WORKSHOP ON THE FUTURE OF EEL ADVICE (WKFEA)

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i Executive summary

The purpose of the WKFEA was to discuss the current ICES advice[1] framework, consider options for future assessment and advice needs and draft a roadmap towards recommendations for a new or adapted advice framework for fishing opportunities and potentially other anthropogenic pressures on European eel.

The current Advice given on eel was considered to be in accordance with the precautionary approach as applied by ICES. However, there is room for improvement in the clarity of the current Advice given to make it relative to fishing opportunity, whilst considering the other anthropogenic impacts in another section of the advice sheet. While there is a need to define reference points to inform managers of the state of the stock and with respect to recovery, the current Advice given was considered to use the best available quality assessed knowledge. Whether the ICES advice supports management decisions sufficiently is difficult to assess since the two are set at different spatial scales.

Options for improving the evidence base and adapting the advice were considered. Whether the advice is given for the whole stock, over its entire distribution area was not questioned. However, given the spatial heterogeneity in the stock and fisheries distribution, a spatialised stock assessment model seems necessary to estimate trends in mortality at the population scale. A table of specific issues relative to general concepts (biological parameters, biological reference points, assessment methods, fisheries and ecosystem issues) was drawn up, and challenges, together with potential solutions, were described.

To scope the need for advice and the associated concepts with the requesters and end-users, an online survey was developed and distributed amongst the requesters and end-users to evaluate their level of awareness on the recurrent ICES advice, its role and contents, and to understand their needs, in order improve either the content or formulation of the advice. Some of the answers are eel-specific and mostly relate to the ambiguity of the current advice, which mixes fisheries opportunities and conservation needs. Others are more general and could apply to most of the ICES advice products and raised concerns on the form and/or language that they may not be so easily understood. A need for a better communication strategy to/between all players was also mentioned.

Finally, the future of eel assessment and advice was addressed through a roadmap that targets two major improvements: 1) to improve the data that should be part of a stock analysis, and 2) to provide more holistic advice by taking the whole ecosystem into greater account and looking in more detail at the impacts of the different types of pressures affecting the eel population.

[1] Note that throughout the text Advice, with a capital letter refers to the headline of the advice sheet, i.e. the section currently called 'ICES advice on fishing opportunities' whereas advice with lower case refers to the full text given by ICES for each stock

ii Expert group information

Expert group name	Workshop on the future of eel advice (WKFEA)
Expert group cycle	Annual
Year cycle started	2020
Reporting year in cycle	1/1
Chairs	Estibaliz Diáz, Spain
	Alain Biseau, France
Meeting venues and dates	By correspondence, 2 November 2020–29 January 2021
	Online meeting, 1–5 February 2021 (26 participants)

1 Introduction

Despite increased efforts to aid the recovery of the European eel stock since the implementation of the "Eel Regulation" (EU 1100/2007) it remains at a very low level, and it is considered to be outside safe biological limits according to the latest ICES advice (ICES, 2020d).

However, the current advice is, almost exclusively based on recruitment time-series (lacking meaningful biological reference points for the management of the stock) and could be improved, to better account for the complex biology, assessment and management of the species.

The stock is considered at two levels:

i) The whole (panmictic) stock, which is scattered across Europe and North Africa;
ii) The regional level, given there is large variation in vital population characteristics (e.g. growth, sex ratio, age at maturation) as well as fisheries and other anthropogenic sources of mortality (e.g. hydropower) across the distributional range, all of which need to be accounted for in the assessment and management of the stock.

The current advice considers the eel at the whole stock level.

Since large improvements have been made in European eel stock data collection and availability (which provided information towards a distribution-wide database developed by the WGEEL) it is deemed necessary to review and improve the current Advice and advice framework whilst developing concepts on how to further improve these to make use of the best scientific knowledge available, in line with the ICES rules on advice, and thus provide a more functional Advice for managers.

2 Workshop Terms of Reference and Reporting

2.1 Terms of Reference

2020/2/FRSG47 **Workshop on the future of eel Advice (WKFEA)** chaired by Estibaliz Diaz, Spain, and Alain Biseau, France, has worked by correspondence from the 2 November 2020–29 January 2021 including a kick-off meeting on the 10th of November 2020, plenary meetings on the 1st and 18th of December 2020 and the 18th of January of 2021 in addition to several subgroup meetings. Finally, from 1–5 February 2021 the group met daily online to finalise the work. The objective of WKFEA is to discuss the current advice framework, consider options for future assessment and advice needs and draft a roadmap towards recommendations for a new or adapted advice framework on fishing opportunities and potentially other anthropogenic pressures on European eel. Acknowledging that ICES has provided advice on fishing opportunities and effectiveness of eel management plans in the past, this WK will provide recommendations for advice and potential approaches to deliver those recommendations to ICES, GFCM and EIFAAC. To achieve this aim, the WK will address the following ToRs:

- **ToR 1:** *Does the current advice include recent methodological advances and current knowledge?* Review and discuss the current advice procedure and identify relevant end-users (also other than the EC). Elicit whether the advice complies with the precautionary approach, is based on the best scientific information available, sufficiently supports management decisions, considers all relevant anthropogenic sources of mortality, or can be improved in any other way. Identify potential issues that need to be addressed in future advice and define evidential needs (assessment requirements) to support management and recovery of the eel stock.
- **ToR 2:** *What are the options for improving the evidence base and adapting advice?* Use all available sources of information (WGEEL Database, FAO data, literature, etc.) and consider general concepts for the future assessment and consecutive advice.

  Evaluate these concepts in terms of their feasibility, considering e.g. the precautionary approach, the support of management decisions, the advisory framework and data needs. Outline the challenges and opportunities for providing a more operational advice.

- **ToR 3**: Scope the needs for advice and the concepts with the requesters, to determine the feasibility for requesters to meet their management objectives.
- **ToR 4:** *What is the future of eel assessment and advice?* Based on the findings of the above, and where deemed appropriate, draft a roadmap (or roadmaps) towards future advice for the European eel stock (in context of the ecosystem approach). This/These should elaborate the modalities of potential assessment approaches (method, frequency, scale, reference points, etc.), customize data needs, define objectives for future work and set a time frame for the completion of these tasks.

2.2 Structure of the remainder of this Report

Chapters 4–7 are structured according to ToRs 1–4 and designed to specifically answer the questions therein. First, each chapter provides a summary answering the questions posed in the ToR based on a detailed analysis of the issue, which is presented throughout the chapter.

Annex 1 provides a list of the references cited in the report.

Annex 2 provides a glossary of terms and acronyms used in this report.

Annex 3 includes the list of participants to the workshop.

Annexes 4 and 5 include the tables regarding the Scientific information potentially challenging the recurrent ICES advice rationales and the available data and their potential use to support the recurrent ICES advice respectively, that have been the basis for the discussion in Chapter 4 about whether the advice is based on the best scientific information available.

Annex 6 contains the recommendations made by WKFEA drawn from the conclusions in the present report.

2.3 Participants

Twenty-eight experts from 15 countries attended the meeting, along with four participants from the European Commission's Directorates Generale (DG) MARE and ENVIRONMENT, the General Fisheries Commission of the Mediterranean (GFCM), FishSec and Chuo University, Japan. A list of the meeting participants is provided in Annex 3.

2.4 ICES Code of Conduct

In 2018, ICES introduced a Code of Conduct that provides guidelines to its expert groups on identifying and handling actual, potential or perceived Conflicts of Interest (CoI). It further defines the standard for behaviours of experts contributing to ICES science. The aim is to safeguard the reputation of ICES as an impartial knowledge provider by ensuring the credibility, salience, legitimacy, transparency, and accountability in ICES work. Therefore, all contributors to ICES work are required to abide by the ICES Code of Conduct.

At the WKFEA online kick-off meeting on 10 November 2020, and for all newcomers later in the meeting, the chairs raised the ICES Code of Conduct with all attending expert members. In particular, they were asked if they would identify and disclose any actual, potential or perceived CoI as described in the Code of Conduct. After reflection, none of the members identified a CoI that challenged the scientific independence, integrity, and impartiality of ICES. Three members declared a potential CoI and offered to remove themselves from relevant discussions, but following consideration by the Chairs and the WKFEA participants, in consultation with the ICES secretariat, it was agreed that there were none.

3 The European eel: life history and production

During its continental phase, the European eel (*Anguilla anguilla*) is unevenly distributed across most coastal countries in Europe and North Africa, with its southern limit in Morocco (30°N), its northern limit situated in the Barents Sea (72°N) and spanning the entire Mediterranean basin.

The European eel life history is complex, being a long-lived semelparous and widely dispersed species. The shared single stock is considered genetically panmictic and data indicate that the spawning area is in the southwestern part of the Sargasso Sea. However, actual spawning and the events leading up to reproduction have yet to be seen with much of this remaining unknown. Artificial reproduction of European eel is still very much in its infancy.

The newly hatched leptocephalus larvae drift with the ocean currents to the continental shelf of Europe and North Africa, where they metamorphose into glass eels and enter continental waters. Glass eel densities are greatest in the centre of their distribution around the Bay of Biscay, with high densities also occurring in the eastern Mediterranean and in the Bristol Channel (Dekker, 2003). The growth stage, known as yellow eel, may take place in marine, brackish (transitional), or freshwaters. This stage may last typically from two to 25 years (and can exceed 50 years) prior to metamorphosis to the "silver eel" stage, maturation and spawning migration. Strong sexual dimorphism occurs in eels with males maturing at a younger age and smaller size.

The abundance of glass eel arriving in continental waters declined dramatically in the early 1980s to a low in 2011. The reasons for this decline are uncertain but anthropogenic impacts and oceanic factors are assumed to have major impacts on the stock. These factors will likely affect local production differently throughout the eel's range. In the planning and execution of measures for the recovery, protection and sustainable use of the European eel, management must therefore account for the diversity of regional conditions.

4 ToR 1: Does the current Advice include recent methodological advances and current knowledge?

The aim of this chapter is to answer to ToR 1. During this chapter detailed analysis of different aspects of the assessment has been made.

The following conclusions have been reached to answer to the ToR requirements:

- The current Advice was considered to be in accordance with the precautionary approach as applied by ICES.
- Whether the Advice sufficiently supports management decisions is difficult to assess since the management decisions are set at spatial scales that are not the same as the scope of the Advice.
- There is room for improvement in the clarity of the current Advice (e.g. "*all anthropogenic impacts...should be reduced to, or kept as close to zero as possible*") to ensure that there will be no ambiguity in future Advice (e.g. "zero catch at all").
- In addition to a clear Advice, there is a need to define reference points to inform managers of recovery of the stock.
- The current Advice uses the best available quality checked knowledge (mostly recruitment indices).

The Identification of the end-users has been made in the Chapter 6 since it seemed to be more related to the content of that chapter.

4.1 Review the current advice procedure

4.1.1 Basis for ICES advice on the European eel

4.1.1.1 Legal framework

The Advice is provided by ICES in a document known as an ICES advice Sheet (i.e. ICES, 2020d). The advice sheet ('advice' in this document) refers to the full text provided by ICES for each stock. Each advice sheet contains different sections. The Advice (with a capital A) refers to the headline of the sheet, i.e. the section currently called '*ICES advice on fishing opportunities*'. The sheets also contain sections related to stock status, quality and issues relevant for the management.

The current request for ICES scientific advice by the EU, (as represented by the European Commission), is stipulated in the Specific Grant Agreement No SI2.826068 (EC, 2020). As a species listed in Annex II of the agreement ICES is requested to produce, among other advisory deliverables, recurring single stock advice for the European eel, which is independent of political influences and subject to the best international quality procedures.

The general purpose of the Advice is to provide '*management advice on fishing opportunities*' (expressed in catches) for the commercial and, where applicable, also recreational fisheries. Considering the possible differences between stock and management areas, ICES is supposed to inform on this discrepancy for stocks listed in Annex II (e.g. the specific distribution of stocks to several management areas). Further expected outputs relevant for the European eel are the delivery of stock-specific reference points, an overall assessment of the status of the stock and whether it is within safe biological limits according to the Common Fisheries Policy (CFP; EU, 2013), in addition to the current annual analyses of long-term development of the stock and its exploitation, accounting for factors other than fisheries. In this context, ICES is committed to advise on any significant changes in the marine ecosystem impacting stocks. Note, that it is not specified in the agreement (EC, 2020) whether changes in freshwater or transitional systems, impacting diadromous fish, are to be addressed.

It is the responsibility of ICES to call for and quality assure the data needed for the advice issued, though it is noted that ultimately ICES Member States are responsible for the quality of the data delivered to Data Calls. ICES will support the implementation of the DCF (EU, 2017), assisting the EC with matters related to the data collection, e.g. by presenting data needs relevant to the work of expert groups as well as inform on any issues encountered with the transmission of data.

4.1.1.2 The ICES advice framework

The ICES approach to the provision of advice on fishing opportunities, integrates the Precautionary Approach (PA) with the objective of achieving Maximum Sustainable Yield (MSY), unless otherwise requested. The aim, (in accordance with the aggregate of international guidelines (e.g. UN, 1995) is to inform policies for high long-term yields while maintaining productive fish stocks in marine ecosystems that meet expected environmental standards (e.g. good environmental status [GES] in the EU).

To address advice requests, ICES has developed a framework that includes specific advice rules (ICES 2020a):

i) for stocks with a management plan/strategy that has been agreed by all relevant parties and evaluated by ICES and found to be consistent with the PA, the advice will be given in accordance with the management plan;
ii) for stocks with no management plan that has been agreed by all relevant parties or evaluated by ICES not to be consistent with the PA, the MSY approach is applied;
iii) for stocks with insufficient information or for stocks that are outside safe biological limits, ICES applies the PA.

