EUROPEAN INLAND FISHERIES ADVISORY COMMISSION
INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA

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

Silkeborg, Denmark, 20–24 September 1999

Food and Agriculture Organization of the United Nations

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PREPARATION OF THIS DOCUMENT

This report summarizes the presentations, discussions and recommendations of the Eleventh Session of the Joint EIFAC/ICES Working Group on Eels, which took place in Silkeborg, Denmark, 20-24 September 1999.

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ABSTRACT

The Eleventh Session of the Joint Working Group on Eels took place from 20 to 24 September 1999, in Silkeborg, Denmark. Forty-one participants attended the Session from 27 countries, including 21 European countries and Canada, USA, Japan, Taiwan, Australia and New Zealand. Altogether, 55 contributions were presented. The general picture throughout Europe is of declining yields in eel fisheries. Recruitment of glass eel from the ocean remains at very low levels. Development of escapement targets has been explored; several options are available, but shortage of data limits their application at the current time. The potential effects of re-stocking glass eel are discussed. Coordination of monitoring and research are badly needed. It is proposed to place coordination of research with an international research management body, in which key management levels and eel fishery and culture industries participate.

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1. INTRODUCTION

At the 85th Statutory Meeting of ICES (1999) it was decided (C. Res. 1998/2:4:15) that:

The EIFAC/ICES Working Group on Eel [WGEEL] (Chair: Dr W. Dekker, Netherlands) will meet in Silkeborg, Denmark, from 20-24 September 1999 to:

a) assess trends in recruitment and their causes, in fisheries and the effects on stock and yield of the species;

b) investigate the impact of fisheries in selected systems, especially with regard to the consequences for spawner escapement;

c) investigate the options for developing escapement targets for selected systems;

d) define relevant units where these targets would apply;

e) suggest type of management actions that may lead to the required escapement;

f) advise on international coordination of research on this species in the future.

The Working Group report of the previous meeting in IJmuiden, the Netherlands, was adopted by EIFAC at its 20th Session, Praia do Carvoeiro, Portugal, 23 June to 1 July 1998 and by ICES/ACFM at its Meeting in May 1998 in Copenhagen, Denmark.

Forty-one participants attended the current meeting of the group, from fifteen countries. The list of participants is given in appendix A.

More than fifty contributions to the meeting were presented, for the larger part in the form of posters. Contributions comprised updates on the state of stock and fisheries in individual countries, development of new techniques for analysis of the state of the stock, as well as results of physiological, methodological, oceanographic and genetics research. Appendix B lists contributors and contributions. Selected contributions have subsequently been published as a special issue of *Dana* (Vol. 12).

During the meeting of the Working Group, it was felt that ongoing management and research of eel necessitated consideration of some major issues that were not covered by the Terms of Reference. It was decided not to exclude these items from the discussions and consequently this report also contains issues not directly related to the TORs. This applies in particular to chapter 5 on re-stocking of glass eel.

The structure of the report essentially follows the Terms of Reference for the meeting, with the additional section on restocking following the discussion of fisheries related management. The last section of the report makes recommendations for the future management and coordination of research on eel.

2. TRENDS IN RECRUITMENT, FISHERY YIELD AND IMPACT FACTORS

2.1 Trends in available data series

2.1.1 Recruitment stages in Europe

There are relatively few data sets which provide information on the recruitment of the European eel and these do not adequately describe the size or pigment stages (glass eel or elver) of the recruitment material. Available time-series from 14 river catchments in 12 countries, together with estimates for the whole of Europe and for the North Sea, were examined for trends (Table 1). The data analysed were derived from both 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. Trends were examined over the entire duration for which data were available, and for the period 1980 to 1999 (to investigate more recent possible changes). The sources of the data are clearly differentiated in Table 1. Figure 1 gives examples of time series for a fishery-independent index at Den Oever, Netherlands and the total catch for the River Loire.

No upward trends were observed in any of these European data sets. Over the full extent of all time-series, downward trends were evident, reflecting the rapid decrease after the high levels of the 1970s. Over the 1980s, the trend was downwards with the exception of the Erne in north-western Ireland in which no trend was apparent. In the 1990's most series have shown fairly stable low levels.

2.1.2 Yellow and silver eel

There are also very few reliable time-series on the status of yellow and silver eel stocks and fisheries across the range of the European eel. The trends in the available data are presented in Table 2, and include information from 6 individual catchments in 5 countries, together with estimates for lakes and coastal lagoons in Italy and a national figure for England and Wales. The majority of the time-series are relatively short (< 20 years) and are derived from fishery-dependent sources; two investigations also provide information on the size/age distribution of fish in the catch. Of the four long-term data sets for yellow eel, two showed decreases and two a stable state. In both of the latter, management included stock enhancement. Silver eel catches showed downward trends in all cases. Ten time-series were examined for yellow eel in Europe and 5 for silver eel. Six of the yellow eel sets were downward, 4 stable. Trends in all silver eel series were downwards. The majority of the data sets were simply quantitative. The two that provided measurements showed that size had decreased in parallel with weight of the catch.

2.1.3 Other species of *Anguilla*

Time-series for the American eel are of potential interest in providing information on the second species of freshwater eel that originates in the Sargasso Sea. Data presented in Peterson (1997) indicated downward trends in many cases, but increases in catch and time-series showing no apparent trend were also numerous. Number of yellow eel recorded at the Moses Saunders Dam on the St. Lawrence rose to a peak in the early 1980s and then declined sharply. Richkus and Whalen (1999) report a general decline in abundance of the American eel. This may suggest common limiting factors during the oceanic phase of these two species.

The data on commercial catches for New Zealand show a peak in the fishery in the mid 1970s, with catches relatively stable from 1982 to 1997 (Peter Todd, pers. comm.) The fluctuations in catch indicate that significant variation over time is not confined to the Atlantic.

2.1.4 Aquaculture

Total annual tonnage produced by aquaculture industries (primarily in Denmark, the Netherlands and Italy) increased through the 1980s and 1990s (Table 3). The total output for 1998 was estimated at 10,280 t.

Table 1

Trends in recruitment

	Dates of time series	Number of years	Fishery dependent (D) Independ. (I)	Overall trend	Trend 1980-99	Reference
EUROPE	1994-98	5	D	↓	↓	Gelin, 1999
	1977-97	21	I	↓	↓	Westerberg, 1999
NORTH SEA						
NORWAY						
Imsa	1983-96	14	I	↓	↓	Moriarty, 2000
DENMARK						
Vida	1978-90	13	D	↓	↓	Moriarty, 2000
SWEDEN						
Nation	1977-97	21	I	↓	↓	Westerberg, 1999
Ringhals	1978-99	20	I	↓	↓	Westerberg, 1999
Viskan	1978-99	22	I	↓	↓	Moriarty, 2000
N IRELAND						
Bann	1959-99	41	I	↓	↓	Rosell, 1999
R IRELAND						
Erne	1965-99	35	I	↓	~	Moriarty, 2000
Shannon	1977-99	23	I	↓	↓	Moriarty, 2000
ENGLAND						
Severn	1987-98	12	D	↓	↓	Moriarty, 2000
GERMANY						
Ems	1965-97	33	I	↓	↓	Moriarty, 2000
NETHERLANDS						
Den Oever	1965-99	35	I	↓	↓	Moriarty, 2000
BELGIUM						
Yser	1973-99	27	I	↓	↓	Moriarty, 2000
FRANCE						
Loire	1965-99	35	D	↓	↓	Moriarty, 2000
SPAIN-PORTUGAL						
Minho	1974-94	21	D	↓	↓	Moriarty, 2000
ITALY						
Nation	1982-99	18	D	↓	↓	Ciccotti *et al.*, 2000
Tiber	1975-99	25	I	↓	↓	Moriarty, 2000

Fishery dependent (D) indicates total commercial catch
Independent (I) refers to scientific sampling

