*): evidence for successful reproduction and fluctuating abundance in space and time. Molecular Ecology, 15: 1903–1916.

Dannewitz, J., Maes, G. E., Johansson, L., Wickström, H., Volchaert, F. A. M., and Järvi, T. 2005. Panmixia in the European eel: a matter of time? Proceedings of the Royal Society of London. Series B: Biological Sciences, 272: 1129–1137.

ICES. 2006. Report of the 2006 session of the joint EIFAC/ICES Working Group on Eels, ICES CM 2006/ACFM:16. EIFAC Occasional Paper No. 38: 352 pp.

Maes, E. G., Pujolar, J. M., Hellemans, B., Volckaert, F. A. M. 2006a. Evidence for isolation by time in the European eel (*Anguilla anguilla* L.). Molecular Ecology, 15: 2095–2107.

Maes, E. G., Pujolar, J. M., Raeymaekers, C., Joost, D. J., and Volckaert, F. 2006. Microsatellite conservation and Bayesian individual assignment in four *Anguilla* species. Marine Ecology Progress Series, 319: 251–261.

Pujolar, M., Maes, E. G., and Volckaert, F. 2006. Genetic patchiness among recruits in the European eel *Anguilla anguilla*. Marine Ecology Progress Series, 307: 209–217.

The Nomination presented by Germany: *Anguilla anguilla*, European Eel (Annex I)

Geographical Extent. "Adult distribution in fresh-water habitats" is too restrictive, should read either "in continental waters", or probably better to read "in coastal and inland waters".

The Black Sea has a small stock whereas the importance of the rest of the Mediterranean is under-emphasized. Quoting Froese and Pauly and Fricke in press (not available to WGEEL) was somewhat unusual: Dekker, 2003, gives the most up to date published distribution of eel and eel fisheries.

Reference to seamounts off Brazil is speculative and should not be used in this context.

Global/Regional Importance. The source of the data quoted in this section was unclear and it was not possible to evaluate how the estimates were derived. The importance of the Mediterranean is again neglected here, where up to 50% of the total stock occurs (Dekker 2003).

Decline. The Terminology needs to be consistent with published literature-"glass" larvae should be "glass-eel"-it is not a larva. "Glass eel" should be used throughout the document.

Less than 1% is not in accordance with published literature. There has been a wide variation in trend of glass-eel recruitment, with an average in the order of 1–5%. The EIFAC/ICES WGEEL in Rome, 2006, reviewed these data.

Figure 1, which has been presented on the web for public viewing, is not the up to date figure. Both WGEEL 2006 and ACFM 2006 show the up to date plots, which should be copied and referenced.

Sensitivity: No need to mention Brazil.

Glass-eel arrive right across the western seaboard of Europe and North Africa, including the Mediterranean, not just the Bay of Biscay, and the harvest of glass-eel, both for consumption/culture and stocking also takes place not only in the Bay of Biscay.

The data for age and longevity has been published by many authors, with reviews by Dekker *et al.*, 1997, Vollestad, 1992, Daverat *et al.*, 2006 and these should be reviewed before quoting 15–20 years as the average-which may be too high. There is such huge variation in growth that quoting averages may not be informative.

Threat. This section is badly researched and poorly written. It needs to be reviewed, restructured and properly referenced.

"European eel is still relatively abundant (mainly due to introductions)…." Without defining relative to what this statement is not helpful. It is unlikely that eel will become extinct in the near future, but will probably become "extinct" at the commercial level. The main difficulty in maintaining or rebuilding the level of stock is the long time-scale required for this, having identified and addressed the main causes of the collapse in recruitment.

The "relative abundance" in many areas may not be only due to stocking (introductions). Stocking may have a local affect in some areas but the low level of stocking overall and the general decline indicates that stocking has had little overall impact on stock and recruitment. Other factors, such as proximity and accessibility to the sea, geographic proximity to the ocean currents, lack of exploitation, slow growth rates, may be as influential as stocking in maintaining local stocks at a "relatively abundant" level.