Due to the variability in stock size, there may be situations where the spawning stock is so low that reproduction is at significant risk of being impaired. A precautionary approach implies that fisheries management in such situations should be more cautious. For stocks where quantitative information is available, a reference point B_{lim} may be identified as the stock size below which there is a high risk of reduced recruitment. In such cases, ICES will advise zero catch until the spawning–stock biomass is above B_{lim} with high probability.

4.1.1.3 The advisory process

In order to deliver the advice, ICES has implemented an advisory process which has been agreed by the Advisory Committee (ACOM): Starting with a client's request, ICES will install an expert group (EG) for recurrent advice requests (or a workshop for non-recurrent advice). A resolution for the group is developed by the chair of the group, together with the steering group and the ICES secretariat for approval by ACOM and the Scientific Committee (SCICOM). Once approved, data will be provided to the EG through Data Calls to facilitate the stock assessment exercises and analyses delivered by the EG. The results are presented in the form of a report, which is submitted to an internal audit, and serves as the scientific basis for the advice, which is drafted by an Advice Drafting Group (ADG) for approval by ACOM before being delivered to the client. While the EG reports do not necessarily represent the view of ICES, all of the ICES advices are under the overall responsibility of ACOM.

The Advice is provided in a document known as an **ICES advice Sheet** (i.e. ICES 2020d).

The advice sheet ('advice' in this document) refers to the full text provided by ICES for each stock. Each advice sheet contains different sections. **The Advice** (with a capital A) refers to the headline of the sheet, i.e. the section currently called ***'ICES advice on fishing opportunities'***. The sheets also contain sections related to stock status, quality and issues relevant for the management. ICES advice Sheets are provided on a recurrent basis (**recurrent ICES advice**); but other ad-hoc advice can be provided to answer **special requests**.

The advisory process is outlined in Figure 1, and is further detailed in the Guide to ICES advisory framework and principles (ICES 2020) and the Guidelines for ICES Groups (ICES 2021).

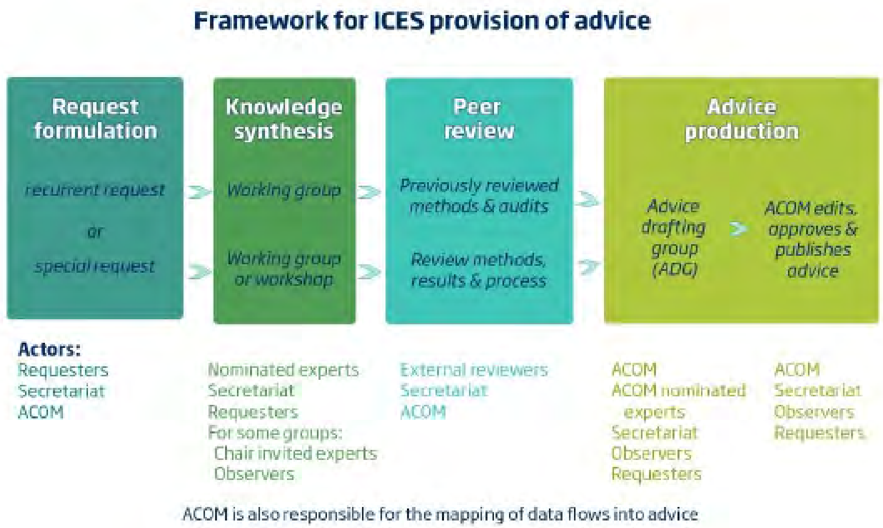

Figure 1. Schematic of the ICES advisory process (ICES guidelines: ICES 2020).

Recurrent Expert groups are subject to periodic benchmarks to develop/improve methods for the stock assessment, including the selection of dataseries to be used. Benchmark reports are peer reviewed. Note, that the methods for assessment of European eel used by ICES have so far not been benchmarked.

4.1.1.4 The European eel in the advice framework

Eel is classified as a category 3 stock: "*stocks for which survey-based assessments indicate trends. Includes stocks for which survey or other indices are available that provide reliable indications of trends in stock metrics, such as total mortality, recruitment, and biomass*" (ICES, 2019). The reason for this is that there are not enough data available for a quantitative assessment (category 1 and 2 stocks), but there is an index available which functions to indicate a trend in eel recruitment.

For those stocks in category 3, without reference points, and with extremely low biomass relative to previous estimates, the provision of a precautionary Advice includes a zero-catch Advice (ICES, 2021).

4.1.2 What happened so far?

4.1.2.1 Reference points for the eel stock, proposed and adopted

This section summarises the reference points (and values), as developed and proposed by WGEEL, and as adopted in the ICES advice. The aim is to provide a comprehensive overview of what has been discussed, without prejudice or preference. As such, this historic overview describes early suggestions and not-fully tested approaches, as well as fully-fledged frameworks. Additionally, this summarises the reference points, as adopted in the ICES advice.

In the light of the growing evidence on the long-term decline of the eel stock across Europe, ICES (1999, 2000) advised that "*the stock is outside safe biological limits*" and recommended, "*that a recovery plan should be implemented for the eel stock*". ICES (2001) later added "*Until such a plan is agreed upon and implemented, ICES recommends that exploitation be reduced to the lowest possible level.*" This advice was primarily based on the observation that landings had been in decline since at least the 1960s, and that glass eel recruitment had been in rapid decline since 1980. As a long-term goal for recovery, ICES (2002a[2]) suggested rebuilding recruitment to levels "*similar to those of the 1980s* [meant is: pre-1980?]." Although "*the ecology of the eel makes it difficult to demonstrate a stock-recruitment relationship, […] the precautionary approach requires that such a relationship should be assumed to exist for the eel until demonstrated otherwise*" (ICES, 2002). This implies that a minimal biomass should be ensured for the oceanic spawning stock, that would not impair future recruitment (see below). "*In order to rebuild that oceanic spawning stock, measures should aim for increased escapement of spawners from continental waters*" (ICES, 2001). While the advice and expert working group reports up until 2001 primarily addressed the fisheries ("*exploitation levels*" and "*F*"), the 2002 Advice (and later) considered "*exploitation and other anthropogenic mortalities*", respectively "*all anthropogenic impacts*".

Subsequently, ICES (2002b[3]) explored options for setting "*preliminary biologically-based goals for selected systems*". Having considered several options that required more detailed data than were available, ICES (2002b) adopted the precautionary framework of ICES (1997), and proposed that "*a mortality rate which provides 30% of the virgin (F=0) SPR [Spawner per Recruit Ratio] is a reasonable first estimate of F_{lim} until further information is gathered. Considering the many uncertainties in eel management and biology and the uniqueness of the eel stock (supposedly single panmictic, spawning only once in their lifetime), a precautionary reference point must ultimately be more strict than the universal reasonable first estimate of F_{lim}. A preliminary estimate for F_{pa} could be 50% SPR. Estimates of spawning stock and recruitment for the European eel are not available and are very unlikely to be feasible at all. Consequently, stock-wide management targets will have to be translated into derived targets for local management units*". Subsequently, ICES (2002a) advised "*Exploitation, which provides 30% of the virgin (F=0) spawning–stock biomass is generally considered to be such a reasonable provisional reference target. However, for eel a preliminary value could be 50%.*" Other than this worded advice on precautionary mortality levels, ICES did not adopt reference points for eel. Since 2018, the advice explicitly states: "*Recruitment at the 1960–1979 level is currently regarded as an unimpaired recruitment level.*"

In 2007, at the EU level Council Regulation (EC) No. 1100/2007 was adopted establishing measures for the recovery of the stock of European eel, with the objective "t*o reduce anthropogenic mortalities so as to permit […] the escapement […] of at least 40 % of the silver eel biomass* [relative to the notional pristine escapement]". The Eel Regulation aims to achieve this reduction in anthropogenic mortalities through the implementation of National or river basin specific Eel Management Units.

To accommodate the international post-evaluation of eel management, and the aggregation of post-evaluation results from Eel Management Units, ICES (2010) introduced a set of common indicators, now commonly indicated as "the 3Bs & ΣA framework" for reporting estimates of the spawner escapement (current, current potential, and pristine biomass – 3Bs) and the impact of anthropogenic actions (lifetime mortality, potentially by impact type – ΣA) (see glossary). This framework has been used in ICES Data Calls and for the compilation and presentation of national stock indicators by WGEEL in 2012, 2015 and 2018.

ICES (2010) indicated that the objective of the Eel Regulation of an escapement of 40% of B_0 will ultimately correspond to a lifetime anthropogenic mortality limit of $\Sigma A = -\ln(40\%) = 0.92$. However, this mortality level will not allow the stock to recover from the currently depleted state (FAO and ICES, 2011). For stocks at low biomass levels "*(below $B_{MSY\text{-}trigger}$), ICES applies a proportional reduction in mortality reference values (i.e. a linear relation between the mortality rate advised and biomass)*" (FAO and ICES, 2011). The determination of an appropriate value for $B_{MSY\text{-}trigger}$ requires contemporary data in the normal range of fluctuations around the long-term biomass target. Noting that eel stock estimates are only available for the depleted state in recent decades, FAO and ICES (2011) concluded that there is no basis to advise on an appropriate choice of $B_{MSY\text{-}Btrigger}$. In subsequent years, however, WGEEL has *de facto* used the long-term objective of the Eel Regulation ($B=40\%*B_0$) as a preliminary value. However, this has not been adopted in the advice.

4.1.3 ICES advice for the European eel

4.1.3.1 Current ICES advice – in accordance with the PA?

The current advice is for the European eel throughout its natural range. This is in accordance with the ICES framework to assess and advise at the stock level (ICES, 2020).

Since '*Recruitment at the 1960–1979 level is currently regarded as an unimpaired recruitment level*' and given the current estimate of recruitment (glass eel index) is very far below this level, the stock size is considered to be '*below potential reference points*'.

The 1960–1979 recruitment is therefore, implicitly, considered as a limit reference point (R_{lim}). Given the current R estimate is below R_{lim} for many years, it is assumed that current biomass is below B_{lim}, leading to the statement '*Stock size is considered to be below potential reference points*'.

Following the ICES guidelines, since the stock size is estimated to be below B_{lim}, the Advice is implicitly for zero catches (*ICES advises that when the precautionary approach is applied for European eel, all anthropogenic impacts (e.g. caused by recreational and commercial fishing on all life stages, hydropower, pumping stations, and pollution) that decrease production and escapement of silver eels should be reduced to, or kept as close as possible to, zero in 2021*). This is in accordance with the PA. However, the way the Advice is written leaves room to interpretation since 'zero catch' is not explicitly stated.

It is recognized that the ICES Advice fulfils the current request on fishing opportunity (see EC 2020, Annex 1). ICES has not been requested to evaluate the Eel Regulation (EU Council, 2007) against the precautionary approach. Therefore, since the Regulation has not been evaluated by ICES and found to be precautionary, the Advice could not be based on it. This is in accordance with the ICES guidelines.

4.1.3.2 Suggestions to improve the current ICES advice within the current framework

Recruitment reference point R_{lim} should be explicitly mentioned in the reference points table. However, the exact value should be determined by a benchmark, which should specify the reference period applied.

Some specific suggestion to improve the advice are:

1. Clarify the headline advice

WKFEA considers that the current Advice drafting deviates from the guidance and from the heading '*ICES advice on fishing opportunities*' since the Advice is to reduce to, or keep as close as possible to zero 'all anthropogenic impacts'.

WKFEA recommends to ACOM to provide an advice on fishing opportunities only and that any other anthropogenic impacts should be addressed in the '*Issues relevant for the management*' section (e.g. gravel extraction for North Sea herring), or in a dedicated section which could be called '*Issues relevant for the conservation*'. In such a section (Issues), it should be clearly stated that, given the poor state of the stock, acting on the fishery alone may not be sufficient to improve/recover the stock.

WKFEA considers that for eel, what is written in the Advice should be clarified. The usual ICES Advice (i.e. for other fish stocks) is for catches. In some cases, where discards occur and where some of them survive, the catch advice is deduced from a removals value corresponding to the level of mortality to be achieved assuming rates of discard and survival.

In the case of eel, and given the state of the stock, WKFEA recommends that 'as close as possible to zero' be replaced by 'zero', and that 'catches' be replaced by 'all recreational and commercial catches of all life stages in all habitats should be kept equal to zero'.

Currently in many/some places, catches of eel comprise recreational and commercial catches, the latter being split between landed fish (for consumption) and fish for aquaculture (both for consumption and restocking) and/or restocking purposes, depending on the life stage. In some cases, catches are made to assist migration around obstacles (known as assisted migration or trap and transport).

2. Clarify how to address restocking/aquaculture/assisted migration

WKFEA considers that there is currently an inconsistency to advise 'zero catch' but at the same time to consider restocking (in a broader sense) further down, even though conditionally on a demonstrated net benefit for the stock.

Following a zero-catch advice, no recreational catch and no commercial landings would be allowed. Furthermore, any catch for aquaculture purposes should not be allowed unless the reared fish are released, and the associated mortality is less than that of the natural mortality; even in this case, the same caveats (e.g. net benefit) as for restocking would exist (see below).

WKFEA questioned if some catches could be allowed only to assist migration (in a given river) and only in cases where the resulting contribution to spawning stock is expected to be higher with these measures than without. Where dams exist and prevent downstream or upstream transport of respectively silver and glass eel, trap and transport could be considered, assuming that any associated mortality is less than that in the absence of such measures. Furthermore, upstream migration should only be applied if future escapement of silver eels is ensured.