↓ = downward trend
~ = no apparent trend

Table 2

Trends in yellow and silver eel catches and indices

Catchment	Dates of time series	Number of years	Fishery Dependent (D) Independent (I)	Yellow eel		Silver eel		Reference
				Overall trend	Trend 1980-99	Overall trend	Trend 1980-99	
N IRELAND								
L. Neagh	1965-98	34	D	~	~	↓	↓	Rosell, 1999
R IRELAND								
Shannon	1984-98	15	D				↓	McCarthy & Cullen, 2000
SCOTLAND								
Dee	1990-96	7	D		~			Carss *et al.*, 1999
ENGLAND and WALES								
National	1987-98	12	D		~			Knights *et al.*, 1999
NETHERLANDS								
Ijsselmeer	1950-98	49	D	↓	↓	↓	↓	Dekker, 2000b
Ijsselmeer	1989-98	10	I		~			Hartgers, 1999
Markermeer	1989-98	10	I		↓			Hartgers, 1999
FRANCE								
Bourgneuf marsh	1987-98	9	I		↓			Baisez *et al.*, 1999
Orne	1989-97	9	I		↓			Legault & Porcher, 1999
ITALY								
Coastal lagoons	1969-96	28	D	↓	↓	↓	↓	Ciccotti *et al.*, 2000
Lakes	1969-96	28	D	↓	↓	~	↓	Ciccotti *et al.*, 2000

Fishery dependent (D) indicates total commercial catch
Independent (I) refers to scientific sampling

↓ = downward trend
~ = no apparent trend

Table 3

Trends in total aquaculture production

	Dates of time series	Number of years	Trend 1980-99
Sweden	1983-98	16	↑
Denmark	1984-99	16	↑
Netherlands			↑
Italy	1984-97	14	↑

↑ = increase

2.1.5 Contamination and parasites

Long-term monitoring of chemical contamination of the eel is in progress in Belgium (Belpaire *et al.,* 1999). The authors make the point that the eel is a particularly useful organism for long-term monitoring of chemical contaminants. Monitoring is known to be in progress in other countries and Knights (1997) has reviewed general results, but there needs to be more international coordination.

There are relatively few published data on the distribution of *Anguillicola crassus* within Europe. However, the available information suggests that the parasite is now endemic throughout most of the range of the European eel (N.B. *A. crassus* has also been recorded in stocks of American eel). Infestation rates within sampled populations have often been high and high levels of incidence within individuals are also common.

The effect of parasites and contaminants on the survival of mature silver eels during their oceanic migration and on egg production is unknown, but it could be important. More research in these areas is needed.

2.1.6 Other time series relating to population

Table 4 lists time series related to eel stocks and fisheries, known to the working group to be available. Intensity is highly variable and in general reflects an ad hoc approach, determined by the need to meet specific limited objectives at the local scale. In many cases, monitoring depends on the interest of a particular organization or individual.

2.2 Conclusion

2.2.1 Data from series available at meeting

The general picture on the status of eel stocks and fisheries throughout Europe is of declining yields. This is apparent both for capture fisheries and for scientific indices. The only exception noted in the case of recruitment was the River Erne. In the case of yellow eel fisheries, declines were noted except in two of the three cases where stock enhancement was well established. Silver eel yields were in decline throughout Europe.

2.2.2 Deficiencies of time series

The Working Group noted that the information available in time-series was, for the most part, limited to quantities of eel either caught or monitored by an index system. While the downward trends in recruitment and catch were established beyond any reasonable doubt, the lack of data on age and size of specimens severely limits the value of the time-series. Management advice based on the existing series is therefore of limited value. Requirements for future monitoring are discussed in section 6.1.

Table 4

Sources of monitoring data in Europe

DENMARK
- Central administration
  - Recruitment
    - 3 sites, two at trapping stations, one electro-fishing
  - Yellow and silver
    - Total weight according to fishing areas

SWEDEN
- Central administration
  - Recruitment
    - Numerous sites at trapping stations
    - International fish larva programme, including eel, at sea
    - Fixed monitoring by drop-net on coast (with Denmark)
    - Intake screens at nuclear power plant
  - Yellow and silver
    - Catches
      - Fresh water (lakes)
      - Coastal water by region
      - Electro-fishing surveys in many inland waters

NETHERLANDS
- Central administration
  - Glass eel at 11 sites
- Specific surveys
  - Glass eel
    - Den Oever
- Yellow and silver eel
    - L. IJsselmeer
    - R. Rhine

BELGIUM
- Central administration
  - Glass eel on River Yser
- Specific surveys
  - Yellow eel country-wide
  - Chemical contamination of yellow eel

FRANCE
- Central administration
  - BHP National database on freshwater fish population
  - Fishermen’s declared catches
    - Professional - estuary
    - Professional - fresh water
    - Non-professional

Specific surveys
- Glass eel
  - Adour
  - Gironde
  - Loire
  - Vilaine
- Recruitment (trap)
  - Sevre
  - Loire basin
  - Arzal
  - Frémur
- Yellow eel
  - Mediterranean lagoons
  - Gironde
  - Loire
  - Vilaine

IRELAND (N)
- Central administration
  - Recruitment (trap) for stocking within Erne catchment
  - Yellow and silver catch data
- Specific surveys
  - Recruitment (trap etc.) for stocking Lough Neagh

IRELAND (R)
- Specific surveys
  - Recruitment (trap)
    - Erne
    - Shannon
  - Yellow eel
    - Erne
    - Shannon
  - Silver eel
    - Corrib
    - Shannon

UNITED KINGDOM
- Central administration
- Commissioned monitoring and research programme for glass, yellow and silver eel (under consideration)

GERMANY
- Central administration
- Commissioned monitoring programme for Baltic yellow and silver eel

ITALY
- Central administration
  - Commissioned monitoring programme for glass eel in Tiber and at national level
  - Yellow and silver - Statistical market data

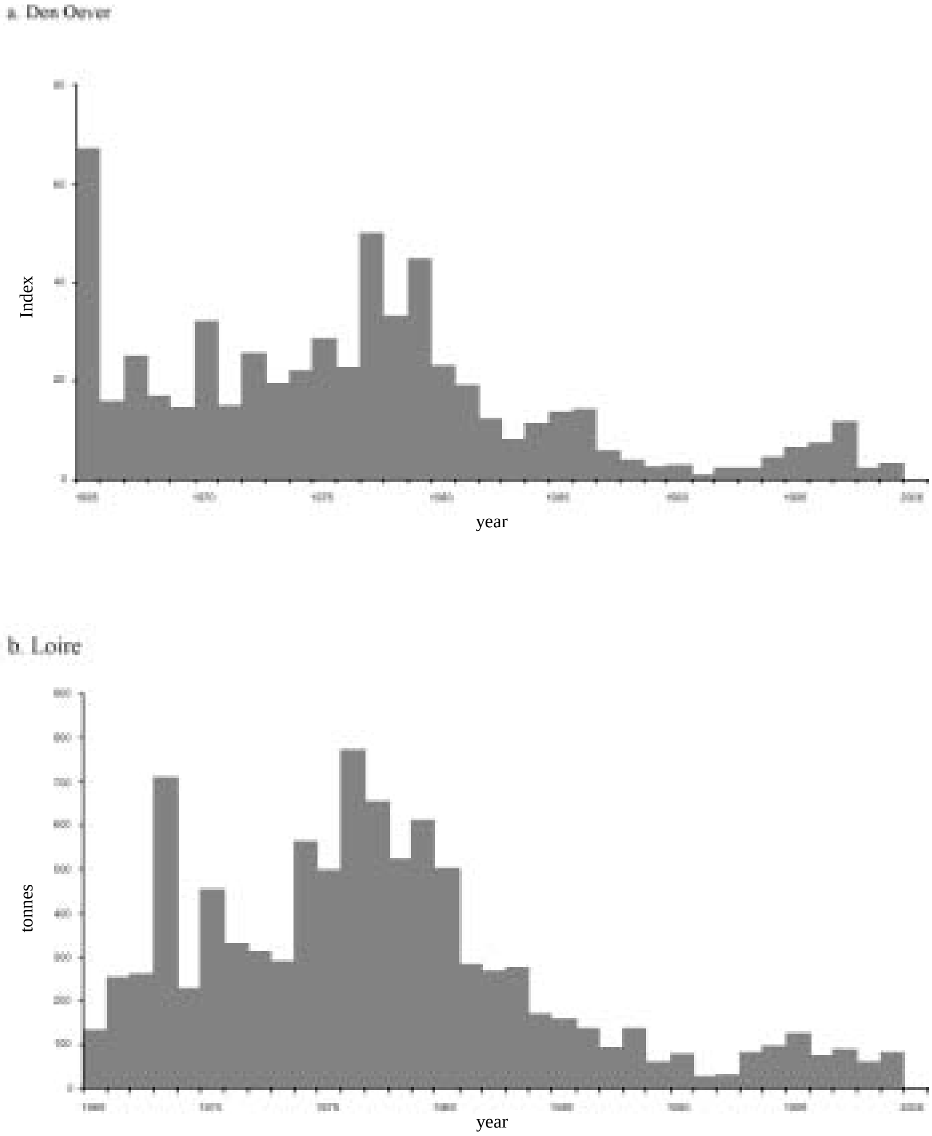

Figure 1 Glass eel trends: April density of migrants at Den Oever, Netherlands and total catch (tonne) for River Loire, France.