"European eels are also caught as bycatch in trawl fisheries." There is little evidence of this having an impact on the stock and this may be due to misreporting of fisheries in the German Bight or outer Baltic.

The section on eutrophication, pollution and parasites is poorly written and incorrect. There seems to be confusion between eutrophication, pollution, and contamination. These are serious problems for eel and there is evidence that chemical contamination can affect spawning success (i.e. WGEEL 2006; EELREP) but there isn't sufficient data to evaluate this at the stock-wide level. Most contaminants are not absorbed through the skin, but in the diet. There is little published evidence for the occurrence of ulcers in eels in lower stretches of rivers-frequently or otherwise. There is no reported evidence that eel skin is sensitive to chemicals, although there is considerable evidence that eel fat, muscle and internal organs accumulate chemical contaminants such as PCBs, Dioxins, and pesticides. WGEEL Rome 2006 reviewed this topic comprehensively.

There is little evidence that "eels are massively affected by parasites". This should be rewritten to refer to *Anguillicola*, where in some cases infection rates may be as high as 100%, and some new virus diseases (i.e. evex), also reviewed by WGEEL Rome 2006. Such parasite infections are not a reflection of general health problems, but in extreme cases, such as with *Anguillicola*, may cause debilitation and even mortality. *Anguillicola* infections have been shown to damage swimbladders and impair the swimming ability of the eel (EELREP, 2005a, b). The impact of *Anguillicola* has also not been evaluated at the stock level.

Glass eel fisheries are not confined to the Bay of Biscay and occur elsewhere for both consumption/culture and restocking, in places such as the Netherlands, the Severn UK, Ireland and Northern Ireland. Fricke (in press) was not available to WGEEL for review.

Dekker 2003 and Moriarty and Dekker 1997 reviewed the locations of fisheries, stocking, etc. The fisheries threat is not confined to glass eel, but applies to all life stages including migrating, maturing silver eel.

Sufficiency of data. Landings data are not widely available and are often inaccurate. WGEEL Rome 2006 reviewed the available data and the report from the Workshop on National Data Collection-European Eel, Sanga Saby, Sweden, September 2005, also reviewed and made recommendations for improvements on monitoring and data collection.

The advice on the status of the eel stock is largely based on the recruitment time-series and second on the landing statistics for adult eel. It is most probable that human factors (including chemical contamination and the spread of *Anguillicola*) contributed to the depletion of eel stocks, although oceanic and climate change factors cannot be discounted.

Changes in relation to natural variability

Expert judgement. These two sections on variability and genetics are now outdated. The genetic isolation by distance scenario has now become somewhat outdated. Wirth and Bernachez (2001) may have identified variation by distance due to sampling inadequacies and when additional samples were reviewed the variation appeared to be more linked with time. The most recent research has shown that the European eel is still believed to be panmictic and that the genetic variation found is mainly temporal and not spatial (Albert *et al*., 2006, Dannewitz *et al*., 2005. Maes *et al*., 2006a, b, Pujolar *et al*., 2006).

The ICES Working Group on the Application of Genetics in Fisheries and Mariculture (ICES, 2004) reported on the possible genetic risks of transferring eels over long distances. There is a reasonably spread consensus that the European eel stock is one panmictic homogeneous stock (Dannewitz *et al*., 2005), but there are dissenters from this view. The ICES WGAGFM concluded that application of the precautionary principle obliges to minimize transfer distances and to manage the stock to produce spawning eels naturally recruited to as wide a geographical area as possible.

The evidence for spatial isolation is weak with high communality in time-trends of glass eel series across the continent, with the exception of the Britain and Ireland (Dekker 2000).

However, despite the apparent genetic similarity with distance, it should be noted that the stock is not biologically homogeneous over its range and there are considerable geographical differences in recruitment patterns, population dynamics (i.e. growth rates, sex ratios, rates of survival, and productivity of the habitat) and consequently in fisheries. This has implications for fishery management and stock recovery times across the continent.

ICES Evaluation. "Under this situation, the advice is to restore SSB above levels at which depensation is expected to occur."