Prior to permitting restocking from a donor river A to a recipient river B, WKFEA considered that it will need to be demonstrated that the carrying capacity of river A is too limited to support the development of all the incoming glass eels (i.e. glass eel are in excess in river A [surplus]) and that the carrying capacity / quality of river B is sufficient to receive the transported glass eels without any impact on the broader river B ecosystem. This concept is reviewed in detail in the WKSTOCKEEL report (ICES, 2016) and it is acknowledged that both these conditions may be difficult to demonstrate.

The current advice states that restocking should only be allowed if an overall net benefit to the whole stock is demonstrated. However, this demonstration is unlikely to happen since it needs to assess the contribution of the different rivers/EMUs to the spawning stock, and, in each of these, the respective contribution from the restocked eels, and from those eels that would have been the amount of spawners without restocking. In any case as stated in the FAO PA guidance (1996) and, in the ICES eel advice, restocking '*should not be used as an alternative to reducing anthropogenic mortality*'.

It will be the responsibility of ACOM to produce an advice on restocking (as a whole) on the basis of:

i. no restocking since there is some mortality associated;
ii. restocking only if a net benefit is demonstrated;
iii. consider restocking only as assisting migration within a river.

Currently, restocking is considered by some EU Member States as a / the only means to fulfil the requirement from the Eel Regulation (EU Council, 2007) of 40% of the pristine escapement in each Management Unit, without any evidence of any net-benefit for the whole stock. WKFEA considers that until the stock has recovered, should restocking continue, it should only be done to achieve the 40% overall target and not to allow the continuation of commercial and/or recreational fisheries in recipient or donor rivers, or compensate for any other anthropogenic mortality.

3. Considerations for the Future advice

If the stock recovers (recruitment is estimated to be above R_{lim}), non-zero catch opportunities will be calculated according to ICES guidelines.

Any (non-zero) advice on fishing opportunities should first be expressed in terms of catches from the stock, for each category (glass, yellow, silver). Catches should be counted as the sum of the eels landed and the eels which die during any aquaculture or restocking process.

WKFEA considered that how these total catches are split among the various sources of mortality (e.g. hydropower vs. fishery) is, and must remain, a management decision, as is any limit/target by EMU.

4.1.3.3 ICES advice in the context of Eel Regulation (EU Council, 2007)

As mentioned above, the current ICES eel advice is for the European eel throughout its natural range; thus, it goes beyond the EU area and the EU Council Regulation.

According to the FAO Code of Conduct for Responsible Fisheries "States should apply the precautionary approach widely to conservation, management exploitation of living aquatic resources in order to protect them and preserve the aquatic environment" (FAO, 1995). A PA for management should cover the whole stock and be based on the best scientific evidence should set stock-specific reference points (or provisional ones where information is poor or absent, as for eel). Unfortunately, the information available for the eel stock as a whole is incomplete: landings data are incomplete and some may be unreliable. The time-series for the recruitment index calculation had been quality checked, but they do not fully cover the European eel natural range.

Although for the majority of human impacts and for the biological characteristics of the stock, national assessments often have access to adequately detailed information (specifically EU Member States, reporting progress on national Eel Management Plans), but that information is not available for the stock as a whole and it is not likely to become available within the foreseeable future.

The dilemma when assessing the effectiveness of the EMPs is therefore how the advice at the whole stock level (disregarding the more detailed information available for many areas, and not directly relating to management actions), relates to the National/River Basin District EMU level (allowing the evaluation of protective measures, but not addressing the overall status of the stock).

On the other hand, while the full recovery of the eel stock is likely to take many decades and the Eel Regulation (EU Council, 2007), aims for a recovery “in the long term”, there is an urgent need to inform managers about the effectiveness of protection measures taken, of the stock abundance indicators and the potential need for additional protective measures.

The recurrent ICES advice on fishing opportunities is not aiming to inform the managers on progress in implementing management plans, such as the EMPs under the Eel Regulation (EU Council, 2007) and their effect on the stock. As discussed above, the ICES Advice on eel is provided under the heading of "*advice on fishing opportunities*". While the impacts of fishing and of other anthropogenic activities are in the same order of magnitude (ICES, 2019), an integrated ecosystem approach is required to protect and restore the eel stock.

4.2 Data and assessment for the European eel

4.2.1 Data collected by WGEEL

Since 2017, there has been an official annual ICES eel Data call (DC) addressed to countries within the geographic range of the European eel. The data collected in the call are stored in an electronic database for the European eel stock (WGEEL database). However, data on eel, fisheries, and other anthropogenic impacts across the whole stock, remain incomplete. There is no international legislative requirement to collect and provide data that cover the entire stock area, but an EU multiannual plan is in place to collect data in at least one river basin per eel management unit (EMU), as defined in the national eel management plans (EMPs, s.a.). The most recent (2020) Data call included:

- Time-series of empirical data (no model output):
  - Recruitment (glass eel and yellow eel recruitment time-series);
  - Yellow eel abundance indices. Note, that these do not refer to yellow eel recruitment time-series, but only to those indices that provide a measure of the standing stock;
  - Silver eel abundance indices;
  - Biometry for each time-series:
    - Mean length, mean weight and mean age for each maturity stage and both sexes.
- Annual update on:
  - Landings for commercial fisheries;
  - Landings for recreational fisheries;
  - Landings related to transport/relocation operations;
  - Releases (restocking);
  - Aquaculture production.
- Metadata:
  - name and email address of a person who can be contacted about the dataset;
  - short description of the method used to collect the data;
  - Indication on whether there was change brought to existing data.

In addition to the data listed above, ICES calls for data on stock indicators (other than recruitment) on a triannual basis (last in 2018), aligned with the national EMP progress reports to the EC (EU Council, 2007). These data are reported per EMU and include (See Annex 2 for more details):

- B_0 – The estimated pristine escapement of silver eels;
- B_{best} – the estimated best possible escapement today (current potential) assuming the absence of all anthropogenic impacts;
- $B_{current}$ – the estimated escapement today (current) including all anthropogenic impacts;
- ΣH – the sum of all lifetime hydropower mortality;
- ΣF – the sum of all lifetime fishing mortality;
- ΣA - the sum of all lifetime anthropogenic mortalities.

4.2.2 Data used in the assessment / advice

4.2.2.1 Recruitment and Yellow eel time-series

The recurrent ICES advice on fishing opportunities for eel is based on a statistical analysis of several time-series on recruitment (glass eel and or a mixture of glass + yellow eels, and of young yellow eel time-series). The indices are based on data from fisheries and scientific surveys. Time-series are included in the analysis if they fulfil the following criteria:

- The time-series is at least ten years old.
- If two series come from the same location, only one is used.
- The series is not obviously biased by restocking.

Currently, the glass eel recruitment indices are based on 52 time-series: 24 in the 'North Sea index' (NO, SE, DE, DK, NL, BE) and 28 in the 'Elsewhere index' (UK, IR, FR, ES, PO, IT). The yellow eel recruitment index is based on 16 time-series (DK, DE, IR, SE, UK).

4.2.2.2 Landings

Landings are reported in the advice sheet but not used, because the total landings are incomplete and effort data are lacking; though for some, gaps in available time-series, data has been reconstructed. In addition, a great heterogeneity is present among the time-series of landings owing to inconsistencies in reporting by, and between, countries.

4.2.3 Stock assessment exercises / analyses

4.2.3.1 ICES advice

The current ICES advice on fishing opportunities for eel is based on a statistical analysis of two glass eel recruitment indices and a yellow eel recruitment index, each comprised of multiple time-series, and based on data from fisheries and scientific surveys. The WGEEL recruitment index used in the ICES advice on fishing opportunities for eel is fitted using a GLM with a Gamma distribution and a log link: glass eel ~ year : area + site, where glass eel are the individual glass eel time-series, including both pure G series and those identified as a mixture of glass and yellow eel (G+Y), site is the site monitored for recruitment, area is either the continental 'North Sea' (NS) or 'Elsewhere Europe' (EE), and year is the year coded as a categorical value. For yellow eel time-series, only one estimate is provided: yellow eel ~ year + site. The trend was hindcast using the predictions from 1960 onwards for 52 glass eel time-series and from 1950 onwards for 16 yellow eel time-series. True zero values were excluded from the GLM analysis: 17 for the glass eel model and 20 for the yellow eel model. This treatment is parsimonious, and tests showed that it has no effect on the trend (ICES, 2017). The predictions are given in reference to the geometric mean of the 1960–1979 period.

4.2.3.2 WGEEL report

In the annual WGEEL report, additional analyses are reported. Most notably, these analyses include:

- GEREM: additional analysis on the recruitment time-series at different nested spatial scales, based on a Bayesian approach;
- Segmented regression to identify breaking points in the recruitment trend;
- Statistical test of whether a significant change in the slope of the recruitment trend occurred since 2011;
- Explorative analysis of yellow and silver eel time-series;
- Reporting of landings in more details;

- Explorative analysis of biometry.

Analyses on the slope of the recruitment trend, based on the previous segmented regression, were reported on the advisory sheet of the previous advice (ICES, 2019) but not in 2020.

4.3 Is the recurrent ICES advice on fishing opportunities for eel based on the best scientific information?

Scientific information can take various forms: knowledge/assumptions from published literature or data and "*best information*" is difficult to define. Much information exists on eels but due to the limitations described above relatively little is used in the recurrent ICES advice on fishing opportunities. The rationales underlying the present form of the recurrent ICES advice have not been invalidated in Section 4.2, but some information could potentially challenge these rationales and lead to non-precautionary advice. However, most of this information is still speculative and its data too limited to account for them. The recruitment indicator, on which the recurrent ICES advice is mainly based, is less affected by local effects than Spawning–Stock Biomass (SSB), but it may take some time before some changes in the population, especially its diversity, are detected by this indicator alone. Diversity in generation length is one issue, where for example, changes in recruitment may be reflected in escapement after five years in warm waters but only after 20+ years in colder environments.

Some data potentially exist that could inform on the status of the population in later life stages (potentially on the escapement), on the life-history traits/diversity and anthropogenic pressures. However, efforts are still needed to improve data quality, consistency and validation, and to develop appropriate spatial analysis/model to aggregate local information at the population scale. Furthermore, data do not currently cover the whole distribution range meaning assumptions would be necessary.

In this section, we review the rationales behind the advice and the potential information that threaten those rationales. We then review whether all available data are used and the potential insights that can be provided by new data.

4.3.1 Rationale behind the current advice

The European eel is considered to be a panmictic species (Als *et al.*, 2011) with a distribution that extends from Norway to Morocco (Tesch, 2003), and as such, ICES assesses the European eel at this scale. The current assessment is carried out using an ICES precautionary approach framework that aims to prevent the spawning biomass becoming a limiting factor that threatens recruitment (ICES, 1997). Reference points such as B_{lim} used in traditional stock assessments are based on this concept and correspond to the spawning–stock biomass below which recruitment can (or has been observed to) be impaired (ICES, 1997, 1998, 2003). For European eel, *the objective of each Eel Management Plan shall be to reduce anthropogenic mortalities so as to permit with high probability the escapement to the sea of at least 40% of the silver eel biomass relative to the best estimate of escapement that would have existed if no anthropogenic influences had impacted the stock* (EU Council, 1100/2007). This objective is based on this same concept – 40% is a limit reference point below which the escapement should not be allowed to be; interestingly, where escapement is below 40% this can be thought of as a target to reach, but it is not a management target because those are typically defined as a level above the limit which management is aimed at to ensure confidence that the limit wouldn't be breached even under natural variation. A theoretical illustration is presented in Figure 2 which displays a traditional stock–recruitment (SSB–R) relationship and B_{lim}.

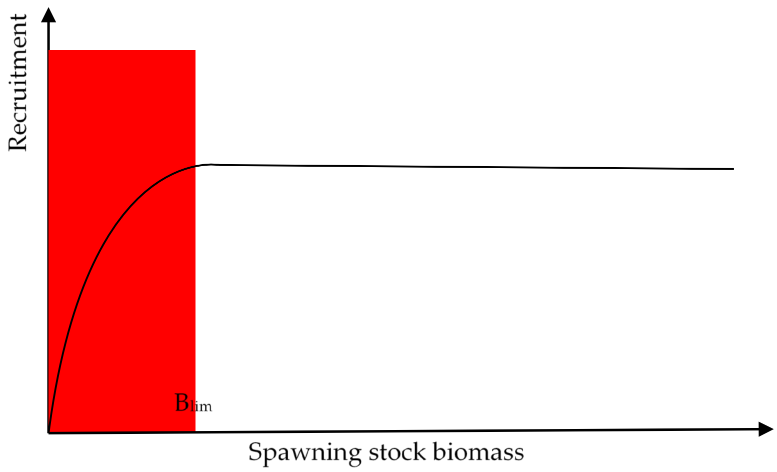

Figure 2. Rationales behind the ICES precautionary approach framework: the concept is to prevent the SSB from falling below a threshold (B_{lim}) where SSB is impairing recruitment. Above B_{lim}, natural stochasticity in recruitment predominates over the effect of SSB.

Several adaptations to the standard rationales described in Figure 4.1 are required to apply it to the European eel. First, since spawning in the wild has not been observed or quantified, SSB cannot be directly calculated. As such, escapement (i.e. the biomass of silver eels that yearly leaves continental waters towards the spawning ground) is the closest stage that can be observed and is therefore used as a proxy for SSB. This, for example, is why the Eel Regulation (EU Council, 2007), sets a target for escapement. However, even a proxy of escapement at the population scale is difficult to quantify. While time-series for escapement are collected at a few sites over the distribution area, their use to infer a trend at the population scale is a challenge because of the complex ecology of eels compounded by the absence of data in some areas. Indeed, local escapement is both the result of large-scale factors (overall status of the population) and local conditions (environment, anthropogenic pressures, local management) (ICES, 2020a), and their relative effects are difficult to disentangle, and, more importantly, based on data drawn from a limited number of sites. On the other hand, recruitment time-series are thought to largely reflect spawning plus impacts during the oceanic migration to continental waters and thus to be less influenced by local conditions and better reflect the overall status of recruitment (and, by association, the population). As such, the ICES recurrent advice is based on the metrics of recruitment produced by the WGEEL (ICES, 2020a).