The fragmented nature of the eel fisheries of Europe limits the value of isolated time series. The lack of an internationally coordinated approach to the collection of long-term data adds a man-made difficulty to the problems resulting from the complex life cycle of the eel and the diverse habitats it occupies. The available information confirms casual observation and indicates both recruitment failure and the decline of the eel fishery at all life stages. Its value in the field of providing firm management advice is seriously limited. Other than monitoring future trends in catches, continuation of existing time-series will do little in the way of determining the effectiveness of any management options adopted. Guidelines outlined in section 6.1 give an indication of the requirements. Agreement by all eel-producing countries to establish a minimum permanent monitoring system is regarded as essential for future rationale management of the resource. The Working Group recommends that a small task force should be convened to develop a detailed protocol.

3. IMPACT OF FISHERIES IN SELECTED SYSTEMS ON SPAWNER ESCAPEMENT

The maturing stages of eel have never been observed in the wild, but are undoubtedly purely oceanic in nature. Escapement of silver eel from the continent provides the best indicator of oceanic spawning stock biomass, but silver eel escaping the continental fisheries are probably more correctly defined as pre-spawners. There are no means available to assess potential losses between silver eel emigrating from freshwater and the oceanic spawning phase in the life cycle. Consequently, discussion will focus on the impact of fisheries on silver eel escapement.

The information available with regard to the impact of fisheries on silver eel escapement is very limited relative to the number of fisheries operating and there are few estimates of fishing mortality. Where available, mortality data have been provided, but these are inconsistent; both instantaneous values and estimated losses over the freshwater phase have been included (see also Knights, 2001). The data also tend to be restricted to larger intensive fisheries that are not necessarily typical of the overall situation across the range of the species (Dekker, 2000a). These larger fisheries are also geographically discrete, with the major glass eel fisheries mainly in the Biscay area and SW England, the freshwater yellow/silver eel fisheries concentrated in mainland Europe and Ireland, and fisheries in the Baltic focusing on silver eel more than elsewhere. The larger fisheries contribute only a small proportion of the total European catch (~5%, Dekker, 2000a). It is thus important to recognise that the following examples do not provide full insight into escapement processes of the species over its whole geographic range.

3.1 Impacts of emigrant silver eel fisheries on escapement

The most significant silver eel fisheries are based in the Baltic (using pound nets and similar passive devices) and in Lough Neagh, N. Ireland (using silver eel traps on the River Bann). A conservative estimate of overall escapement of silver eel from European waters is 595t, estimated in Moriarty and Dekker (1997) from a known yield of 1,929t and an assumed escapement of 12% (Moriarty and Dekker, 1997). Although there are no firm data, actual escapement is believed to be higher than this in some river-based silver eel fisheries, due to inherent gear inefficiencies and current management actions to promote escapement (see below). In the Baltic, where silver eel dominate the catches, fisheries are relatively efficient and tend to take larger more fecund females. In addition, there are concerns about the ability of stocked eel to migrate successfully out of the Baltic.

The value of the above escapement estimates with regard to ensuring an adequate spawning stock biomass is restricted, both, because of the low geographical coverage and the inability to quantify mortality during the oceanic migration of silver eel. It is impractical to set separate escapement targets for either sex, but it is emphasised that females being larger and older at migration are more vulnerable to capture (and turbine mortality in power stations) than males. Therefore, increased emphasis should be given to protecting females.

3.2 Impacts of yellow/silver eel fisheries on spawner escapement

The major yellow/silver eel fisheries are the Italian lagoons and the fyke net/long-line fisheries of the Netherlands, Germany, Denmark and N. Ireland. There are few reliable data sets with regard to effects on spawner escapement. The Italian lagoon fisheries are mainly closed and stocked systems and escapement can generally be regarded as zero. Estimates for the mortality rate in the IJsselmeer fishery are high ($F = 1.0$; Dekker, 2000b) and spawner escapement is estimated to be low for males and practically nil for females. Exploitation of yellow eel in Lough Neagh is also high and, although not quantified, escapement of silver eel is thought to be low. Although these two larger scale fisheries constitute a notable part of the total yellow/silver eel fisheries, they cannot be considered to be representative of the multitude of smaller fisheries that make up the rest (Dekker, 2000a). Consequently, assessment of the continent-wide escapement is unachievable.

The above examples illustrate that yellow eel fisheries can impact upon silver eel escapement. The effect of other yellow eel fisheries on spawner escapement is unknown. However, assessment of lake IJsselmeer fisheries (Dekker, 2000b) suggests that even moderate exploitation of yellow eel results in substantial reduction in silver eel production. There are some indications that there is insufficient escapement from yellow eel fisheries in general; controlling yellow eel fisheries might enhance escapement.

3.3 Impacts of glass eel fisheries on spawner escapement

The major glass eel fisheries are based on estuaries facing the Atlantic coast of France, Spain, Portugal and south-west England (Bristol Channel). The major market in the past was for direct human consumption in Spain and Portugal, plus stocking in central, northern and Eastern Europe. However, high demands as a seed source for aquaculture in Europe (Italy, Netherlands and Denmark) and, especially the Far East, has resulted in very high prices in recent years.

Effectively, none of the glass eel catches used in aquaculture yield spawners. Limited re-stocking of cultured eel has been initiated in some parts of Europe, but this appears to be mostly for the benefit of fisheries and is thought to produce relatively few spawners.

There is little information on the impact of glass eel fisheries on recruitment into freshwater or the subsequent escapement of silver eel, for selected systems. However, natural mortality (exacerbated by density-dependent factors) is expected to be very high where abundance is very high in relation to the carrying capacity of the receiving river. Glass eel runs that exceed a river's carrying capacity may be a source for transfer to other rivers (but may also be important in contributing to the overall ecosystem). In England and Wales, relatively high fishing pressures on large glass eel runs have not produced measurable changes in riverine stocks over the last 20-25 years (e.g. in the Severn and Wessex rivers – Knights *et al.*, 1999).

In France, very high levels of fishing mortality have been recorded in certain glass eel fisheries. On the River Loire, a decrease in glass eel recruitment is followed by a reduction of yellow eel populations 8 to 15 years later (Feunteun, in press). This is consistent with an observed reduction in subsequent silver eel catches. In another example, on an obstructed catchment (River Vilaine, Brittany) which has very high fishing effort on glass eel, a reduction from 99.6 % to 96% in fishing mortality and the use of a fish ladder may have resulted in an increase (x 2.8) in the density of yellow eel in the watershed (Briand, 1999).

3.4 Conclusion

It is impossible to assess the effect of fisheries on the overall escapement of the European eel stock with any real confidence as there are insufficient data and existing estimates for specific fisheries are mostly rather crude. However, the available information indicates that fisheries on all life-stages can impact upon spawner escapement within particular locations and further suggests that some fisheries are capable of completely precluding escapement of potential spawners from a catchment or fishery.

It follows that further controls on fisheries on all components of the stock are appropriate and should contribute to enhancement of production and escapement of spawners.

4. OPTIONS FOR DEVELOPING ESCAPEMENT TARGETS FOR SELECTED SYSTEMS

Evidence presented in chapter 2 confirms a continuation of the general decline of European stocks noted in previous Working Group reports. The Working Group reiterated the need to (a) avoid collapse of the whole stock and (b) to maintain sustainable fisheries, by setting common stock-wide targets translatable into country or local fishery targets. The Working Group further recognised the particular uncertainties associated with the European eel and the requirement for adopting a Precautionary Approach for the management of the species (Russell and Potter, 1999). The Working Group were of the opinion that other 'targets' for eel fisheries might also need to be considered, such as socio-economic targets, but that these were not the primary requirement at this time. Options for setting whole-stock threshold reference limits (conservation limits) and management target levels, with discussion of applications to geographical regions and associated life-stage fisheries, are discussed below.