The ICES evaluation paragraphs are largely lifted from the WGEEL Galway 2004 report-the WGEEL Rome 2006 report is more recent and not quoted.

Threat and link to human activities. See previous comments relating to skin ulcers, chemical and parasites. These paragraphs need to be rewritten.

"Due to its unusual and complicated life-history, reasons for the decline of the European eel are not fully understood. However, there is a link between the decline of European eel larvae and human activities, especially by fisheries on eel larvae, construction of dams, weirs or embankments in rivers, chemical pollution and eutrophication of eel habitats." This "link" has not been statistically proven although many activities are now known to act negatively on the eel stock. Negative impacts by fisheries on the eel stock are not, however, restricted to only the fishery on glass eel, but have to include fisheries on all life stages of eel.

Management Considerations. "There is a need for action regarding the fishing of European eel larvae". This action should not be confined to glass eel, but should be applied to the fishing of all life stages of eel. Given the long time-scale of a recovery of the eel stock, it is of paramount importance that glass eel recruitment and spawner escapement are afforded immediate maximum protection.

References

Fricke. In press, Fricke *et al.* In press and Fricke. In prep. were not available to the Working Group.

Additional references for the German proposal

Albert, V., Jónsson, B., Bernatchez, L. 2006. Natural hybrids in the Atlantic eels (*Anguilla anguilla*, A rostrata): evidence for successful reproduction and fluctuating abundance in space and time. Molecular Ecology, 15: 1903–1916.

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Maes, E. G., Pujolar, J. M., Hellemans, B., Volckaert, F. A. M. 2006a. Evidence for isolation by time in the European eel (*Anguilla anguilla* L.). Molecular Ecology, 15: 2095–2107.

Maes, E. G., Pujolar, J. M., Raeymaekers, C., Joost, D. J., and Volckaert, F. 2006. Microsatellite conservation and Bayesian individual assignment in four *Anguilla* species. Marine Ecology Progress Series, 319: 251–261.

Moriarty, C., and Dekker, W. 1997. Management of the European Eel. Fisheries Bulletin. Dublin, 15: 110 pp.

Pujolar, M., Maes, E. G., and Volckaert, F. 2006. Genetic patchiness among recruits in the European eel *Anguilla anguilla*. Marine Ecology Progress Series, 307: 209–217.

Vollestad, L. A. 1992. Geographic variation in age and length at metamorphosis of maturing European eel: environmental effects and phenotypic plasticity. Journal of Animal Ecology, 61: 41–48.

Annex 5: Indicang I

Implementation of a network of indicators of abundance and colonization in the central part of the colonization area of European eel: The INDICANG project

website address : http://www.ifremer.fr/indicang/

1-Objectives of INDICANG

Initiated within the framework of the INTERREG IIIB "Atlantic Area" programme, the INDICANG project federates more than 40 partners belonging to 4 countries of the Atlantic Arc: Portugal, Spain, France and UK. This project aims at the transfer and the valorisation of knowledge of the exploitation, the characteristic of the environment and the evolution of European eel population in order to help the managers to restore eel stocks, species currently in danger.

The scale of management used for European eel is the catchment area (as advised by the WG on Eel). It makes it possible to optimize the eel production by the limitation of anthropogenic constraints (of which fishing activity).

In addition, the use of this scale of studies makes it possible to associate to the maximum the eel fishers and managers by integrating at the same time their observations and by associating them to the discussion on the scientific and technical follow-ups and on the definition and estimation of the different indicators concerning the fishing activity (total captures, fishing effort, catch per unit of effort, climatic variability…).

The study at the scale of the catchment area also makes it possible to have analysis according to an ecosystemic type (framework of ecosystemic approach for Fishery management).

On 13 catchments belonging to 8 different administrative areas, the abundance of the population of eel and quality of its habitats were thus evaluated (see figure 1). The principal factors of disturbance were identified.

From these observations, the partners of the project defined relevant indicators bearing on the environmental quality, on the abundance of glass eels migrating through estuaries, on the intensity of the colonization of young yellow eels upstream, and on the abundance of the silver eels that descend the rivers and migrate towards the Sargasso Sea.