As a summary, while the recurrent ICES advice on eel (ICES, 2020d) is based on the ICES precautionary framework, several modifications are applied to the traditional Figure 4.1 for eels. First, in the Regulation, following WGEEL work, the x-axis was implicitly modified, and escapement was used as a proxy of SSB when setting the management target. Second, since a suitable indicator is not available for this x-axis, the recurrent ICES advice is mainly based on the recruitment, i.e. the coordinates on the y-axis. Moreover, in the absence of the "usual" reference point(s) based on the recruitment, ICES considers that pre-1980s recruitment was relatively stable and can be viewed as unimpaired.

4.3.2 Scientific information that challenges the rationales

Annex 4 lists the scientific information that potentially challenges the rationale behind the current recurrent ICES advice. To some degree, this information is either still too speculative or a lack of data/methods prevents its use in the recurrent ICES advice. However, it is interesting to explore whether not accounting for the information might lead to non-precautionary advice: it informs on the robustness to uncertainty of the recurrent advice and can also be considered by managers. The information listed in Annex 4 challenged three rationales of the current advice:

1. Is escapement a reliable proxy of SSB?
2. Is the shape of the SSB–R relationship correct?
3. Are important changes in the populations being missed through the analysis of SSB and recruitment indicators?

Other information, denoted category 4 in Annex 4, was listed as having no immediate implications for the recurring ICES advice.

Regarding the use of escapement as a proxy of SSB, first, there is the long distance and time between the silver eels leaving continental waters and arriving at the spawning area. There has been no observation of their fate along the way, other than tracking studies that have observed notable levels of predation in tagged silver eels (Righton *et al.*, 2016) – this has also been noted in other tagged anguillid species (Beguer-Pon *et al.*, 2012). Secondly, various issues (Annex 4) suggest that the conversion rate between escapement and SSB has decreased through time. As such, a stable escapement might hide a decrease in SSB such that an Advice based solely on escapement might not be precautionary. However, this does not weaken the current recurrent ICES advice based on recruitment, this being the result of SSB.

Regarding the possibility of an invalid assumption due to the shape of the SSB–R, the effects are heterogeneous. While the occurrence of a regime shift would lead to the setting of SSB-based reference points at levels that cannot be achieved under the present regime (i.e. setting the bar too high), recurrent ICES advice would remain precautionary in terms of protecting the stock, though overly so. The potential existence of an Allee effect (Dekker, 2004; ICES, 2012) would be more problematic with the risk of accelerated, and potentially irreversible, collapse at low levels of population. In that case, reference points, based either on recruitment or SSB, should be adjusted to avoid the inflexion point in the SSB–R.

Finally, because of the complex life cycle of eels, changes in the populations might not be detected when analysing standard indicators such as yearly SSB or yearly recruitment. For example, male and females display distinctly homogeneous length and age-at-silvering (Vøllestad, 1992) and therefore do not have the same weights in the SSB (if a female weighs twice as much as a male, she will count twice as much in SSB). We do not know whether males or females are limiting, as both sexes do not necessarily exhibit the same trends because of the spatial pattern in sex ratio (Kettle *et al.*, 2011). The existence of the variable age-at-silvering among growth habitats lead to overlapping generations which might result in a storage and a portfolio effect that contributes to population stability (ICES, 2009). However, SSB and recruitment do not highlight changes in the age-at-silvering in escapees (or with great delay in recruitment). More generally, long-term losses in life-history traits and genetic diversity over multiple generations would be difficult to detect using yearly standard stock indicators, however diversity is thought to contribute to the resilience of the population (Secor, 2015; Drouineau *et al.*, 2018).

4.3.3 Are we using the best data to support the advice?

"Best" is a difficult notion to define. Instead of trying to subjectively define "best" datasets, we chose to list all potentially available datasets and to discuss:

1. what they would inform in the recurrent ICES advice; and
2. whether the quality of data – (e.g. appropriate spatial and temporal scales, length of time-series, quality of the datasets, meta-information on the data - and the existence of suitable methods), would allow using these in the advice.

The first objective of the recurrent ICES advice to the requesters is to inform on the status of the population. This is primarily through the analysis of recruitment abundance indices collected in many sites across Europe. Other data are available but not used – though these may have value outside of the advice. Several kinds of data potentially inform temporal trends - indices for yellow and silver eels, $B_{current}$ and B_{best} - but abundances of yellow eels and silver eels are the result of both the overall status of the population and of local conditions e.g. environmental conditions, anthropogenic pressures, management, etc. These are difficult to disentangle and therefore aggregate at the population scale. Moreover, too short time-series hinder the analysis of this data, and insufficient meta-information, potential inconsistencies and lack of validation in protocols give doubts to their use to inform the status of the population at large scale. As such, it is currently not possible to derive an escapement indicator for the whole population, and there is a need to develop a spatialised analysis/method. An indicator of SSB is even more complex and the data that would enable correcting the conversion rate between escapement and spawning–stock biomass do not exist

5 ToR 2: What are the options for improving the evidence base and adapting advice?

Chapter 4 described the ICES advice process and reviewed the current annual Advice for eel confirming consistence with the PA approach, but it could be improved with additional knowledge, and as such be more informative to managers. The current chapter assesses the general concepts to be considered to improve the advice, and then building on the findings and conclusions of Chapter 4 examines the specific issues to be solved.

5.1 General concepts to take into account in the advice improvement

5.1.1 Trend-based or analytical model-based assessment

The recurrent ICES advice is based on a trend analysis based on recruitment time-series. As such, European eel belongs to the category 3 of the ICES framework, i.e. "*stocks for which survey-based assessments indicate trends".* While several issues have been listed regarding the ongoing analysis of trends in recruitment, they are mainly minor and do not question the indicator by itself. However, the ICES framework mentions that category 3 "*includes stocks for which survey or other indices are available that provide reliable indications of trends in stock metrics, such as total mortality, recruitment, and biomass*". The question then is, whether additional indicators can be derived to inform on biomass and mortality. Indeed, recruitment is known to be a highly stochastic, potentially environmentally driven, process (Myers, 1998). For example, the European eel, which undergoes a long larval drift, a correlation of recruitment and North Atlantic Oscillation (NAO) has been observed for some time (Kettle *et al*., 2008; Arribas *et al*., 2012; Correia *et al*., 2018; Díaz *et al*., 2018). While data on larval abundance in the spawning area remains scarce, the continuation of recent regular surveys could provide time-series of abundance, help clarify the mechanisms and inform modelling exercises. As such it might appear suitable to complement the recruitment trends with trends in silver and yellow eel abundances enabling the use of traditional reference points such as B_{lim}. The opportunities to use existing time-series and the challenges are documented in the issue tables in Section 5.2. However, recruitment, yellow and silver eel abundances relate to the status of the population but do not directly inform on trends in mortality. Deriving mortality estimates for eel is far from simple because of the complexity of eel ecology. During its growth phase, eels are subdivided into river basins which behave almost as independent units, and are submitted to contrasting environmental conditions and anthropogenic pressures. This phase can last between three to 30 years depending on areas, so the duration during which environmental pressures apply is also variable. In this context, to estimate mortality trends at the population scale, it might be necessary to have spatially disaggregated estimates of abundance and mortality. Stock assessment models, classically used in stocks of category 2 (stocks with analytical assessments and forecasts that are only treated qualitatively) and category 1 (stocks with quantitative assessments), are aimed at simultaneously estimating trends in abundance and trends in mortality.

Many stock assessment models have been developed to assess the status of fishes and trends in mortality (especially fishing mortality). They are also relevant to estimate standard reference points. These can be roughly divided into three main categories:

- **Surplus production models** (e.g. (Schaefer, 1957)): are among the simplest models and describe how the biomass of the stock varies over time, because of intrinsic growth rate (a non-explicit balance between body growth, reproduction and natural mortality) and fishing mortality. These models are well suited in data-poor context; they just require an abundance index at the population scale and time-series of catches. Extensions have been proposed, for example to account for environmental variability (Fréon, 1988), use external covariates (Prager, 2005) or account for sources of stochasticity (Pedersen and Berg, 2017). For eels, various problems impair the use of non-spatial surplus production models: quality of landings data, spatial heterogeneity in growth rate/natural mortality rates and anthropogenic pressures leading to spatially heterogeneous intrinsic growth rate, and the absence of abundance indices at the population scale. Regarding a spatialised surplus production model (e.g. (Thorson *et al.*, 2017), the problem is that intrinsic growth rate (balance between growth, recruitment and survival) is assumed to be a function of local biomass, and as such, they generally postulate that reproduction can occur "independently" in any zones of the model, whilst eel on the other hand is a panmictic population with reproduction depending on the overall biomass.
- **Age, length or age-length structured models:** are among the most widely used stock assessment models, from the traditional extended survivor analysis which used to be a standard in ICES (Shepherd, 1999) to more complex model such as Multifan-CL (Fournier *et al.*, 1998), with the existence of dedicated modelling framework to develop specific models (e.g. stock synthesis (Methot and Wetzel, 2013)). For the European eel, a spatialised model would be required to deal with the spatial heterogeneity in growth. However, unavailability of length (or age) structured catch data, time-series of abundance, and the difficulty in reading eel otoliths impairs the use of such models.
- **Stage-structured models:** are an intermediary between the two. In such models, the population is divided into stages, each stage submitted to growth and mortality (natural and fishing) and to stage transition. For example, in CSA (Mesnil, 2003) or BREM (Trenkel, 2007), the population is structured in two stages (recruitment and older individuals). Depending on cases, such models can be fitted on time-series of abundance only (e.g. BREM) or on both time-series of abundance per stage and commercial landings (e.g. CSA). For eels, a spatialised stage-based model with three stages (recruits, yellow eel and silver eel) was proposed by Dekker (2000). It is worthwhile mentioning the case of the Atlantic salmon: recently a hierarchical Bayesian stage-structured assessment model has been proposed (Olmos *et al.*, 2019; ICES, 2020b). This model is composed of 13 units and several stages (egg, smolt, pre-fishery, salmon at sea, return, spawners). The hierarchical Bayesian structure allows the transfer of information from data-poor stock units to data-rich stock units. One time-series of abundance of returns and catches per stock unit is used to fit the model and is incorporated as a pseudo-observation (Michielsens *et al.*, 2008), i.e. multiple raw time-series are pre-treated in each stock unit to provide a single time-series of abundance with a quantification of the uncertainty per stock unit. In the SUDOANG project a model is under development combining the GEREM model that provides pseudo-observations of recruitment per zone, and the EDA model, that provided pseudo-observations of yellow and silver eel abundance. Commercial landings are used as additional observations and allow an estimate of fishing mortality. The model describes the evolution of biomass of each stage through a time-varying zone-specific intrinsic growth rate (as in BREM or in surplus production model) corresponding to the balance between growth and survival, whilst a time-varying silvering proportion describes the transition from yellow to silver stage. A similar approach was used by Beaulaton and Briand (2018) in France, but with stages having fixed and predetermined durations.

In addition to previously mentioned stage-structured models, several stock assessment models of different types have been developed for eels (e.g. Lambert *et al.*, 2006; De Leo and Gatto, 1995; Van De Wolfshaar *et al.*, 2014), but most of them were applied locally and can not necessarily be applied at larger scales due to a lack of available data.

Most stock assessment models consider that mortality is mostly due to natural mortality plus fishing mortality. As such additional mortality is either included in the potentially time-varying natural mortality (which is implicitly included in the intrinsic growth as in surplus production model). As discussed in Chapter 4, the lack of knowledge impairs the quantification of the effects of habitat loss, deteriorated habitat quality, contamination or diseases at the population scale. As such, it seems impossible to explicitly account for their effects on the population dynamics and they would instead be included as trends in natural mortality/intrinsic growth rates. On the other hand, as detailed in Chapter 4, it might be possible to model and quantify the hydropower plant-induced mortality which could then be treated as fishing mortality in a stock assessment model. It could also be possible to address the issue of habitat when producing the pseudo observations of yellow and silver eel using a spatially explicit prediction.

The opportunities and challenges related to each of the following three options are discussed in the following section:

- a trend-based advice based on recruitment;
- a more complete trend-based advice; or
- a move towards an analytical assessment.

5.1.2 Local versus global assessment

According to the FAO Code of Conduct, "*To be effective, fisheries management should be concerned with the whole stock unit over its entire area of distribution*". In this context, European eel being a panmictic species (Als *et al.*, 2011), is assessed by ICES at the population scale. It should be noted that assessing the population at this scale does not imply that spatial structure of a stock should not be considered in the assessment. Spatialised stock assessment has been developed to address spatial heterogeneity in stock or fishery distribution. This kind of model allows estimating trends in mortality and abundance both at the population scale and at finer spatial scales. As discussed above, a spatial stock assessment model seems necessary to estimate trends in mortality at the population scale. This kind of model would have the advantage of providing spatially disaggregated estimates that are likely valuable for managers in the context of the implementation of Eel Management Plans. In other words, whatever the option, consistent with the PA, ICES advice will be based on assessment at the population scale. However, while the current category 3 trends-based approach only provides qualitative information on abundance at the population scale, the development of an appropriate stock assessment model would turn European eel into a category 2 (or 1) stock enabling the provision of not only mortality trends at the population scale, but also spatially disaggregated estimates.