4.1 Threshold reference levels (conservation limits)

The following strategies were identified for further consideration as a basis for setting targets:

- input-output estimates (i.e. comparing recruitment of glass eel with silver eel escapement). This would enable the derivation of a stock-recruitment relationship and would be the preferred option for rationale management. Collection of such data for specific stocks would need to be extrapolated to other systems and allow assessment of the impact of exploitation on spawner escapement. There are insufficient data to consider such an approach at the current time, but this should be considered as a long-term goal for management of the European eel.

- comparisons of indices of exploited and unexploited populations (e.g. density, length-class structure, sex ratios, length at maturation, etc). Target compliance would require sampling of populations in both types of environments to ensure that exploited populations were producing sufficient proportions of escaping silver eel relative to unexploited ones. Such a target would have to be based on population monitoring programmes.

- escapement of emigrant silver eel in comparison with the area of available habitat and average productive capacity of silver eel for the habitat 'type'. This approach is analogous to that adopted for Atlantic salmon and would allow levels of escapement to be set for individual catchments/fisheries or for larger management units (e.g. nationally).

Escapement targets could then be set as a proportion of total capacity and would allow individual countries/regional fishery authorities flexibility in how these targets were met. However, given the current state of knowledge, setting the level of escapement required against the potential capacity would initially be largely arbitrary. Measurement of target compliance would also require direct assessment of silver eel escapement for each specified area/management unit or require further development of techniques assessing the strength of silver eel escapement from characteristics of the yellow eel stock (Feunteun *et al.*, 2000).

- Mortality model approaches (i.e. estimation of the impact of fisheries on recruitment and escapement in comparison to an unexploited state). This conforms to the approach taken in most exploited marine fish stocks. Noting that the amount of information on eel stock and fisheries is limiting this approach, only a few of the options presented in the literature on general stock assessment are currently applicable to eel management. Suggested options explored further by Dekker (1999) comprise constraints on fisheries mortality to levels not exceeding natural mortality on the basis of stock production models (F=M) and constraints on the relative impact of fisheries on the production of spawning stock biomass per recruit (%SPR) based on comparison to better known fish stocks.

- It was decided that these approaches could not be meaningfully applied to eel fisheries at the current time, given the lack of suitable base-line data for the majority of the stock and the difficulties in extrapolating from the few, relatively data-rich, subsets to potentially incomparable data-poor areas. However, the Working Group felt these options merited more detailed consideration as a basis for eel management in the longer term and suggests provisional options for conservation targets.

4.2 Provisional threshold reference levels (conservation limits)

In consideration of the current requirement for management action, the Working Group felt there was a need for a pragmatic short-term approach and suggested the following options as provisional threshold reference levels (conservation limits):

The Working Group recognises that there are no reliable data or time series on which to base a recommendation for a conservation limit. They concluded that one option was to hold exploitation at current levels (based on average catches/recruitment series and/or fishing effort over the last five years). However the absence of adequate scientific information could not be used as a reason for postponing or failing to take conservation and management measures. Consistent with the Precautionary Approach, the alternative would be to recommend some reduction in overall catch and/or effort in fisheries on all life stages, initially by an arbitrary 10%, or more where appropriate. Although there is no adequate basis on which to make such a recommendation, other than that recruitment has fallen and fishing mortality is too high in many fisheries, managers should be made aware that a provisional reduction in fisheries would be consistent with the Precautionary Approach. Noting that eels presented particularly high levels of uncertainty, and in the absence of options to quantify risks involved, the Working Group considered there was an inadequate basis for offering definite and unambiguous advice.

The Working Group recommended that fisheries should be subject to enhanced monitoring so as to enable refinement of the proposed provisional reference points, as improved information becomes available.

4.3 Management target levels

These targets are based on very idealistic aims and would be impossible to achieve in a short time scale, but are worth consideration.

4.4 Definition of relevant units where these targets would apply

Target options discussed above refer to whole-stock threshold reference limits (conservation limits) which need to be translated into appropriate local-system targets. The European eel population shows limited genetic variation only at large geographical scales (Daemen *et al.*, 1999; Maes and Volckaert, 1999), but other characteristics of the stock vary at distances of few kilometres (Dekker, 2000a). Moreover, fisheries are generally organized at small to very small scale (Dekker, 2000a), with very little and mostly clinal geographical differentiation (Moriarty and Dekker, 1997). Neither biological characteristics of the stock nor structure in exploitation patterns provide a key to develop relevant geographical management units at reasonable scales. It is therefore recommended to focus on jurisdictional entities (countries, regions, etc.), allowing for differentiation by life stage and by catchment area. This will entail:

- deriving appropriate targets from the best available catch (or effort) statistics and units of measurement available (e.g. see summaries in Moriarty and Dekker, 1997 and current report, chapter 2).
- setting, applying and enforcing targets as appropriate throughout the jurisdictional area of fishery controls to achieve the overall limits recommended above.

4.5 Management actions that may lead to the required escapement

With reliable data on recruitment, catches, effort, escapement and the status of stocks it would be possible to consider long-term management, define targets for spawning stocks and coordinate management efforts across the geographic range of the European eel. However, the current data-starved position requires a pragmatic approach before such facts and figures are available.

Where stocks are known or suspected to be depleted, application of the precautionary approach requires that recovery plans are set up to restore stocks quickly (i.e. commonly 1-2 generation times). This might represent a time span of 15 to 20 years for eel. This is probably an appropriate time period to have in mind as a basis for management.

In relation to fishery controls, there are various management options potentially available to fishery managers in individual countries to achieve the targets recommended above. Some of these are already applied to eel (see Moriarty and Dekker, 1997). In view of the volatility of eel market demands and hence possible short-term but large fluctuations in fishery pressures (as witnessed by sharp rises and falls in the markets for glass eel as seed-stock for aquaculture), fishery legislation needs to provide the capability for rapid response. In this context, it is important that individual countries have the legislative framework available to enable such management measures to be implemented. Such legislation and enforcement also need to be flexible to allow for the fact that both recreational (non-professional) and commercial eel fishermen operate in many countries. It may also be possible to combine controls on eel fishing with other requirements, e.g. controls on fyke netting to protect migratory salmonids or prohibition of in-river traps because of flood-prevention requirements.

Possible management options include:

4.5.1 Prohibition of fishing

Commercial glass eel fishing is banned in countries where elver recruitment is low (Sweden, Denmark, Germany, N. Ireland, Ireland, Netherlands, Belgium). Closure of traditional fisheries would be legislatively difficult and could result in socio-economic hardship but might be essential under extreme needs to achieve targets.

4.5.2 Total allowable catches/quotas

Application of catch size restrictions requires knowledge of stock and recruitment and identification of escapement targets. Such data are not available for different life-stages of eel and these would be difficult to monitor and enforce in the scattered inland fisheries. Therefore TAC approaches are probably not appropriate.

4.5.3 Gear controls

Controls on, for example, number, size, mesh-size, usage and location are already enforced in some eel fisheries to control fishery mortality. For example, in the Severn (England), fishing for glass eel from a moving boat is not allowed and only hand-held dip nets of a set size can be used. In some silver eel fisheries, gaps in fishing gear coverage have to be left to allow some escapement.

4.5.4 Landing size limits

Minimum size restrictions could help to reduce excessive exploitation of yellow and pre-spawner eel. For example, minimum mesh size limits could be imposed for fyke and other nets. Limits on maximum size would promote escapement of larger (that is: female) pre-spawners, but would also trigger increases in fishing efforts aiming at smaller sizes.

4.5.5 Closed seasons

Closed seasons are currently used in some countries. They are commonly based on traditional or practicable fishing season (e.g. Ireland) or are primarily related to requirements to allow unhindered migration of salmonids (e.g. Denmark, and N. Ireland). The effectiveness of fishing time controls is affected by temporal variations in eel activity and migrations, often as a result of changing environmental parameters. Only banning of fishing over relatively long time periods would be fully effective, e.g. if extending beyond the duration of local glass eel immigration or silver eel emigration runs. The timing of closed seasons must be related to local characteristics of eel and fisheries; there are no seasons in which all eel fisheries in Europe are in operation.