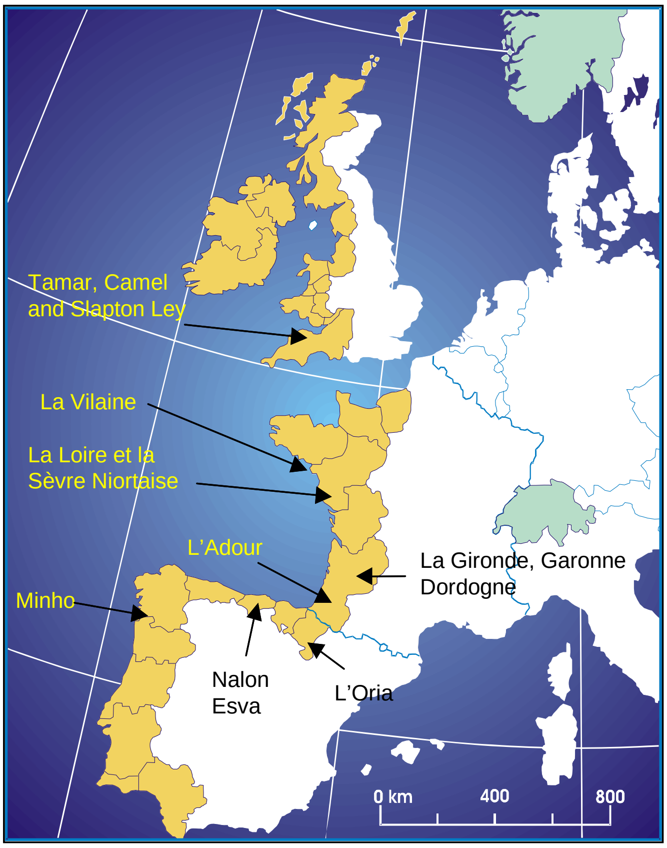

Figure 1 Geographical location of the catchment areas of the INDICANG net.

2-Implementation of indicators

Several indicators, were thus defined, being able to be potentially used for an operational and adaptive management on local and regional scales:

- the indicators of estuarine recruitment to measure the evolution of the arrivals of glass eels into the estuaries. That allows following fishing mortalities and abundance of glass eels runs towards the upstream part of the estuary. They are based on fisheries surveys, coupled with experimental fisheries. In the absence of fisheries, recruitment is deduced from experimental fisheries, counting of individuals through fish ladders;
- the indicators of colonization are used to follow the evolution of the spatial distribution, the demographic structure and the levels of yellow eel abundance on a catchments scale. Methods remain to be developed according to the constraints of the habitat and being able to provide indices from the simple presence-absence to the densities estimates.

Indicators are proposed within the framework of this project to evaluate the evolution of the colonization front of young yellow eels on the principal fluvial axes or their tributaries. They make it possible in particular to see whether the population is in phase of increasing or decreasing trends.

- the indicators on the escapement or on the potential spawning biomass produced by the catchments areas, on the sexual proportions and on the quality of silver eels. These studies are made from professional or experimental fisheries. But in the majority of the situations, the usable information comes from indicators collected on yellow eel population taking account of the proportion of silver eels.

- the indicators of environmental quality allowing to study the evolution of the biotic capacity of the continental waters, in particular by defining surfaces of available areas, suitable to produce eels and their accessibility by the inventory and mapping of obstacles to the eel migration (upstream and downstream). The standards of water quality for eel remain to be defined. Currently, they are those defined by the Water Framework Directive. Other standards will have to be worked out to evaluate the effect of contaminants on the quality of spawners and their aptitude to migrate to their zone of reproduction located at several thousands of kilometres of their production areas.