5.2 Specific issues to take into account in the advice improvement

Building on the findings and conclusions of the chapter 4, a table has been created outlining the identified issues and potential solutions (Table 1). Those issues were ranked according to their priority in terms of improving the ICES advice and the probability of solving the respective issue (Figure 3).

Table 1. Summary of issues identified for the advice and assessment approach with related options to address them.

	General concept	Specific issue	Challenge	Potential Solutions
1a	Biological Parameters	Age at silvering (and growth)	High spatial heterogeneity; correlation with mortality and productivity; possible link to storage/portfolio effects	Well documented patterns of age at silvering across the distributional range; partial/theoretical knowledge on link to mortality and growth; use in age-based approaches (tracking cohorts)
1b	Biological Parameters	Sex ratio	High spatial heterogeneity; correlation with mortality and productivity; invalidates the assumption of comparable biomass between spatial units; unknown which sex is limiting	Spatial pattern of sex ratios well established
2a	Fisheries & ecosystem issues and data	Landings	Lack of effort data; data are deficient; heterogeneity among time-series; incomplete reporting; recreational landings not well documented; IUU hard to quantify	Effort data not *per se* required in production model, thus landings data could be used; reconstruction of missing data could be improved
2b	Fisheries & ecosystem issues and data	Fishery mortality	Quantifying the variable mortality per age at maturity would require a spatialised analysis.	Age at maturity patterns well documented (Vollestad, 1992); Portfolio and storage effects demonstrated in theory (ICES, 2009); can be derived from landings with appropriate models.
2c	Fisheries & ecosystem issues and data	Hydropower plants (HP/P), Pumping stations and other water intakes	This information is currently missing/ incomplete in many countries; Characteristics and locations not fully known; indirect effects (delayed mortality, reduced fitness) often neglected, thus SSB potentially overestimated; knowledge of spatial distribution in a given waterbody required; caveats vs. risks associated with current and past restocking practises above structures	Hydropower mortality better documented than other anthropogenic mortalities (ICES, 2019); crude estimate seems possible given additional data collection. The current uncertainty can be dealt with by appropriate models.
2d	Fisheries & ecosystem issues and data	Habitat loss	Lack of appropriate data, thus difficult to quantify; reference period is not certain (also "biological reference points")	Possibility to collect information in future Data Calls; link to biodiversity strategy. GIS based layers of rivers, when combined with dams and associated waterbodies, but also information on temporal streams drying out part of the year may provide a large source of information.
2e	Fisheries & ecosystem issues and data	Spawner quality (pollution, parasites, diseases...) Habitat quality	Effects occur across different life stages; no known thresholds, with particular concerns around impacts affecting migration and reproductive success	Contamination levels and prevalence of diseases & parasites are documented to different extents; ongoing research on effects and thresholds; possibility do derive standard sampling protocols. Possibility to use the WFD data to assess the quality of waterbodies on a large scale and include that scenario in models to deal with that uncertainty.

	General concept	Specific issue	Challenge	Potential Solutions
3a	Biological Reference Points	Explicitly define limit reference points	Species specific reference points unknown; no known stock–recruitment relationship	Use of provisional reference points; assessment model could provide species specific reference points
3b		Reference period	Current reference period for recruitment mostly driven by data availability	Review during benchmark process
3c		Contribution of different spatial units (e.g. EMUs) to SSB	Unknown whether or to what extent different subregions actually contribute to the spawning stock	Possible inferences can be made based on theoretical considerations (timing of migration, condition etc.) And modelling exercises, Surveys of larval abundance in the Sargasso see could further clarify the relationship and would inform modelling exercises
3d		Are indicators robust to uncertainty to Stock–recruitment relation/alle effect	No known stock–recruitment relationship	Modelling exercises could provide an estimate of robustness, Surveys of larval abundance in the Sargasso see could further clarify the relationship and would inform modelling exercises
4a	Assessment method	Tuning new recruitment series	Differing methods; varying precision between sites	Keep on-going monitoring series in key areas; establish new monitoring series in areas with low coverage; pilot studies to estimate precision; absolute recruitment estimates would significantly increase understanding and substantially improve modelling exercises; establishment of index rivers
4b		Standardizing yellow eel series	Limited availability of longer time-series; lacking effort for fisheries-dependent time-series; heterogeneity in reporting; limited spatial coverage; heterogeneity in protocols; bias due to restocking	Data collection is ongoing, wider range, better protocols and inclusion of all countries in the natural range of eel could mitigate problems; ensure reporting of biological and other data (management, restocking) associated to the series
4c		Standardizing silver eel series	Limited availability of longer time-series; lacking effort for fisheries-dependent time-series; heterogeneity in reporting; limited spatial coverage; heterogeneity in protocols; bias due to restocking	Data collection is ongoing, wider range, better protocols and inclusion of all countries in the natural range of eel could mitigate problems; ensure reporting of biological and other data (management, restocking) associated to the series
4d		Problems of the current assessment method (calculation of the recruitment index)	Selection of most appropriate series; varying effort in fisheries-based time-series (but trends are rather robust to these series); insufficient spatial coverage; regional differences in trends (no overall trend); difficulties in defining reference period (s.a.); low availability of long running time-series	Objective selection of appropriate time-series (mostly done); establish new, fishery-independent time-series; complement analyses using other models (partially done); review reference period in benchmark

	General concept	Specific issue	Challenge	Potential Solutions
5a	Others	How should re-stocking be accounted for in the advice	Potentially affects indicators (e.g. double-banking of eels "killed twice"); impacts monitoring series; uncertainty whether stocked eels contribute to SSB	Account for potential double-banking in the data collection and analyses; consider different scenarios with and without contribution of stocked eels to SSB
5b*		Risk of missing long-term changes in the population, what/which diversity matters? Caveats of using only SSB and R?	Biomass only calculations miss changes to (regional) stock structure; if unaccounted for, changes in life history parameters (e.g. changes in mortality due to competition) will lead to false estimates	Regularly monitor life-history parameters and stock structure. The use of stock model with adequate spatial structure will show regional trends.

*** generally considered of high relevance, but will only become relevant at a later stage in the process and is thus (for now) considered a low priority.**

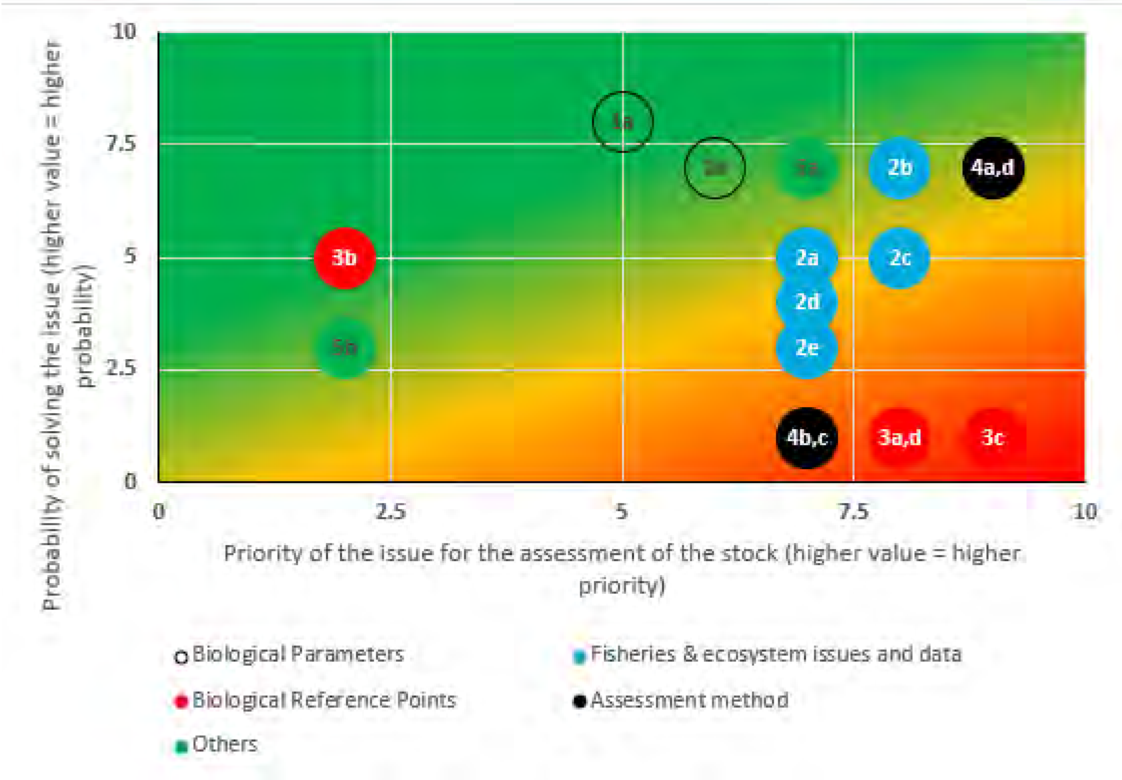

Figure 3. Plot of priorities for the eel assessment and advice identified in Table 1 vs. the probability of addressing them (factoring in the potential time required to do so). See Table 1 for the identification of the number and letter code.

In terms of the priority of each issue, three groups have been identified (Figure 3).

1. Low: Those that are not a priority now (define the reference period, or Risk of missing long-term changes in the population). However, these issues are easy to solve.
2. Medium: Those with a medium priority (between 5–7.5). Within this group there are in turn two subgroups:
   a) Those that are considered to be easily solvable (problems related to biological parameters);
   b) Those that are more difficult to resolve (problems related to landings, habitat loss, spawner and habitat quality and the standardisation of yellow and silver eel series).
3. High: Those with a high priority (between 7.5–10). Within this group there are two subgroups:
   a) Those that are considered to be easily solved (problems related to fishing mortality, Tuning new recruitment series and problems of the current assessment methods);
   b) Those that are more difficult to resolve (problems related to limit reference points, contribution of different spatial units to SSB and stock–recruitment relation and Standardisation of yellow and silver eel series).

Following this analysis, the issues have been analysed and grouped according to the solution in the following section. See Figure 4 (proposed road map) in Chapter 7 to visualize the steps of the proposed solutions.

5.2.1 Time-series of yellow and silver eels, biological parameters and long-term changes

Problem

Time-series of yellow and silver eel abundance are tools which will certainly help to assess trends in the status of the population.

While such data exist, the workshop pointed out some quality problems:

- Length of many series is too short to derive a trend;
- Heterogeneity among countries in the scale of reporting and in the sampling protocols;
- Many fishery-dependent series lack effort data which may influence the trend;
- Not all areas are covered;
- Series might be influenced by environmental and management conditions that produces local trend changes.

Thus, the challenge for time-series is to increase the number of fully described and validated yellow and silver eel series with the correct metadata to allow their analysis.

Biological parameters such as age-at-silvering, length-at-silvering, and sex ratio are important parameters that govern population dynamics and inclusion of these parameters would improve stock assessment. These parameters show a great spatial heterogeneity. However, data are still scarce, especially in some areas, and when such data exist, the workshop pointed out several quality problems related to the heterogeneous protocols and associated environmental conditions. Thus, the challenge for biological parameters is to have a more complete and standardized dataset.

There is also the risk of missing **long-term changes** in the population (reduction of life-history traits or genetic diversity). Calculations only based on biomass can miss changes to the stock structure on a regional basis. For example, as a consequence of the removal of males from northern catchments, biomass remains the same yet individual counts of eels decrease as they are composed of larger females. Many models use fixed growth rates and sex ratios when calculating biomass and mortality; are these updated to capture changes over time and what time frame should these be (e.g. decadal). Can mortality rate be wrong if sex ratio or other criteria are changed? For example, a change/reduction in age at silvering due to reduced competition/ density-dependence, results in an increase in migrating silver eels. This can be thought to be a result of the management measure but is actually just eels silvering earlier.

How could this be solved?

To address these issues, it is recommended to work on both the collection and analysis of time-series and the collection of biological parameters within the WGEEL framework. The specific objectives of the workshop would be to:

- Collect yellow and silver eel time-series data and develop methods to analyse their trends.
- Collect data and biological parameters from index rivers (age at silvering, sex ratio, age).
- Provide a method to expand biological parameter data from those index rivers and EMU level.

Given the heterogeneity among countries across the scale of reporting renewed focus should be on expanding those series which correspond to index sites. The collection of a larger dataset (e.g. WFD) may allow the reconstruction of abundances over a wider area. This can be used in a second step to adjust the population dynamics model. (see GANTT chart for Roadmap). This work will be pulled together with the collection of data for biological parameters.

How will that improve the advice?

Collecting time-series on yellow and silver eels and their associated biological parameters will provide a different insight into the trend of the population than the analysis of recruitment series alone. Such trends will be influenced by local management, and anthropogenic and environmental impacts, and relate to different subunits of the stock. Therefore, on the one hand, their collation to a global index will be challenging; whilst, on the other they provide the opportunity to look at local effects and variations. Finally, and more importantly, they will enable the construction of models based on local trends and conditions.

Time frame

It was decided to undertake time-series analysis and the development of a biological data model during the 2022 WGEEL meeting. In order for this task to be carried out, the data from **previous Data Calls** (2019 and 2020) and the database structure and importation tools already developed in WGEEL will be used. However, an additional **Data call** will be needed in May 2022 to gather data relevant in relation to time-series and biological data.

5.2.2 Commercial and Recreational landings Data

Problem

The current catches and analysis of trends in the data needs careful interpretation as fisheries management measures have impacted multiple time-series. However, without an indication of effort and how effort changes through time, these time-series remain limited in their use. The current advice sheet states that '*ICES does not have the information needed to provide a reliable estimate of the total catches of eel. Furthermore, the understanding of the stock dynamics is not sufficient to determine/estimate the level of impact that fisheries or non-fisheries anthropogenic factors (at the glass, yellow, or silver eel stage) have on the reproductive capacity of the stock.*'

How could this be solved?