4.5.6 Closed areas

These could be locally effective, e.g. in preventing extension of fisheries (particularly for glass eel) into new areas or for protection of vulnerable glass eel or silver runs. Alternatively, closed areas could be used to designate ‘reserves’ where no exploitation would be permitted; such an approach is currently used in the management of eel stocks in New Zealand.

4.5.7 Licensing for fishermen and dealers

Licensing of fishermen, fishing gear and dealers could help provide, via catch returns and market statistics, information for monitoring catches and compliance with targets. The quality of such information is currently often poor, but licensing of fishermen and gear offers opportunities for controlling and monitoring fishing effort.

4.6 Conclusion

It is recognised that eel as a species presents particular management problems and that this can be further complicated by diverse interest groups with a lack of common ground. It must also be recognised that eel stocks are vulnerable to over-exploitation at all freshwater life-history stages. However, a clear need exists for active management of the resource. In the long term, enhanced monitoring of stocks would provide a more rationale basis for management; this would also facilitate identification of alternative threshold reference levels. Thus, all countries should to the greatest extent possible:

- monitor natural recruitment,
- evaluate changes in spawning escapement,
- assess stocks and population characteristics within national territory.

There is a need for uniform national standards for the collection and reporting of monitoring data to assess fishery impacts, inform management and assess compliance with and the success of fishery management initiatives. With such data it would be possible to consider long-term management and to define targets for spawner escapement more precisely and to coordinate management efforts more effectively.

5. EFFECTS OF TRANSFERS AND RE-STOCKING OF EEL

5.1 Introduction

Re-stocking can be a cost-effective means of restoring or maintaining yields in fisheries (Knights and White, 1998). To this end, it is essential in catchments with barriers where fish passes are ineffective and in isolated waters suitable for eel. Stocking in the Baltic and in mid-European countries occurs mainly because of the low recruitment over the last decades and reflects the very unequal distribution of recruitment material across the range of the European eel. Potential increases in escapement of silver eel might possibly also enhance the spawning stock. Re-stocking may be considered as an attractive alternative to a reduction in fisheries to the degree that increased escapements of silver eel result.

Re-stocking of eel has a long tradition, in some countries going back to the 19th century or earlier. It has been practised in nearly all EU-states, several middle and eastern European states, in north-African states and Norway.

Both transports within and between river systems have occurred. Transports within river systems consist of estuarine glass eel fisheries providing elvers for stocking up-river areas (e.g. glass eel in the river Bann being re-stocked in Lough Neagh). Transports between river systems involve re-distribution of glass eel over rivers within countries (e.g. Swedish west coast catches being re-stocked at the east coast) as well as long-distance international transports from the Bay of Biscay and the Bristol Channel to northern and eastern Europe (e.g. development of eastern European fisheries outside the natural distribution area). In the remaining discussion, both intra-catchment and inter-catchment re-stocking will be discussed.

5.2 Magnitude of re-stocking

The re-stocking of inland waters in Europe is believed to have dropped from unknown but probably much higher levels to approximately 33 t per year recently (Moriarty and Dekker, 1997); this is equivalent to only 6 % of the total glass eel catch (583 t per annum). The amount of glass eel used for re-stocking (both from inter-catchment and intra-catchment transports) may exceed the natural recruitment in all but the glass eel exporting countries (Dekker, 2000c).

Declining catches of glass eel, in conjunction with the rise in aquaculture demand has significantly increased the costs of purchasing glass eel for re-stocking. This has restricted the amount of glass eel re-stocked in recent years.

5.3 Re-stocking and local populations

Knights and White (1998) have described effects of eel transfers on local eel populations. Experiments show reduced growth at higher densities, but it is unknown whether these densities are reached in re-stocking practices. Re-stocking therefore might induce a decrease in growth rate in recipient populations if carrying capacity is exceeded. There are indications for differences in growth performance of glass eel originating from geographically different regions (Klein Breteler, 1991).

Fisheries, handling and transport of glass eel for re-stocking generate a mortality of unknown magnitude. Little information is available about mortalities of glass eel in the estuaries in the traditional donor areas. Mortality of ascending eel has been shown to be density-dependent within a year-class, but densities comparable in magnitude to the natural recruitment in the Bay of Biscay have not been assessed. Most glass eel in the traditional donor areas will die naturally when not fished; re-stocking will undoubtedly improve overall survival of the recruitment material in any year.

In several cases an increase in relative numbers of male eel has occurred following re-stockings. Higher densities of eel also seem to be related to a dominance of males. Transfer of glass eel from areas of high eel density to areas of low eel density may promote the overall production of females.

Transfers of eel, for trade and for re-stocking purposes, present risks of spreading diseases and parasites. *Anguillicola crassus*, a swimbladder parasite, has invaded wild eel populations throughout Europe after unintended introduction from the Far East. Negative effects of this parasite on local eel populations have been reported. Risks of transfers of diseases or parasites apply particularly to transfers of eel between catchments, but also apply, to a lesser extent, to transfers within catchments.

5.4 Re-stocking and spawning stock

5.4.1 Homing of silver eel derived from transfers

There are indications that silver eel derived from re-stocked French glass eel show a reduced ability to successfully navigate their way out of the Baltic Sea on their spawning migration. Recent experiments, however, show that migrating silver eel derived from such re-stocking have been captured off the Swedish coasts close to the exit of the Baltic Sea. The results of these experiments therefore appear to be conflicting.

5.4.2 Genetic Considerations

Available genetic evidence supports the established view that a single spawning stock breeds in the ocean (Moriarty and Dekker, 1997).

Preliminary results from genetic studies suggest that three putative, genetically distinct sub-groups may exist:

- Northern European - corresponding to the Icelandic stocks
- Western European- including Mediterranean, western European and Baltic stocks
- Southern European- corresponding to eel stocks of Morocco.

If natural gene flow between the putative sub-groups is high, the risks associated with transfer and re-stocking is low. Data on gene flow are not yet available.

5.5 Re-stocking and fisheries

A number of studies have indicated that re-stocking contributes positively to fisheries yield (Knights and White, 1998). Lough Erne fishery is completely dependent on re-stocking, while glass eel re-stocking contributes to the Lough Neagh fishery (Rosell, 1999). Yield per re-stocked recruit (glass eel) ranges from 20 to 90 g in the Baltic, but figures for Lough Neagh and Lough Erne fisheries are substantially lower.

5.6 Re-stocking and other components of ecosystems

Introductions and re-stocking of eel can affect the abundance of the crayfish *Astacus astacus* and possibly also signal crayfish *Pacifastacus leniusculus*. Impacts on other common crayfish species, such as *Austropotamobius pallipes* have not been assessed. There are no known effects on native local fish populations, except where densities of eel are high or under extreme environmental conditions.

5.7 Re-stocking in obstructed water systems

Regulation of natural river systems has obstructed migration routes of eel in many catchments. In these cases, restocking of glass eel derived from down-stream sources restores former natural conditions. Of the total of 87335 km^2 of continental waters, 3.6% has been classified as 'artificially obstructed' (Moriarty and Dekker, 1997). Hydropower stations reduce the chance of successful emigration of silver eel, specifically for the larger female eel. Eel ladders, downstream migration facilities for silver eel and intra-catchment re-stocking should be considered for restoration of eel stocks in obstructed waterways.

5.8 Conclusion

- Where possible intra-catchment re-stocking (as opposed to inter-catchment re-stocking) should be the preferred option for enhancing stocks, to minimise the risks of transfer of diseases and parasites,
- Where no alternative to intra-catchment re-stocking is available, efforts should be made to minimise the distance between the donor and recipient sites,
- To compensate for human-induced loss of safe and open migration routes for eel, re-stocking of eel should be considered when eel ladders are not sufficient to maintain adequate population sizes above in-river obstructions.

6. COORDINATION OF MONITORING AND RESEARCH

6.1 Monitoring

In contrast to the situation with many marine fishes, the distribution of the eel is too fragmentary to permit truly representative sampling. Indications are that the eel population in every one of many thousands of habitats has different characteristics (Dekker, 2000a). Nevertheless, a sampling scheme might be devised which would give some indication of the degree of variability and which would allow better global management advice to be given than is currently possible.

Two types of sampling units should be considered:

- major fisheries that make significant contributions to national yields;
- entire catchments of unspecified size in which data relating to all life-stages is obtained.