3-A methodology and a scientific and technical approach shared by the implementation of methodological and sanitary guides and a website

The approaches and the work developed within the network of partners were discussed and confronted during two end of the year seminars (Rochefort and Oporto), a final meeting at Nantes in June 2007 and different workshops of the Scientific and Technical Committee gathering the different partners working in the framework of the catchment areas groups and thematic groups. The pooling and sharing of knowledge within the website INDICANG (http://www.ifremer.fr/indicang/) was carried out and must be supplemented by the actualization of the actual status of European eel in the catchments concerned.

The theoretical and practical knowledge, either already acquired or developed within project INDICANG and adapted in the context of the network of the net of catchments, was gathered within a methodological guide.

This one will make it possible to have a practical and theoretical common base in order to set up and, if necessary, to upgrade the indicators for the evaluation of the effectiveness of management and restoration plans that the European regulation on eel will implement since 2009.

A sanitary guide is also developed in order to build a network of monitoring on the sanitary conditions of the eel populations. This document is accessible to the non-specialists and aims at:

- to sensitize the operators with the interest to collect sanitary descriptors during their operations of sampling and surveys;
- to define the design and the implementation of particular surveys requiring of sampling for sanitary analysis;
- to provide technical elements that allow the integration and the collection of external sanitary descriptors during the operations of monitoring implemented in a recurrent way in the catchments;
- to provide elements allowing to react during appearances of abnormal phenomena on a catchment area (massive mortalities, strongly suspected pathologies,…).

The follow-up of the medical aspect of the eel populations is, indeed, particularly crucial at one moment when the European Union considers the use of restocking as one of a possible solution to restore the European eel population.

4-INDICANG: its prospects "To act locally while coordinating on the Atlantic Space"

The implementation of dashboards, ultimate objective of project "INDICANG", should help the managers on a Europe and catchment area scales to evaluate the effectiveness of the restoration and management plans required by the European Union from January 2009.

The Figure 2 showing an "eel tree" summarizes the biological mechanisms involved in the production of European eel and the philosophy of the INDICANG project.

The INDICANG project fits thus in this context and takes into account this tree structure while recommending to deal locally with the leaf (action on the level of the hydrographic unit), while coordinating the actions undertaken on a significant number of leaves (action on the scale of the Atlantic Arc) so that the restoration of the foliage is sufficiently important to have a significant effect on the development of the roots.

The phase 2 of "INDICANG" will thus consist to put into practice the methods and the indicators tested on the catchment areas of the current network and to adapt them and test them on an increased number of catchments located in a larger number of areas of "the Atlantic Arc". Currently, around 25 catchments are potentially involved in that second phase.