A Data Call hosted by ICES, EIFAAC and GFCM and covering all natural Range States of the European eel was implemented in 2017 and is issued on an annual basis. The data are stored in a WGEEL database developed to assist the assessment of the stock. It is proposed to hold a workshop (**WS 1)** to progress the modelling of landings data with reconstructions for historical data and missing years/gaps in the data. This analysis will have to reflect the uncertainty around the Illegal Unreported and Unregulated aspects of the landings in the dataseries. This information should be brought further into the models to help reflect the uncertainty in the advice.

How will that improve the advice?

Catches are not part of the recurrent advice, but during the last four years, the WGEEL has expended a lot of effort into building a more consistent and complete database of landings. Working on an assessment of catch data, combined with their correction / raising for missing data and underreporting is a prerequisite to their inclusion in the ICES advice.

Time frame

The landings analysis will require a dedicated workshop in 2023 (**WS 1)** which will feed into the Data Compilation Workshop meeting planned for 2027.

5.2.3 Habitat, hydropower, yellow and silver eel population assessment and trends

Problems

Several issues are discussed below as they will be addressed by the same model / data collection process.

Hydropower structures directly impact both upstream and downstream migrating eels and reduce available habitat. The precise location of many hydropower dams and/or **pumping stations** and their characteristics are not known. Mortality depends on site, type of structure and direct and indirect mortalities have to be included to account for their full impact. Delayed mortality and reduced fitness are expected for eels that survive passage through such structures. Basins where eels have been transported above barriers or pumps increase their overall mortality to very high levels, while the natural distribution of eels in the downstream reaches have lower hydropower related mortalities. Currently the coverage of known hydropower mortality is only partial (ICES, 2019).

A quantitative assessment of the effects of **habitat loss** will be challenging. Quantification of habitat loss due to river regulation and channelization is difficult but the effect of obstacles on eel river colonisation can be integrated into models if appropriate information on dam height and type is available. There is a need to quantify the destruction / creation of wetland as these habitats include a large amount of potentially high-quality eel habitat. Eels utilize a variety of habitat types, and endure anthropogenic impacts in different ways yet we don't know of any habitat effects on eels, either qualitatively or quantitatively.

How could this be solved?

To tackle this issue, a project should be implemented (**Project 1)** on quantitative assessment of habitat and its alteration and estimation of HP/P mortality throughout the distribution area of eel. Gathering data on eel abundance, and running a spatial model enabling the prediction of yellow and silver eel abundance, is a prerequisite to running a turbine mortality model. The inclusion of a model that would predict spatial and temporal patterns in sex ratio, size structure, size structure of silver, would address the risk of missing long-term trend to population structure.

The specific objectives of the project will be to:

- To estimate current and historically accessible eel habitat throughout the range of eel repartition in Europe and in the Mediterranean. This should include rivers, coastal areas, estuaries, lakes and reservoirs.
- Collect spatial data on HP/P and dams' locations using existing barrier dataset (e.g. AMBER international database, SUDOANG, GFCM project and national datasets).
- Collect data on direct and indirect HP/P reasoned silver or yellow eel mortality (delayed) at the spatial and temporal basis.
- Estimate the HP/P mortality (direct / indirect) using the actual data collected in the project.
- Integrate the data on key optimum habitat conditions for eel in each habitat into stock assessment models. These would also include information on the size structure or sex ratio of silver eels.
- Modelling the relationship between habitat characteristics and eel population. This would enable the estimation of the current and pristine habitat to be able to apply the stock assessment models.

How will that improve the advice?

The eel habitat covers both the marine and continental areas. We need a spatial GIS database to account for spatial complexity and to start modelling the impact. Gathering the huge amount of yellow eel data available within the WFD monitoring will help to build models that predict the yellow eel population repartition, abundance, and can predict the silver eel production.

These yellow and silver eel abundance trends can then be used to build eel specific stage structures surplus production models. This would strengthen the evidence-based part of the advice.

Silver eel productions are also necessary to assist in creating models accounting for the effect of hydropower, pumps and water intakes at different spatial scales (basin, EMU, national, international). Anthropogenic impacts other than fishery can then be incorporated in the eel models, as pseudo catch stemming from the mortality model.

Finally, the information collated from the WFD can inform on habitat quality. While further research will be needed to translate those data into models, the uncertainty about anthropogenic effect of habitat alteration can be incorporated into a global / regional eel model, possibly using spatial information.

Time frame

The process will start in 2023 end in 2025, and consists of several steps (see Figure 4 in Chapter 7).

Project 1:

- Project Design and funding options;
- Kick-off meeting (**KoM**) to design a Data call to gather WFD data (2023);
- **Data call** for WFD data and Habitat data (2023)
- Initial (WS II, 2023) - end (WS III, 2024) workshops to design and integrate those data into a consistent GIS database;
- **Data call** for HP/P information and Eel data from WFD surveys (2024);
- Modelling to produce spatial yellow eel and silver eel outputs (2024);
- Modelling to build local/national HP/P mortality models and describe habitat loss/change (2024);
- Integrate data and model results in a data base (2025).

5.2.4 Assessment method

Problem

This issue has been divided into several subissues. The first group of issues relates to the current recruitment trend-based approach. They concern the selection of the most appropriate time-series, the weight of fishery-based time-series, the method to select the most appropriate reference period (and the limited number of series in old times), the existence of several trends in Europe that lead to separate indices and the lack of data in some regions (Mediterranean). Regarding the last point, a specific group of issues has been pointed out on the need to standardise newly implemented recruitment time-series (and ideally, to achieve absolute estimates of recruitment in considered river basins). The last group of issues relates to the potential use of yellow and silver eel abundance time-series to provide additional trends. Most of the problems noted for recruitment time-series are also relevant for these types of time-series. However, they raise additional challenges. While several time-series are collected, many are collected in close areas so that the resulting spatial coverage is more limited than for glass eels (especially for long-term time-series – ICES, 2020a; ICES, 2020c). Although abundance indices are collected in many basins, the relative contribution of local conditions (e.g. local environmental conditions, anthropogenic pressures, management measures) and large-scale factors (population status, large-scale environmental factors) are difficult to disentangle and would require an appropriate method and more meta-information describing the time-series.

How could this be solved?

Recruitment trend-based approach issues have been addressed by WGEEL: criteria to select recruitment time-series have been formalized (an equivalent work should be made for yellow and silver eel time-series), sensitivity analysis to fishery-based statistics have been evaluated (the work can be renewed periodically), and the GEREM model has been tested to combine the different trends into a single indicator. Work on the reference period is still needed but options are limited given the limited number of time-series for the period pre-1980. This issue is one of the points to be addressed during a future benchmark exercise.

In relation to the implementation of new monitoring time-series, several initiatives have supported this idea (e.g. WKESDCF 2012; EU MAP). Interreg SUDOANG has recently developed a monitoring network and provided protocols that can be applied elsewhere.

Regarding yellow and silver eels, a preliminary analysis was carried out in WGEEL 2020. Further work is needed to develop criteria for selecting time-series, to collect and standardise meta-information required to describe local conditions, and to develop a statistical analysis to disentangle local and global influences in trends. At the same time, the possibility of developing a spatialized assessment model (see Section 5.2.3) will be explored.

The statistical analysis of the time-series data will be handled during one working group and may necessitate some adjustment to future Data Calls to get to a finalised trend.

Project 1 will produce information regarding yellow and silver eel production, habitat loss, HP/P mortality. This information, together with the one described in 5.2.1. and 5.2.2, would allow the implementation of a Spatial Stock Assessment Model. However, the development of the Spatial model will require a specific research project.

How will that improve the advice?

It is highly likely that none of the changes brought to the recruitment time-series analysis would bring any significant change to the current annual advice. However, it would make the analysis more robust to uncertainties. Achieving the analysis of yellow and silver eel time-series would provide a basis to the Advice that it is not solely derived from recruitment trends (recruitment is a stochastic process, and consequently very noisy), but also from additional indicators. Developing a Spatial Stock Assessment Model would ensure the Advice is based on both trends in abundance and trends in mortality, and if spatially structured, will provide spatially disaggregated estimates of these trends. Moreover, this would enable the estimation of biological reference points, though this would require a reflexion to find the reference points making sense to eels.

Time frame

Improvements in time-series analysis will take place during WGEEL 2022. An assessment models' development project (**Project 2**) will be required (2023–2026). The final steps will include the development of a **Spatial Stock Assessment Model** and the evaluation of the robustness of this model and reference points to all sources of uncertainty that were not accounted for because of lack of knowledge/data (e.g. climate change, quality, contamination, spatial pattern in life-history traits, etc).

6 ToR 3: Scope the needs for advice and the concepts with the requesters

The objective of this chapter is to determine the feasibility for the advice requesters to meet their management objectives. To do so, the end-users of the ICES advice on eel were identified. Then an online survey was developed and sent to a list of representatives, to evaluate the level of awareness amongst requesters and end-users of the recurrent ICES advice, its role and its contents, and to understand their needs, in order improve either the content or formulation of the advice. The main conclusions were:

- End-users of the advice include GOs, IGOs and NGOs representing a range of stakeholder groups involved in policy, management, science, conservation and industry.
- There is a range of interpretation and understanding of the advice amongst end-users. In some cases, it appears that this may be because the conditions under which the advice is requested of ICES are not clear – i.e. by the EC in the context of the Common Fisheries Policy – and as such, that the output will not be able to meet the needs of all end-users.
- Key points raised in the survey responses were:
    - Quality and availability of data used in the advice;
    - The advice being in a form and/or language that may not be digestible to all stakeholders;
    - A more holistic approach to the stock status would be preferred, i.e. that fisheries was not the focus.
- Where appropriate specific points were passed on to relevant organisation/groups, e.g. ICES, ACOM and WGEEL.
- Many of the issues seemed to be down to communication to/between all players, both at the national and international levels, and several solutions were proposed.

6.1 Identification of the end-users

The European Commission was the only official requester of recurrent advice on eel from ICES (see Section 4.1) at the time the WKFEA was started. However, as the UK has now become an independent coastal state and signed a MoU with ICES, it is now also an official requester of recurrent advice.

The scope of WKFEA is to assess possible developments/improvement, and these might include additional requests for advice. In addition, there are many organisations that use the advice that are not official requesters; thus, the WKFEA interpretation of ToR 3 was that to identify other end-users that were also important. WKFEA participants identified a range of potential end-users of the ICES eel advice:

- CITES;
- GFCM;
- CMS;
- IUCN;
- EIFAAC;
- Regional seas conventions: OSPAR/HELCOM/Barcelona convention;
- Eleven Advisory Councils (ACs);
- National and regional managers;
- Non-EU countries (Norway, UK…) ;
- Stakeholders (Fisher, NGOs…).

6.2 End-user request and feasibility to meet their management objectives

An online survey was developed to evaluate the level of awareness amongst the requesters and end-users of the ICES advice, its role and its contents, and to understand their needs, in order to improve the content and formulation of the advice. While it was recognised that gathering feedback from all of these end-users would be of value, compiling and analysing data could be time-consuming if it was open to all. Therefore, the questionnaire was only sent to representatives of CITES, GFCM, CMS, IUCN, EIFAAC, OSPAR, HELCOM, the Barcelona Convention and the ACs, in the hope of gathering general opinions from a broad subsample of potential end-users. In addition, staff from the DG MARE and DG ENV of the European Commission took part in WKFEA and provided comments as Commission service policy officers.

The survey was sent via a Google form and a total of 29 users responded. Some of the ACs forwarded the survey to individuals representing their member organisations, who answered directly. or on behalf of their organisation.

The form provided defined answers (drop-down menu) for some questions, whereas others invited free text.

The responses were reviewed for common themes and messages, as summarised in the following section. WKFEA has considered all the points and suggestions, and several are addressed below or in other parts of this report. However, there were a number that were outside the remit of WKFEA and proposals are made as to which other groups (within ICES and outside) might consider these.

We note that some respondents gave identical answers for some questions. Where we have counted the number of answers of a certain type, we have treated these identical ones as independent.

Due to the links to ICES, both GFCM and EIFAAC responses were recognised. Otherwise, responses have been anonymised. We have used quotes in some places where this was considered the most direct way to express the point; in some cases, we have adjusted quotes to preserve anonymity.

There is a range of interpretation and understanding of the recurrent ICES Advice amongst end-users. In some cases, it appears that this may be because the conditions under which the advice is requested of ICES are not clear (see Section 4.1) and, as such, that the output will not be able to meet the needs of all end-users.

The bold headlines are the questions as they were posed in the survey; responses are summarised in text below these.

1. How does your organisation engage on the European eel?

This question allowed for free text answers. The answers were varied, but some words appeared to be common/repeated.

The engagement of respondents depended on the type of organisation. Three respondents are engaged in policy and management. One is the European Commission, that is the organisation requesting advice from ICES and that is involved in implementation of EU policy for eel management through the Eel Regulation (EU Council 1100/2007). The engagement for the EU is important, and it can be identified as the main requester and end-user of the ICES advice.