For major fisheries, a protocol should be drawn up specifying regular collection of data under the following headings: Total catch, Employment and effort according to gear type, Length and weight measurement, Age and life stage determination, Sex distribution, Contaminant and parasite burden.

Sample sizes and frequency of sampling should be determined by reference to specific habitats, subject to an internationally agreed minimum.

For entire catchments, all the above data should be collected together with observations on migration activity and a high frequency of length measurements from a large sample of both migrating juveniles and adults.

In addition, the value of established time-series cannot be over-emphasised. Continuation of collection of data at existing monitoring stations should be facilitated by national governments.

Future management of the European eel fishery needs to be put on a sound footing and cannot continue to rely on haphazard and inadequate levels of monitoring. The future of the eel fishery exceeds the capabilities of the industry alone. National governments must accept responsibility for establishing existing monitoring stations as permanent institutions. This requires adequate manpower and funding, which should be internationally coordinated. It is recommended that an ad hoc study group be convened to establish standards for monitoring with respect to sampling methodology, data recording and exchange and to set up a mechanism for regular reporting of monitoring results.

6.2 Research

The terms of reference given to the joint ICES/EIFAC working group on Eel included the request to "To advise on international coordination of research on this species in the future". In the 1993 meeting of the Working Group (Olsztyn, Poland), a preliminary overview of required research on eel was compiled (EIFAC, 1993). Moriarty and Dekker (1997) subsequently embedded research requirements in the management plan for the eel stock and suggested structures for funding. An updated overview of research needs is presented in Appendix C.

In the current request for advice, two questions must be addressed:

- What are the best means to generate cooperation on a European or wider scale?
- What are research priorities?

6.2.1 International coordination of research

International research programmes on eel require an international coordination framework. Coherent research plans have been prepared (EIFAC, 1993; Moriarty and Dekker, 1997), but research programmes have been influenced only marginally. Apparently, current management structures for research are not able to respond to (international) fisheries management needs to the full extent. If there is to be an international coordination of research, this should involve representatives of key national, international and EU organisations (management and industries), with the capacity to influence and fund relevant research. Internationally coordinated studies to date, such as the EU 1993 Concerted Action on Management of the Eel and planned work on recruitment indices, have depended entirely on the initiative of concerned individuals from EU member countries with a particular interest in eel, that is usually the scientists involved. The creation of a more formal international framework directing or requesting particular research in both individual countries and on a coordinated basis would considerably enhance the prospects for effective management of the eel stock. It is possible that the formation of an institution along similar lines to the North Atlantic Salmon Conservation Organisation (NASCO) might represent a way ahead for the European eel. However, integration of any new body into existing structures would be essential.

Where individual centres of excellence have particular capabilities to answer key questions related to eel biology and management, these organizations should be encouraged to take part in internationally coordinated programmes, thus extending techniques available at specialist centres to wider scientific community. This implies basic data currently available at national levels should become more widely available and research programmes should be geared to international rather than only national management needs.

6.2.2 Research priorities

An updated overview of research requirements is presented in Appendix C. Priority should be given to the following subjects:

Investigation of the relationship between quantity and quality of spawner emigration and glass eel recruitment on a European scale.

Research into the integrity of the stocks: is there a single stock or could there be several sub-populations? If sub-populations do exist, does this have real implications for fishery management?

Improving knowledge of the relative importance of fishing and natural mortality and the extent of density dependence at all life stages between glass eel and emigrating silver eel quantified on a Europe-wide scale.

Developing understanding of the relative contribution of various stocks (freshwater, estuarine and coastal as well as latitudinal) in Europe to overall spawner escapement.

Fisheries management changes should be accompanied by monitoring and research programmes capable of measuring their effect. Current management practices with potential adverse effects (e.g. habitat improvement, facilitation of migration or the application of re-stocking) should be subject to similar evaluation.

7. FURTHER DEVELOPMENT OF THE ADVICE ON EEL

The WG has had a dual purpose in the past: to provide requested management advice but also to provide a forum for scientific communication between eel workers. It has been suggested this duality be abandoned by organizing scientific symposia on eels, separate from the WG meetings, the latter continuing to deal with management advice. The meeting in 1999 in Silkeborg had an intermediate position, in that terms of reference specifically relating to requests for management advice were addressed in the discussions, while a wide variety of poster presentations stimulated communication between eel workers. In 2000, the American Fisheries Society together with the Electric Power Research Institute (Virginia, USA) is organizing an international symposium on Anguillids, related to management issues for the American eel in eastern Canada and USA. With respect to information related to management of the European eel, the French participants at Silkeborg announced the intention of GRISAM (Groupement d'Intérêt Scientifique pour les Poissons Amphihalins, France) to organize an international symposium on eel in France in 2001. The Working Group welcomed this initiative and recommends that ICES and EIFAC support this initiative. With respect to future work, the Working Group is of the opinion that the current management advice could be developed further in coming meetings. Future progress is principally determined by the ability to direct and coordinate monitoring and research, as discussed in section 6.2.1. With respect to the development of management advice by the Working Group, this will require scheduling the next meeting of the Working Group in due time (autumn 2000), with terms of reference focusing on:

- development of harvest rate models for eel fisheries in data-rich systems
- assessment of density-dependent processes (growth and mortality) and impacts on spawner escapement in fished v. un-fished systems
- development of proximate criteria for management of fisheries in data-poor systems
- development of procedures to post-evaluate potential effects of eel fisheries management measures, in data-rich and data-poor systems
- assessment of the (positive) impacts of management measures not directly related to exploitation, e.g. fish passes, habitat improvement, re-stocking, etc.

8. RECOMMENDATIONS

The Working Group on Eel at its eleventh session, 20-24 September 1999 in Silkeborg, Denmark, recommends that:

(1) Re-stocking of glass eel in obstructed waters preferably applies seed material of the same or nearby catchment areas.

(2) Monitoring of recruitment, stocks, fisheries and escapement be enhanced as a matter of urgency. To initiate international coordination, an ad hoc study group should be convened.

(3) Research on eel be coordinated by an international research management body, involving national and international managers and the fishing industries.

(4) ICES and EIFAC support the organization of an international symposium on eel in 2001, as is currently initiated by GRISAM (Groupement d'intérêt scientifique pour les poissons amphihalins)

9. REFERENCES

Baisez, A., C. Rigaud, E. Feunteun and J. Massé, 1999. Monitoring of European eels (*Anguilla anguilla* L.) in littoral marshes of the Atlantic coast. Paper presented at the 11th session of the EIFAC/ICES Working Group on Eels, Silkeborg, Denmark, 20-24 September 1999.

Belpaire, C., G. van Thuyne, S. Callaars, P. Roose, K. Cooreman and P. Bossier, 1999. Spatial and temporal variation in organochlorine pesticide and polychlorinated biphenyl pollution in fresh water aquatic ecosystems in Flanders using the European eel (*Anguilla anguilla* L.) as an indicator. Paper presented at the 11th session of the EIFAC/ICES Working Group on Eels, Silkeborg, Denmark, 20-24 September 1999.

Briand, C. and D. Fatinn, 1999. Late entry estimate. Paper presented at the 11th session of the EIFAC/ICES Working Group on Eels, Silkeborg, Denmark, 20-24 September 1999.

Carss, D., N.D.A. Elston, K.C. Nelson and H. Kruuk, 1999. Spatial and temporal trends in unexploited yellow eel stocks in two shallow lakes and associated streams. *Journal of Fish Biology*, 55:636-654.

Daemen, E., F.A.M. Volckaert, T. Cross and F. Ollevier, 1999. New evidence of genetic structure in European eel. Paper presented at the 11th session of the EIFAC/ICES Working Group on Eels, Silkeborg, Denmark, 20-24 September 1999.

Dekker, W., 1999. Is the European eel overfished? Paper presented at the 11th session of the EIFAC/ICES Working Group on Eels, Silkeborg, Denmark, 20-24 September 1999.

Dekker, W., 2000a. The fractal geometry of the European eel stock. *ICES Journal of Marine Science*, 57:109-121.

Dekker, W., 2000b. Impact of yellow eel exploitation on spawner production in Lake Ijsselmeer, the Netherlands. *Dana*, 12:17-32.

Dekker, W., 2000c. A Procrustean assessment of the European eel stock. *ICES Journal of Marine Science*, 57:938-947.