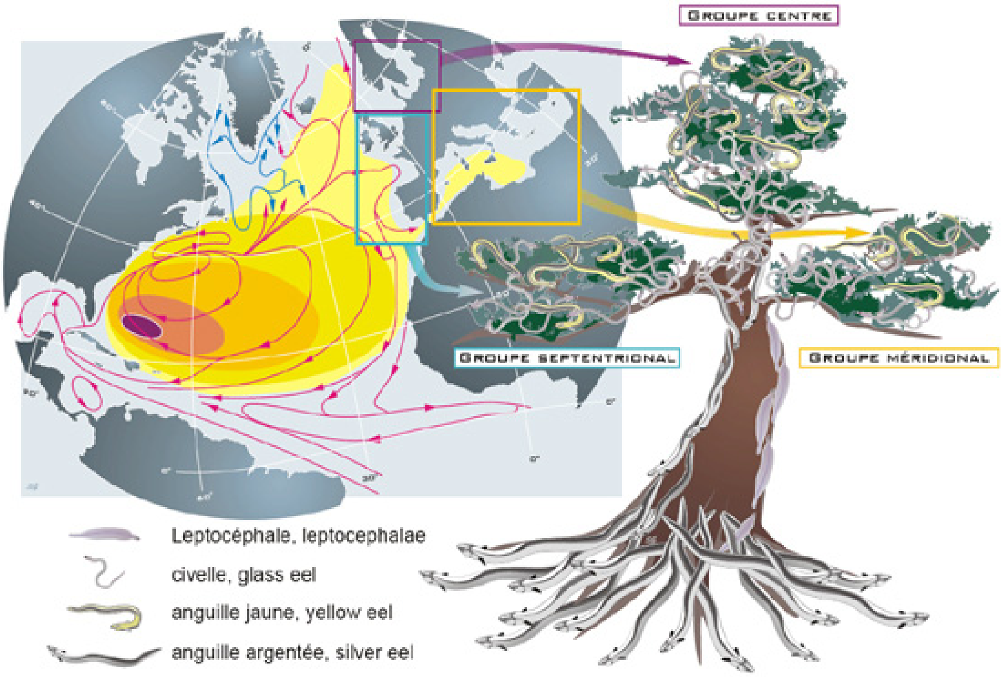

Figure 2 The Eel Tree

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Annex 7: Recommendations

The 2007 session of the Joint EIFAC/ICES Working Group on Eels at CEMAGREF, Bordeaux, France, recommends that:

a) Since recruitment remains at an all time low since records began and stock recovery will be a long-term process for biological reasons, all exploitation and other anthropogenic impacts on production/escapement of silver eels should be reduced to as close to zero as possible, until long-term recruitment recovery is assured.

b) It is of utmost importance that existing recruitment monitoring is continued, improved (e.g. removing the dependence on commercial fisheries) and extended. An assessment of the current status of the European spawning stock, including an assessment of the impact of anthropogenic mortalities, is urgently needed.

c) Research is urgently required to support the implementation the EU Regulation for recovery of the eel stock, including: development of proxies for mortality rates; develop coherent local stock assessment procedures; progress and improve population models to assess compliance with the recovery target and focus and evaluate management actions.

d) Fundamental research must also be immediately initiated and financed. The priorities include possible density-dependence effects on various processes (mortality, growth, movement, maturation and sex differentiation), and also evaluating the potential net benefit of stocking.

e) Guidelines, or best practice manuals, should be established for methodologies for assessment of the status of the eel population, the impact of fisheries and other anthropogenic impacts, stocking of eel and data quality assurance.

f) The European Eel Quality Database (EEQD) should be further developed and maintained and Member States should initiate harmonized monitoring strategies for eel.

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

Annex 8: Technical minutes ICES/EIFAC WGEEL 2007

Chair: André Forest

Reviewers: Volker Hilge and Maris Plikshs

Chair of WGEEL: Russell Poole

October 2007, by correspondence.

General comments

This is a very informative report, which shows how many aspects of the biology of the species need to be further examined in detail with regard to measures taken in support of the European stock. The report has a good quality and it is clearly a result of an ongoing process that started years ago, and therefore does not present a comprehensive overview but should be read in conjunction with previous reports. It is understandable that so wide stock distribution area and different regional investigations make it very difficult to prepare one general recommendation for whole stock that expands outside the Europe.

The executive summary gives a good overview of the results obtained in the report.

All TORs have been addressed.

The WG group has put a lot of effort to summarize available information on eel ecology (predation, mortalities), possible anthropogenic impacts, etc. However after that, there are no clear statements for present management considerations. There is list of very wide range of possible measures that have to be taken into account. Should priorities be given? This would be very useful also for ACFM advice on eel stock.

Also, it would be useful if WG would address the last year's reviewer's comments (i.e. Is the use the landings as a proxy for stock size in the S–R relationship appropriate? Are cpue relevant indicators of stock size in the case of eel? Is it appropriate to assume that fishing effort is directly related to fishing mortality? Are there indicators for trends in the fishery available, e.g. number of fishers, fishing effort, etc.?)

The main message is that the eel stock is in a very poor state since many years, and this is consistent with the previous report.

A certain number of questions were posed by the review group in 2006, but the majority remain unanswered.

Section 2. Trends in recruitment, stock and yield

No information on landings is provided. They are reflected in the national reports but not summarized. It could be appropriate to compile the landing information not only on national level but also by defined RBD; WG should consider it for the next meeting.