Two respondents are involved in advising for policy and management, one is a FAO Regional Fisheries Management Organization (RFMO), the General Fisheries Commission for the

Mediterranean (GFCM), and the other is the FAO European Inland Fisheries and Aquaculture Advisory Commission (EIFAAC). Their positions are end-users of the ICES advice. Their joint engagement in the WGEEL (Joint EIFAAC/ICES/GFCM WGEEL) points to the fact that they are also involved in advice development, but their role as developers is not clearly defined. GFCM clearly considers itself to be a developer, according to the GFCM inclusion in the Joint WGEEL being formally approved by the 14th session of the GFCM Scientific and Advisory Committee on Fisheries (SAC) and the 36th Session of the GFCM Commission (based on a MoU between GFCM and ICES) in 2014. GFCM contributes by supporting the participation of experts to the WGEEL meetings, backing up their data contribution through a joint ICES/GFCM Data Call (to be implemented). EIFAAC also considers itself to be a contributor to the development of ICES advice and supervises the dissemination of ICES advice to non-ICES countries.

Eight respondents are Organisations or NGOs involved in protection of resources and/or habitat. Their awareness and involvement was not uniform, as some are strongly involved in eel and/or habitat protection, while others appear less directly involved.

Fourteen respondents are stakeholders involved in commercial or recreational fisheries and trade.

The other two respondents did not provide detail at a level that would allow them to be assigned to such a group.

2. Are you aware of the ICES advice for the European eel?

The answers were limited to three options. All the respondents were at least aware of the advice. Twenty-two chose "*I know it well*", and among the respondents that chose this option were Commission service policy officers and the two FAO Commissions, as well as most of the Organisations involved in protection and the NGOs and most of the stakeholders involved in fisheries. One, that was a fishers organisation, chose "*Yes, but partially, The ICES advice is too complex to fully understand*", whereas five, including two conservation organisations, chose "*I have heard something about it*".

3.

a) Does your organization use some, or all, of the information included in the ICES advice for eel?

Twenty-six respondents said that they used the advice in some way, three said they did not use the advice.

b) Which part of the advice do you use and what for?

The answers to the question of which part of the advice is used, and for what purpose, were quite varied. They ranged from 'all of it' (three) to quite specific parts or even information for a specific region (i.e. Baltic Sea) (one). The answers mostly used the headings from the advice, but in some cases, where they used different words, WKFEA interpreted these and 'assigned them' to the headings that fit most closely. The respondents who worked for the EC were those that used all parts of the advice, for gaining insights and to get an update on the state of the stock and the pressures impacting it, to inform the decision-making at EU level on the management and conservation of European eel. The GFCM also responded that the whole of the advice is used as a basis for GFCM decisions concerning eel, such as the Recommendation GFCM/42/2018/1 on a multiannual management plan for European eel in the Mediterranean Sea in 2018.

Among others, five respondents specifically noted using the headline '*advice on Fishing Opportunities*'. The '*Stock Development over time*', '*Stock and exploitation status*', '*Issues relevant to the advice*', and '*History of catch and landings*' were all listed five times, though not necessarily by the same five respondents in each case. Two respondents said they used the '*History of the advice, catch and management*'. The '*Quality of the assessment*', and the '*Summary of the assessment*' (the recruitment series) were mentioned by one respondent. Two respondents said that they used not only the advice but also the WGEEL report and the Country Report annexes.

In contrast to declaring which parts were used, some respondents specifically identified parts of the advice that they considered not useful: *advice on fishing opportunities* (1), *Stock and Exploitation Status, Catch Scenarios* (2), *Reference Points* (2), *Basis of the assessment* (1), and *Information from stakeholders* (1). Some explained that parts were not useful because they are not relevant to eel, or there are no data.

c) Are there sections you find more useful than others?

Commission service policy officers answered that all sections are relevant but commented that even if the advice focuses on the fisheries-related impacts, ICES cannot assess the exploitation status relative to MSY and PA reference points as those are undefined. Therefore, for the Commission service policy officers some relevant data are incomplete.

Most respondents find the section "*ICES advice on fishing opportunities*" useful, but for some, the advice is too focused on this aspect even if all anthropogenic impacts (e.g. caused by recreational and commercial fishing of all life stages, hydropower, pumping stations, and pollution) are addressed. In their opinion, management authorities may only focus on fisheries. Some respondents expressed the view/answered that the "*Issues relevant for the advice*" section is the most useful, as it addresses all the mortality factors on eels. WKFEA notes that the advice is requested in the context of the Common Fisheries Policy, and therefore would be expected to have a focus on fisheries.

d) Why don't you use the advice?

Three respondents that said they did not use the advice answered this question.

One reported that "*the advice has a focus on stocks and fisheries which is not the main focus of [our organisation, as per our mandate]. Advice that would be more directed as evidence base for the specified actions would make it more directly useable. Actions include eel fisheries, but also actions to improve eel habitat in coastal and inland waterways.*"

4. For those organisations that do not use the advice, what should be done to make it more useful for your organization?

One respondent suggested that advice more directed to specified actions would be more useful.

Another suggested that a non-scientific summary would be useful. This is addressed in Q6 below.

5. Do you understand the process of how the advice is developed?

Three answers were given as options: *Perfectly* (nine), *More or Less* (16), *Not at All* (four).

Commission service policy officers and the two FAO bodies indicated that the process of advice development is clear; among the conservation organisations only one thought the process was clear, while others responded that the process was "*more or less*" clear. Among the stakeholders, only three respondents thought the advice development was clear, for seven it was "*more or less*" clear, and for three "*not at all*".

6. What could be done to make the advice more understandable?

From the answers in Q5 it seems that there are elements of the process of advice drafting that some end-users find unclear. Several suggestions related to the desire to make the advice more readable to all end-users, e.g. scientists, managers and fishermen, and a non-scientific audience. These suggestions included a simpler formulation, a shorter, non-scientific summary, "*a 'lay-person' description of how [the advice] is developed as an Annex of the WGEEL report*", a simplified description of the methodology, and the advice in simple bullet point form. It was also suggested that *'the data in the various tables… …deserve to be analysed for a better understanding'*. Ultimately, the advice is drafted in accordance with a standardised ICES template based on scientific expertise. At present there is no plan within ICES to provide a simplified 'lay' version – however, ACOM has been made aware of this feedback for consideration. The process of developing ICES advice is described here. A schematic (Figure 1) is referenced in Section 4.1.1.3 as an illustration of the process, though WKFEA understands that the received comments probably related as much to the contents as to the process itself.

Two respondents expressed concern about the lack of reporting data by some countries, suggesting this prevents ICES from providing more detailed advice. They suggested that ICES should be clear about this absence of data, and that with more complete reporting, biological reference points could be developed, trends in catch and landings time-series could be analysed, and information from non-EU countries could be included providing more comprehensive population level advice throughout the eel's natural range. In reality, it is likely that there are multiple reasons why data are not submitted and/or included in analysis, e.g. time-series are too short, datasets are incomplete, countries lack capacity and/or resources to collect long-term series. However, there is an on-going examination of datasets that could be used in the advice by WGEEL. These include catch and landings, time-series data of all life stages and data relating to non-fisheries anthropogenic mortality, as well as appropriate models and analysis to utilise said data. The WGEEL report details which data are included or excluded from the analyses and why (see Section 4.1). This includes data from some non-EU countries, and efforts continue to increase data reporting from all eel range states. However, the WGEEL report is produced to support the advice but is not part of the advice. The WGEEL report is cited by the advice and is published on the ICES website, but WKFEA recognises that it is a large and complex report that is not easily understood by all.

One respondent suggested that ICES should be more proactive in the advice and "*not just answering questions asked by the organisation ordering advice*" but noted this "*is a common problem with several species*". In this context, it was requested by another respondent that the advice should include prioritised management options to address known threats that would support range states in the recovery of the European eel. Ultimately, the advice follows a procedure on both framework and content. Wider issues relating to how the advice translates into implementation at the national level could be addressed though Special Requests to ICES.

In summary, WKFEA notes the challenge of producing advice that is shorter, more concise and formatted for the wider audience, while at the same time including more analyses. WKFEA notes too, that data and information are reported from some non-EU countries and WGEEL has worked with EIFAAC, GFCM and ICES Member States for several years to extend the spatial coverage. Nevertheless, WGEEL would welcome further data and information which are missing from across the natural range of the European eel.

7. Do you think the process of developing the advice is transparent?

Three responses were available to participants, who answered as follows: Totally transparent (five), More or Less (20), No (four).

8. What could be done to make the process more transparent?

From the answers to Q7 it seems that there are elements of the process of the development of the advice that some end-users felt could be more transparent.

One respondent called for a simpler formulation to the process of developing the advice, which would require a wholesale change of ICES advice structure and content, and is unlikely to be feasible. Another respondent suggested the methodology behind developing the advice should be explained more clearly to make the process more transparent. A specific point relating to how the analysis carried out by WGEEL, relates to the advice was raised by another respondent. As noted above, the process steps are described in the advice drafting process document, and the WGEEL report plus accompanying Stock Annex describe the data and analyses, but these are complex documents not easily understood by all. WKFEA will make ICES aware of this desire for non-scientific descriptions.

There were a number of respondents that proposed that stakeholders should be involved in the process, for example, through stakeholder meeting(s) where they could express their views and experiences, or if they would be able to attend as observers to the Working Group or the Advice Drafting Group (ADG), and observe directly or via online streaming of meetings. This was both to increase transparency in the process and to aid understanding of what data are used or not. Several called for clarity on which data are used or not used in the advice, and whether data reporting was consistent across countries. There were several questions regarding the absence of specific datasets.

At present, ICES does not permit stakeholder observers to attend WGEEL – as an 'assessment' WG (ICES, 2020). However, WKFEA did discuss options that might allow stakeholders/end-users to better understand the production of the advice and its contents. This could include options such as a FAQ document and/or webinars, once the eel advice has been produced. This could also help to address some of the comments in replies to Q6 in relation to how understandable the advice is. It was also recognised that in many instances, respondents had questions relating to, and/or wished to understand the advice in, the national context. As such, WKFEA would propose that European eel Range States consider how they communicate about data provision, ICES advice and stakeholder engagement within their countries, e.g. establishment of national networks.

Several respondents noted that information about ICES meetings relating to eels could be more widely communicated and easier to find if listed by topic on the ICES website instead of by meeting acronyms. Similarly, the announcement of the advice could be more widely communicated. There were a number of comments on how the ICES website was difficult to navigate and search. WKFEA has ensured that ICES is aware of these communication issues.

It was noted that the link between national Eel Management Plans and ICES is not clear, and it was asked why the information from Eel Management Plans was not used in the advice, and whether ICES gives its opinion by taking the 40% escapement target into account or are these different. This issue is an ongoing discussion between ICES and the European Commission. Similar to previous issues, improved engagement through international webinars and national stakeholder networks could help address this issue in general. Specific to using the EMPs in the ICES advice, this would require ICES to have positively evaluated the Eel Regulation (EC 1100/2007) for its conformity with the precautionary approach (ICES, 2020d) and this has not been done.

9. Are there any issues that need to be addressed in future advice? Which issues should be improved and how?

The final question elicited a wide range of suggestions, often relating to the specific interest(s) of the end-user.

Echoing points made in response to previous questions, it is very clear that there is a desire from end-users to see a more balanced discussion of the fisheries and non-fisheries impacts. This could include a synthesis of all the identified pressures and their effects and impacts. ICES has been attempting to address this point for many years and the limited data has proved challenging. Regardless, a key discussion point in WKFEA, which includes representatives from ACOM, has been how the advice may better communicate non-fisheries impacts.

There were several suggestions that related to the data that were used and/or presented in the advice. One respondent suggested there should be clearer discrimination of catch data, e.g. marine or inland; commercial/recreational; legal/illegal, and that mortality of each life stage should be described. A fundamental issue with this is that these habitat and fishery-type terms may have different meanings between Range States (ICES, 2020c). Further, visualisation of these data would make the advice overly long. ICES are exploring ways these data might be presented outside of the existing reporting mechanisms. It was also raised that there should be greater examination of data inconsistencies, and efforts should be made to gather similar series from all countries across the species range. A standardised Data Call has been issued by ICES, GFCM and EIFAAC ahead of the WGEEL annual meeting since 2017, and there has been a considerable improvement in both data consistency and area coverage (see Section 4.1.4.1). This is an ongoing process, and also requires examination of how data are analysed and the resources available at the national level, and within WGEEL, to progress this.

In addition to this, there were comments that related to data from other regulatory mechanisms – most prominently the EU Water Framework Directive (WFD) – being incorporated into the analysis that informs the advice. Those data include indicators of the state of river morphology and continuity, chemical pollution, nutrient pollution, physicochemical conditions and biological conditions. It was proposed that incorporating these data may help to address indirect causes of eel mortality…, e.g. aquatic habitat loss, fragmentation and/or quality. It was proposed that this may help to define inland waterbodies key to the eel population, which could help prioritise national and international management efforts. WKFEA recognised that some countries are already using WFD data to inform eel management and in their submissions to the ICES Data Call. It is worth noting that the proposal of using EU mechanisms may exacerbate the previous concerns relating to inconsistencies of data, as non-EU Range States may not be collecting this.

A suggestion that has been an ongoing discussion in WGEEL, is the merit of developing mortality-based targets and/or recommendations for management that can help to achieve these, in the context of EMPs. This point touches on the previous answers relating to linkage between the work of the WGEEL and the ICES advice, and the EMPs. Further, presently the mandate of ICES is to produce science-based advice for interpretation by end-users and, as such, proposing management measures is outside this remit. WKFEA plenary discussions have frequently touched on this, and it returns to the point made previously, about ICES providing advice outside the remit of the request.

In the context of how the data are translated into advice, there were a number of comments; which to some extent refers back to the responses that requested simplified language. One comment suggested that the text in the advice '*…all anthropogenic impacts… …that decrease production and escapement of silver eels should be reduced to, or kept as close as possible to, zero…*' may be confusing with regard to whether managers establish a zero catch and/or zero mortality. This links to other comments regarding the absence of a definition for recovery of the stock, and how this is associated with reference points and possible catch scenarios. In this context, another response requested a better explanation of the recruitment trend reported in the advice and what this statistical output means for the stock. WKFEA has taken these points into account and a timeline towards a Baseline Assessment to address them is outlined in Chapter 7.