EIFAC, 1993. Report of the eighth session of the Working Party on Eel, Olsztyn, Poland, 24-29 May 1993. *EIFAC Occasional Paper*, 27:21 p.

Evans, D.W. and M.A. Matthews, 1999. *Anguillicola crassus* (Nematoda, Dracunculoidea); first documented record of this swimbladder parasite of eels in Ireland. *Journal of Fish Biology,* 55:665-668.

Feunteun, E., A. Acou, P. Laffaille and A. Legault A., 2000. The European eel (*Anguilla anguilla* L.): prediction of spawner escapement from continental population parameters. *Canadian Journal of Fisheries and Aquatic Science*, 57:1627-1635.

Feunteun, E., in press. Management and restoration of the European eel: an impossible bargain? *Ecological Engineering* (in press).

Gelin, C., 1999. The status of intensive eel culture in Europe, 1998. Paper presented at the 11th session of the EIFAC/ICES Working Group on Eels, Silkeborg, Denmark, 20-24 September 1999.

Hartgers, E.M., 1999. Visstand en visserij op het IJsselmeer en Markermeer: de toestand in 1998. RIVO-DLO

Klein Breteler, J.G.P., 1991. Growth and survival of glass eels *Anguilla anguilla* (L.) from different catch areas in natural, drainable ponds. Paper presented at the EIFAC Working Party on eel, 20-25 May 1991, in Dublin.

Knights, B., 1997. Risk assessment and management of contamination of eels (*Anguilla* spp.) by persistent xenobiotic organochlorine co mpounds. *Chemistry and Ecology* **14**, 171-212.

Knights, B., A. Bark, M. Ball, F. Williams, E. Winter and S. Dunn, 2001. Eel and elver stocks in England and Wales - status and management options. R&D Technical Report W248. Bristol, United Kingdom, The Environment Agency, 294 p.

Knights, B. and W. White, 1998. An appraisal of stocking strategies for the European eel, *Anguilla anguilla*. *In* I.G. Cowx, ed. *Stocking and introduction of fish*. Oxford, Fishing News Books, pp. 121-140.

Knights, B., I. Russell and R. Hamilton, 1999. National report on eel stocks and fisheries in England and Wales – 1999. Paper presented at the 11th session of the EIFAC/ICES Working Group on Eels, Silkeborg, Denmark, 20-24 September 1999.

Legault, A. and J.P. Porcher, 1999. Eel populations and recent evolution on the Orne River, Normandy, France. Paper presented at the 11th session of the EIFAC/ICES Working Group on Eels, Silkeborg, Denmark, 20-24 September 1999.

Maes, G. and F. Volckaert, 1999. Genetic structure of (sub)adult European eel based on allozyme markers. Paper presented at the 11th session of the EIFAC/ICES Working Group on Eels, Silkeborg, Denmark, 20-24 September 1999.

McCarthy, K. and P. Cullen, 2000. The River Shannon silver eel fisheries: variations in commercial and experimental catch levels. *Dana*, 12:59-68.

Moriarty, C., 2000. Monitoring results for glass eel and elver 1965-1999. *Dana*, 12:69-70.

Moriarty, C. and W. Dekker (eds), 1997. Management of the European eel. *Fisheries Bulletin (Dublin)*, 15.

Peterson, R.H. (ed.), 1997. The American eel in eastern Canada: Stock status and management strategies. *Canadian Technical Report of Fisheries and Aquatic Sciences,* 2196.

Richkus, W.A. and K. Whalen, 1999. American eel *(Anguilla rostrata)* scoping study: A literature and data review of life history, stock status, population dynamics, and hydroelectric impacts. Palo Alto, USA, EPRI Report TR-111873, 126 p.

Richkus, W.A. and K. Whalen, 2000. Evidence for a decline in the abundance of the American eel, *Anguilla rostrata* (LeSueur), in north America since the early 1980s. *Dana*, 12:83-97

Rosell, R., 1999. Key conclusions arising from Lough Neagh production data, 1959 to 1999. Paper presented at the 11th session of the EIFAC/ICES Working Group on Eels, Silkeborg, Denmark, 20-24 September 1999.

Russell, I. and T. Potter, 1999. Origin and principles of the precautionary approach and how these might apply to the European eel. Paper presented at the 11th session of the EIFAC/ICES Working Group on Eels, Silkeborg, Denmark, 20-24 September 1999.

Westerberg, H., 1999. Eel investigations 1992-1999, preliminary results. Paper presented at the 11th session of the EIFAC/ICES Working Group on Eels, Silkeborg, Denmark, 20-24 September 1999.

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APPENDIX B

List of presentations at the meeting

Anon., Portuguese data on glass eel capture.

Antunes, C., *Anguillicola* infestation of eel population from the Rio Minho (North Portugal).

Aoyama, J., S. Watanabe, T. Miyai, S. Sasai, M. Nishida and K. Tsukamoto, Invasion of the European eel into the Japanese waters: species identification and distribution inferred by mitochondria DNA. (Subsequently published in: *Dana*, 12:1-6)

Baisez, A., C. Rigaud, E. Feunteun and J. Massé, Monitoring of European eels (*Anguilla anguilla* L.) in littoral marshes of the Atlantic coast.

Bark, T. and B. Knights, Studies of historical trends in eel populations in the Severn, Dee and Dorset Rivers.

Belpaire, C., G. van Thuyne, S. Callaars, P. Roose, K. Cooreman and P. Bossier, Spatial and temporal variation in organochlorine pesticide and polychlorinated biphenyl pollution in fresh water aquatic ecosystems in Flanders using the European eel (*Anguilla anguilla* L.) as an indicator.

Briand, C. and D. Fatinn, Late entry estimate. (Material accepted for publication as Briand et al., in press. Estuarine and fluvial recruitment of European glass eel in an Atlantic exploited estuary. *Fisheries Management and Ecology*)

Carss, D., N.D.A. Elston, K.C. Nelson and H. Kruuk, Spatial and temporal trends in unexploited yellow eel stocks in two shallow lakes and associated streams. (Subsequently published in: *Journal of Fish Biology*, 55:636-654)

Ciccotti, E., S. Busilacchi and S. Cataudella, *Anguilla anguilla* (L. 1758) in Italy: recruitment, fisheries and aquaculture. (Subsequently published in *Dana*, 12:7-16)

Daemen, E., F.A.M. Volckaert, T. Cross and F. Ollevier, New evidence of genetic structure in European eel.

Dekker, W., A Procrustean assessment of the European eel stock. (Subsequently published in: *ICES Journal of Marine Science*, 57:938-947)

Dekker, W., Impact of yellow eel exploitation on spawner production in lake IJsselmeer, the Netherlands. (Subsequently published in *Dana*, 12:17-32)

Dekker, W., Is the European eel overfished?

Dekker, W., The fractal geometry of the European eel stock. (Subsequently published in: *ICES Journal of Marine Science*, 57:109-121)

Durifil, C., G. Adam, S. Dufour, P. Elie, J. Marchelidon, M. Sbaihi and B. Vidal, Preliminary results on the morphological and physiological characterisation of the different stages of eel silvering.

Evans, D.W. and M.A. Matthews, *Anguillicola crassus*. (Subsequently published in: *Journal of Fish Biology*, 55:665-668)

Evans, D.W. and M.A. Matthews, Endoparasites of yellow eels from the Erne catchment.

Evans, D.W. and M.A. Matthews, Stomach contents of yellow eels from the Erne catchment, Ireland.

Feunteun, E., A. Acou, P. Laffaille and A. Legault, The European eel (*Anguilla anguilla* L.): prediction of spawner escapement from continental population parameters. (Subsequently published in: *Canadian Journal of Fisheries and Aquatic Science*, 57:1627-1635.

Gelin, C., The status of intensive eel culture in Europe, 1998.

Hahlbeck, E. and F.-W. Tesch, The urgency of oceanic surveys on eel spawning and larvae stock for the management of the eel population and a possible financial resolution.

Hamilton, R., Eel fishery management initiatives in England and Wales.

Haro, A., T. Castro-Santos and J. Boubée, Behavior and passage of silver-phase American eels at a small hydroelectric facility. (Subsequently published in *Dana*, 12:33-42)

Jellyman, D., The new Zealand longfinned eel (*Anguilla dieffenbachii*) Can stocks sustain present levels of exploitation?