Quality of data from fishery dependent sources can be poor as reporting can be poor, especially with valuable fish. Is there any information on unreported landings (angling, black landings, etc)? Another issue is the glass eel export to Asia for aquaculture (outside stock distribution area). Is it included in landing figures? Is it possible to quantify this and reflect dynamic in future? Generally it would be useful to have special subchapter on trends in landing/catch for glass/yellow/silver eels.

It is not clear if it is appropriate to use the landings as a proxy for S-R relationship (Figure 2.6; see more comments under section 6 below).

Additionally, if the stock consists of several substocks/components (e.g. by RBDs) is it not better to consider the SSB-R relation for several RBDs where the data are more sufficient in order to avoid incomplete information and data corrections.

The origin of the high landings of the late 1970s is probably the result of intensive stocking activities during the preceding years. Could the WG comment on that?

Trend in glass eel prices: it would be interesting to learn about prices glass eels imported by Spain and those exported to PR China.

Layout: in Table 2.2 it is not clear (especially for LV) if the 0.0 values mean that stocked eel was less than 0.05 million, or no stocking took place.

Section 3. Stocking and transfers of eel as an aid to stock recovery

3.1 The relationship between stocking and transfer and spawner escapement is important in view of the basic concept of the EU regulation. For this reason much emphasis should be put on this monitoring. This must include in the future an increased surveillance of glass eel monitoring, because higher glass eel numbers are an expected result of this exercise. Otherwise the enormous efforts related to these aspects of the management plans have to be revised, and the possibility of fundamental influence of oceanic events on glass eel have to be looked at in more detail.

3.2 Interesting results from Lough Neagh and Baltic Sea. The latter leads to the question on the proportion of marine residents as part of the whole stock. There are estimates for the Baltic but do they exist for other parts of the East Atlantic?

Results from various studies on the contribution of stocked eels to the spawning stock are reported; most of them are preliminary and unpublished results, so it is quite difficult to draw firm conclusions, particularly because the classification between natural and stocked eels seems to be problematic.

3.4 and 3.5. These two sections provide rather good guidance for eel stocking. In the past sometimes too large numbers of glass eels have been stocked per unit area. It would be important to know how many can be stocked with regard to natural productivity of the water over the whole of the natural occurrence of the eel without depressed growth and/or impaired sex ratio. This relates to the question on which habitats eels should be stocked preferably.

3.5.5 This stocking strategy is really questionable! What are doing the glass eels arriving naturally every year at the European coasts and entering the rivers? At a 12-year generation time, what are the 11 cohorts doing?

3.8 In times of low supply of glass eel, the optimization of survival of stocked eel should have a high priority.

Section 4. Eel quality

In this section, the background information looks very wide, but it is not clear how much it contributes to the reduction of spawning stock.

4.2 Obviously PCB levels in the aquatic medium were higher a few decades ago than they are today, although the analytical tools at that time were limited. Thus the possibility exists that PCBs had a negative effect on reproduction and embryonic development. The results from recent experiments show a clear relationship. But they do not take into consideration that remobilized organic contaminants in active fish (like those during oceanic migration) are at least partly metabolized and evacuated from the body and will not be deposed with the organic material in the growing oocyte. Research to quantify this effect would be helpful and should be performed prior to its use in EMPs.

Table 4.1 The prevalence in % of the occurrence of *Anguillicola crassus* to two decimal places does not reflect the actual precision!

4.3.2 The infection rate of the European eel with EVEX is probably low. Thus it is questionable if a monitoring for this virus is really necessary. This may be more urgent with herpes virus infections.

4.9 EEQD-is there an ICES policy on the use of such databases?

First recommendation on top of page 46 ("All efforts to improve water quality…"): this is not only the business of WFD, there are other regulations and institutions to deal with that.

Second recommendation: monitoring of contaminants in fish is NOT part of WFD!

Fourth (final) recommendation: notifiable diseases are to be dealt with by veterinary services. But *A. crassus* is a disease of eel in natural waters and vets will not act in free waters. EVEX due to low incidence is not listed by O. I. E.

The whole EEQD part including research needs should be thought over by experts.

Section 5. Anthropogenic impacts on migration

This is a nice short description of the problems related to upstream and downstream migration of eels due to barriers and in particular to hydropower installations, additionally resulting in habitat loss.

Only in several cases are mentioned possible mortalities. Conclusions and recommendations of this chapter seem too general. WG should consider the overall evaluation of magnitude of downstream migration because it can be important for restocking if it could be used for increasing SSB in some RBDs.

In recent years quite a number of papers and meetings have dealt with this including possibilities to resolve the problems with bypasses. Despite WFD provisions, differences in national legislation call for joint action with the hydropower industry, but the problem of large numbers of small installations remains unsolved. Climate change discussions will even enhance the construction of hydropower dams in the future. Therefore solutions have to be found politically and recommendations as in 5.4 remain non-binding.

Section 6. The restoration process: concepts, methodologies, research needs

The whole problem related to eel recruitment, stock assessment and fisheries is reflected in this chapter:

- The amount of unreported landings (of all the three life stages glass eel, yellow eel, and silver eel) is probably among the highest of exploited fish species although it may differ among these stages.
- The lack of data on the contribution of stocking to the total stock and the catch during the past decades.
- The lack of knowledge of the density-dependence for population dynamics.
- The amount of eels resting in the marine milieu and not entering the fresh waters, which is not taken into consideration.

Are the very high catches of eels and glass eels during the 1970s a result inter alia of stocking during the years before? And why despite this important stock such a sudden decrease in the early 1980s? Looking back to about 1900 there are long-term changes in the catches that need to be explained.

SSB is estimated at approximately 10% of all landings. The mentioned background documents e.g. Dekker, 2003b was not available and therefore for such assumption more details must be provided, e.g. is SSB proportional to landings of yellow or silver eel or both together and from where (fresh waters or sea). SSB of eel can be understood as an abundance of silver eels; do the landings of silver eel constitute 10% from the total eel landings? Landings usually are dependent from the effort and therefore are not better to use the cpue series instead? Are such series exists? Furthermore, as it was noted in the technical minutes from last years, the assumption of a constant ration between SSB and landings means that F was more or less constant over 50 years. Although there could be some justification this remains speculative.

Before this background it is not unlikely that oceanic events may play a much greater role as assumed in the models presented in the report.

Before this background the recommendations proposed by the Working group and leading to an amelioration of the insufficient data situation with regard to the anthropogenic mortalities as well as on research on density-dependence processes are important but insufficient, although the latter is "basic" research. All other sources of mortalities have to be looked at as well with sufficiently high resolution.

Section 7. Sampling methodologies

No comments.

Section 8. Predation

8.10 It must be emphasized here to note that predation on eels is a factor to be considered in mortality estimations. The seriousness of the data (e.g. numbers of cormorants; % of eel as part in cormorant diets, etc.) used for eel mortality estimation should be scrutinized in the future.

Section 9. Research needs

There is much urgent research to be done on eel. The question is where will the money for it come from? This holds the more as the request for fishery-independent data gets stronger and stronger. This also indicates a situation of increasing confrontation that could lead to the exclusion of an important stakeholder, the fishery. It would be preferable to resolve raising problems by communication.

As money will be a limiting factor for research also in the future a clear ranking of research needs in the future is imperative.

Annex 9: Country Reports: Eel stock and fisheries reported by country–2007

In preparation for the Working Group, participants of each country have prepared a Country Report, in which the most recent information on eel stock and fishery are presented. These Country Reports aim at presenting the best information, which does not necessarily coincide with the official status. This Annex reproduces the Country Reports in full detail.

Participants from the following countries provided an (updated) report to the 2007 meeting of the Working Group:

Norway
Sweden
Finland
Latvia
Poland
Germany
Denmark
The Netherlands
Belgium
Ireland
The United Kingdom of Great Britain and Northern Ireland
France
Spain
Portugal
Italy
Canada

For practical reasons, this report presents the country reports in electronic format only (http://www.ices.dk/reports/ACOM/2007/WGEEL/WGEELcountryreports07draft.pdf). In the printed version, these can be found on an enclosed CD-ROM.