Jessop, B.M., Size and exploitation rate by dip net fishery of the run of American eel *Anguilla rostrata* elvers in the East River, Chester, Nova Scotia. (Subsequently published in *Dana*, 12:43-58)

Klein Breteler, J.G.P., Effects of transfers and stockings of eel *Anguilla anguilla* on local eel populations, the European eel stock, fisheries and environment.

Knights, B., Enhancing immigration and recruitment of eels: the use of passes and associated trapping systems. Based on paper by Knights and White, 1998, published in *Fisheries Management and Ecology*, 4: 311-324)

Knights, B., Eel catches in England and Wales: information from import/export data.
Knights, B., Eel life cycle mortality model for England and Wales.
Knights, B., Review of natural v. fishing mortality and escapement.
Knights, B., Status of eel studies in England and Wales.
(Results of these 4 papers were subsequently published as Knights *et al.*, 2001, as R&D Technical Report W248 Bristol, United Kingdom, The Environment Agency)

Knights, B. and M. Lindsay, Relationships between fecundity, age and body size of a sample of silver eels from the River Stour (S. England).

Knights, B., I. Russell and R. Hamilton, National report on eel stocks and fisheries in England and Wales – 1999.

Legault, A. and J.P. Porcher, Eel populations and recent evolution on the Orne River, Normandy, France.

Maes, G. and F. Volckaert, Genetic structure of (sub)adult European eel based on allozyme markers.

Matthews, M.A. and D.W. Evans, Summary results from an intensive fyke net survey of the Erne system, Ireland.

Matthews, M.A. and D.W. Evans, The Erne eel enhancement programme.

McCarthy, K. and P. Cullen, The River Shannon silver eel fisheries: variations in commercial and experimental catch levels. (Subsequently published in: *Dana*, 12:59-68)

Moriarty, C., Glass eel and elver catches 1965-1999. (Subsequently published in *Dana*, 12:69-70)

Mower, D., Elver studies at Leighton Moss.

O'Connor, W. and T.K. McCarthy, Recruitment and stock enhancement of eel in the River Shannon, Ireland.

Oliveira, K. and J.D. McCleave, Sexually dimorphic growth of American eels from Maine rivers.

Olsen, N.K. and M.I. Pedersen, The Poseidon theory.

Pedersen, M.I., Long term estimate of survival and growth of stocked eels *Anguilla anguilla* (L.) in a small eutrophic Danish lake. (Subsequently published in: *Dana* 12:71-76)

Pedersen, M.I., Fishing mortality on silver eels. (Subsequently published in *Dana*, 12:77-82)

Richkus, W.A. and K. Whalen, Evidence for a decline in abundance of the American eel (*Anguilla rostrata*) in North America since the early 1980s.

Rosell, R., Key conclusions arising from Lough Neagh production data, 1959 to 1999.

Russell, I. and T. Potter, Origin and principles of the precautionary approach and how these might apply to the European eel.

Thomassen, S., M.I. Pedersen and G. Holdensgaard, Tagging European eel with coded wire tags.

Tzeng, W.N., C.H. Wang, H.R. Lin and S.N. Nu, Sexual differences in age at maturation and growth rate of the Japanese eel *Anguilla japonica*: A life history strategy.

Van Ginneken, V. and G.V.D. Thillart, Fat stores of European silver eel (*Anguilla anguilla*) are sufficient for spawning migration.

Van Ginneken, V. and G.V.D.Thillart, Seasonal changes of endocrine and metabolic parameters of European yellow and silver eel.

Westerberg, H. and M.-L. Begout-Anras, Observation of silver eel (*Anguilla anguilla*) in a disturbed geomagnetic field.

Westerberg, H., Eel investigations 1992-1999, preliminary results.

Wickström, H., K. Limburg, H. Svedäng and L. Westin, Do freshwater eels and even stocked ones contribute to the spawning stock?

Williamson, G.R., Drifting and dreaming: is this how baby eels cross the Atlantic?

APPENDIX C

Detailed research requirements

Within the overall research priorities given in the main text, the following detailed issues, grouped in terms of critical phases within the eel life cycle, are not yet sufficiently understood to allow effective management of the European stock or stocks. The information in this appendix derives in part from the text of "Management of the European eel" (Moriarty and Dekker, 1997), but also includes important new items raised in discussion of papers and posters presented at the ICES/EIFAC meeting.

C.1 Yellow eel phase

C.1.1 Quantitative Investigation of how the growing and fished stocks contribute to the production of viable spawners.

C.1.1.1 Effects of stocking and transplantation at varying stages from glass eel to yellow eel and over varying distances

C.1.1.2 Development of indices of habitat suitability for eel in order to model potential capacity of freshwater systems

C.1.1.3 Quantification of accessible and inaccessible but potentially usable production areas and the degree to which these are currently utilised by eel.

C.1.1.4 The mechanisms of sex determination, whether genotypically and/or environmentally controlled.

C.1.1.5 The effects of bioaccumulation of pollutants, disease status and parasite burdens

C.1.2 Other issues relating to yellow eel phase

C.1.2.1 Effects of eel management and conservation on ecology of aquatic ecosystems

C.1.2.2 Effects of fishery regulations, of potential fishery management changes, and current practices on socio-economic issues

C.2 Silver eel phase

C.2.1 Developing common methods to assess silver eel escapement

C.2.2 Investigation of triggers inducing "silvering" and migration

C.2.3 Quantifying the cumulative stock-wide effect of man-made and natural impacts on downstream migration.

C.2.4 Measuring the relative contribution of silver eel from differing regions to the spawning stock with reference to divergent "population" characteristics such as size, fecundity, and pollutant burdens.

C.2.5 Further investigation of migration success of silver eel transplanted or stocked earlier in life.

C.2.6 Investigation of means by which silver eel navigate.

C.3 Oceanic phases

There is still a major gap in knowledge of what happens between potential spawners leaving coastal waters and the subsequent return of glass eel. Almost nothing is known of what happens between silver eel departure and the appearance of *Leptocephalus* larvae in the plankton. While coastal based measures of the possible quantitative relationship between emigrating silver eel and returning glass eel appear more likely to yield useful management information in the short or medium term, developing our understanding of the whole life cycle, while clearly difficult, must remain an ultimate goal.

C.4 Spawning eel

C.4.1 Identifying emigration routes and (if possible) more accurate location of spawning grounds. This might require intercontinental coordinated projects. There is a strong possibility that remote sensing and tagging technology will soon be available in sufficiently miniaturised form to enable tracking of oceanic silver eel.

C.4.2 Laboratory studies of sexual maturation mechanisms.

C.5 *Leptocephali*

Investigations on oceanic *Leptocephali* are likely to require large scale and expensive ship based work. While studies under C.4.2 are likely to be more feasible/fruitful in the short term, a long-term goal of fully understanding the biology of the *Leptocephalus* phase is clearly desirable. There are possibilities for useful studies in this area, including:

C.5.1 Investigations of effects of oceanographic events on stock/recruit relationships.

C.5.2 Possible effects of climate change on oceanographic events with consequent effects on eel. Both this and C.5.1 would require new collaboration between eel scientists and oceanographers prepared to present their expertise with a focus on oceanic stages of eel.

C.5.3 Investigations of the fundamental biology of the *Leptocephalus* stage.

C.6 Coastal and estuarine returning phase (glass eel)

C.6.1 Natural and fishing mortality in estuaries and whether or not these are factors critical to the development of upstream stocks.

C.6.2 Factors (manmade and natural) affecting upstream migration

C.6.3 Carrying capacities of continental areas.

C.7 Research issues relating to all life cycle phases

C.7.1 Further genetically based assessments of the integrity of the stock of European eel.

C.7.2 Biological databanks off all life stages from all regions should be compiled as a follow up exercise to and extension of the earlier databank of glass eel material created following the 1993 EIFAC working group on eel.

C.7.3 Wider cooperative projects should be considered where benefits are to be gained from cooperative studies of European eel and other global species

C.8 General principles governing international research programmes:

C.8.1 In any internationally coordinated programme or research project, attention should be given at the outset to issues of data comparability and quality.

C.8.2 Where possible, methods used in gathering data used in internationally compiled sets should be intercalibrated between participating organizations.

C.8.3 Agreement on definitions is required in presentation of international data using the terms silver eel and glass eel.