There were a number of comments on the need for more advice on restocking. Some related to broad questions such as "*…the role of stocking in the future?*' and "*What is the efficiency of restocking?*". In contrast, there were several more specific points, such as the logic of upstream releases and how this relates to the calculation of mortality due to dams/hydropower, and the risk of diseases and viruses in released eels. See Section 4.1.3.2 for WKFEA recommendations on how restocking is proposed to be addressed in the advice.

There were comments that related to the linkage between the advice and implementation of management measures to aid the recovery of the European eel. For example, one respondent requested a better explanation of migration periods so managers can implement appropriate fishery controls in relevant months. This was addressed, to a large extent, in WKEELMIGRATION (ICES, 2020c), but reflects previous comments about the communication of meetings and outputs relating to eels. More broadly, it was whether it was possible to provide guidance on effective measures to address all anthropogenic pressures to help managers prioritise actions. It was recognised that this is likely to vary across (sub)regions and depend on EMPs and associated measures. This latter point is key when the advice relates to the stock across its full range; however, it is possible that *ad-hoc* advice could be produced outside of the annual recurrent advice.

Referring to previous points, there were comments about how stakeholders might engage in the process. In addition to previous reflections made by WKFEA, it should be noted that the end-users identified had different relationships with ICES and that, in some cases, amendment of legal agreements/MoUs may mean that a more active role in developing advice is possible.

7 ToR 4: What is the future of eel assessment and advice

Based on the findings of the precedent chapters, a road map (Figure 4) towards the future advice for the European eel stock was drafted. According to the ToR requirements, it details the potential assessment approach, data needs, defines objectives and tasks to achieve them and sets a time frame for the completion of these tasks. It also details the logistical (human and technological resources, funding) means that will be required at each stage of the process.

The proposed roadmap targets two major improvements. The first relates to improving the data that should be part of a stock analysis. The second is to provide more holistic advice by taking greater account of the whole ecosystem and looking in more detail at the impacts of the different types of pressures affecting the eel population.

Whether this roadmap can be implemented depends on the involvement of different actors. First, ICES will drive the collection and analysis of eel habitat and data (WGEEL, ACOM, Data Centre), acting through ICES the member countries. Thus, ICES will have a central role in orchestrating different actors at different levels: local, national and international. The road map includes two projects which are crucial to achieving holistic advice but are resource intensive, and for which external funding must be secured. In that sense, ACOM and WGEEL should act as the main drivers to get the road map implemented.

The implementation of the road map will be completed with a benchmark in 2027. This may seem a long period, but although the improvement of the information already collected in the WGEEL (landings and certain biological parameters) can be done in a shorter period, the road map foresees an ambitious collection of new information (electrofishing, dams and HP/P), which unlike stock indicators collected so far, rely on detailed geographic data, not indicators collected at the larger EMU scale. In this case, a new database must be developed and completed from scratch and then a new **Spatial Stock Assessment Model** should be implemented to estimate new indicators of stock status. While the possibility of having an intermediary data-related benchmark after four or five years was envisioned during the meeting, it was found that a better option would be to wait for the development of corresponding analytical methods that will be available a few years later, instead of having two successive benchmarks in 2–3 years. Furthermore, even if the process would not be fully completed in 2027, it will not be necessary to wait until then to obtain a better assessment, as new and corrected information relevant for the recurrent advice will be incorporated immediately.

7.1 Road map towards the future advice for the European eel stock

This year (2021) work is already set, with the Data Call and collection of national stock indicators on mortality and biomass, so the road map only starts in 2022 (Figure 4). The road map for strengthening the advice has been built considering the feasibility of the work. Work already initiated within WGEEL (like collecting and analysing time-series and biological parameters) will be finished first. Other more complex tasks relating to different challenges have been grouped together because they relate to each other – for instance, you need yellow and silver eel models of spatial distribution that estimate abundance to build a hydropower mortality model – but also because the workload behind these tasks is more important and will not be answered by a single workshop. Getting these tasks done will require both international coordination and research time to build the tools and the different models necessary to build the final **Spatial Stock Assessment Model** to be used in the ICES advice. As a consequence, the road map time frame is just indicative. The issues identified in Chapter 5 have been merged into categories that will be addressed as follows:

1. Time-series of yellow and silver eels and biological parameters (2022)

In the timeline, the first task will be to address the issues of biological parameters and yellow and silver eel time-series. A Data Call will be launched to collect time-series and biological parameters data that could be collected from the EU MAP data and other sources. The work will probably be managed by WGEEL only, as a similar Data Call was dealt with in 2020.

2. Landing reconstruction workshop (2023)

As a second step, rebuilding corrected landing series will be done during a workshop (WS 1), as this is a key issue to the **final Spatial Stock Assessment Model proposal** and the results could be incorporated in the advice.

3. Habitat assessment, WFD data and HP/P mortality–Project 1 (2023–2025)

A project (**Project 1)** on quantitative assessment of habitat, its alteration and estimation of HP/P mortality throughout the distribution area of eel should be implemented. This project will start with a meeting (KoM) to assess which WFD data are available and, as a next step, produce a Data Call. From then on, the first task will be to collect the habitat GIS, and then to collect all available electrofishing and other sampling related to eel, and finally to integrate other aspects like habitat quality. This will require a close interaction of national correspondents with a strong international coordination, probably involving two workshops and several meetings.

As a second part of the project, once habitat data are ready and the electrofishing collated, a model of yellow and silver eel production in the different EMUs and in different types of water will be built.

Linking the results of the yellow and silver eel production models and the HP/P and obstacle projections in the GIS layers should allow to build local/national HP/P models and describe habitat loss/change. These models will allow input of HP/P mortality and other aspects – like habitat quality – to the stock assessment model.

4. Design a population model–Project 2 (2023–2026)

Designing the **Spatial Stock Assessment Model** will probably take many years and asks for a specific project (**Project 2**). Data and results obtained in the 1, 2 and 3 categories described above will feed the proposed Spatial Stock Assessment Model as they are collected. A stage-structured model will rely on the information derived from the yellow and silver eel production predictions. But a simpler model based only on trends can be built as a first step. Finally, the evaluation of the robustness of this model and reference points to all sources of uncertainty that were not accounted for because of lack of knowledge/data (e.g. climate change, quality, contamination, spatial pattern in life-history traits, etc) will be carried out.

5. Data compilation meeting and benchmark (2026–2027)

To finish the process, a **Data Compilation Workshop** should take place in 2026 in order review, discuss and quality-check the data gathered so far (recruitment time-series, yellow and silver eel series, biological parameters, spatial abundance of yellow and silver eel, HP/P mortality and habitat data). The approved data will be used in the final **benchmark** in 2027 to evaluate the candidate Spatial Stock Assessment Models.

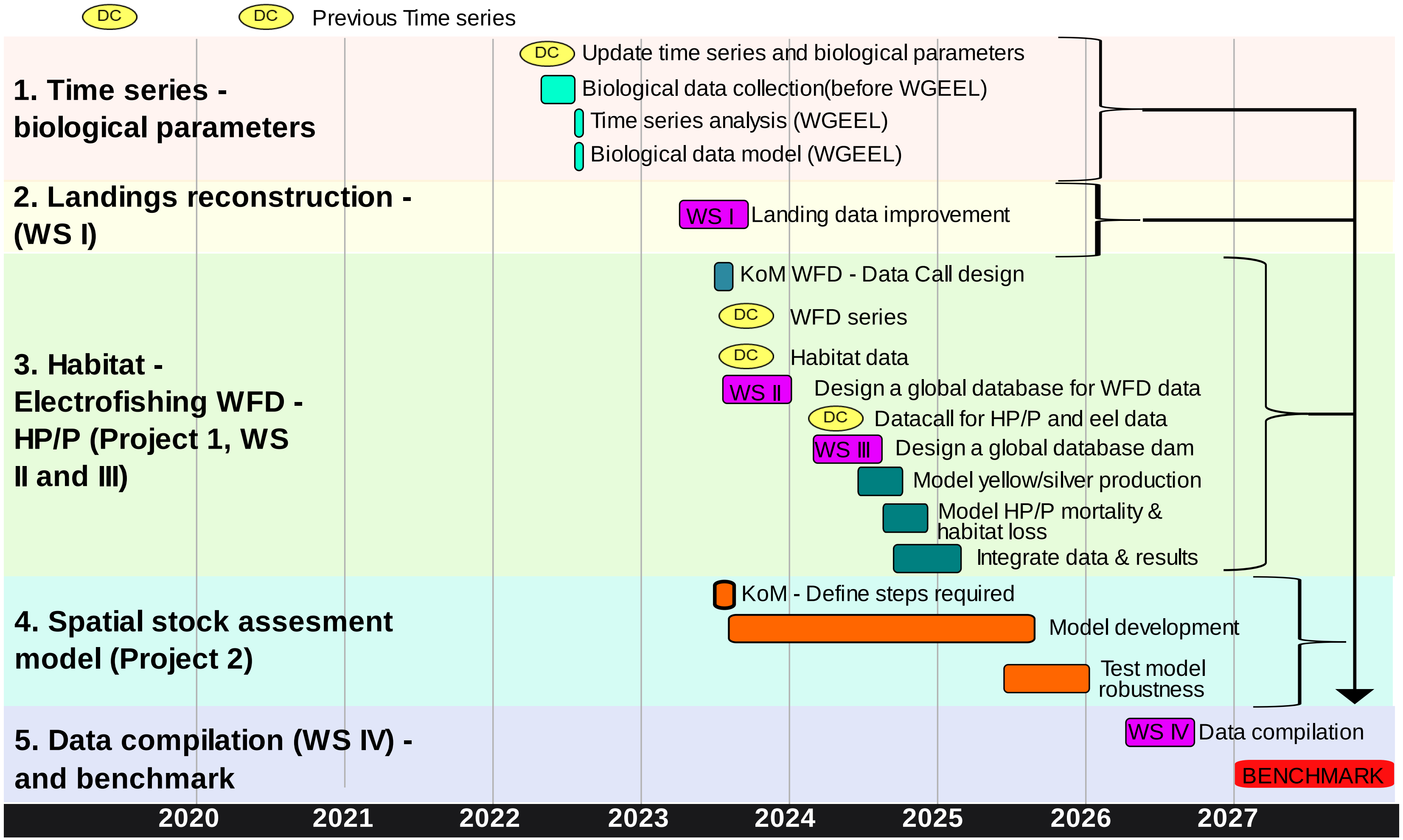

Figure 4. Proposed road map to improve the future advice for the European eel stock. DC: Data Call, WS: workshop, KoM: Kick-off meeting and HP/P: Hydro Power Plants.

7.2 How would the proposed road map improve the assessment?

The road map proposed here presents two general improvements. The first relates to improving the data that should be part of a stock analysis. The second is that it takes a more holistic approach to the advice, taking the whole ecosystem into greater account and looking in more detail at the impacts of the different types of pressures affecting eel population. The following provides more details about improvements.

7.2.1 Time-series of yellow and silver eels, and biological parameters

Relates to: Time-series Data Call; Biological data collection; Time-series analysis; Biological data model; Data compilation Workshop.

Rationale: Time-series of yellow and silver eel abundance with adjacent biological data provide fundamental information on both regional and global trends and the development of all continental life stages, and are thus vital for spatialised analyses.

Improvements: Availability of reliable indicators of yellow and silver eel abundance, as well as stock structure on a regional level, as well as providing towards a full assessment model (see below).

Requirements: two WGEEL meetings and a new Data Call.

7.2.2 Commercial and recreational landings Data

Relates to: Workshop on landings reconstruction; Data compilation Workshop.

Rationale: Data on landings can be used to estimate fishing mortality for assessment models and provide estimates for trends in the stock. Reporting of landings data has been incomplete and heterogeneity among the time-series made them difficult to use, but additional efforts in data collection and reconstruction of historical data can solve these issues at least partly.

Improvements: Landings data can be used as an additional indicator in the ICES advice and will provide better estimates of fishing mortality, hence providing towards a full assessment model (see below).

Requirements: Specific workshop to improve landings data collection and processing.

7.2.3 Habitat, hydropower, yellow and silver eel population assessment and trends

Relates to: Biological data collection; Kick-off meeting WFD – Data Call design; Data Call for WFD series; Data Call on habitat; Design a global database for WFD data workshop; Data Call for HP/P; Design a global database dam workshop; Modelling of yellow and silver eel production and HP/P mortality and habitat loss; Integrate data and results; Data compilation Workshop.

Rationale: Hydropower (causing notable mortality) is closely linked to the issue of habitat loss (i.e. major changes in the ecosystem), since it is the cause of many river obstructions thus knowledge of both (HP/P mortality and habitat loss) is crucial to assess the potential of the stock to recover. The quantification of HP/P mortality and habitat loss will largely depend on the underlying population structure (e.g. biomass-based mortality will vary with sex ratio as males are considerably smaller and productivity and hence population structure depend on the habitat type).

Improvements: While requiring considerable effort, habitat quantity and quality estimates are a crucial prerequisite for spatial modelling approaches, as are robust estimates of hydropower mortality and population structures (also see above). As a result, such information will allow for a better estimation of trends in the whole stock but notably also on a regional level, thus being of immediate relevance to policy makers. It will further provide towards a **Spatial Stock Assessment Model** (see below).

Furthermore, the resulting global dam database will be of immediate use for other diadromous species and ecosystem-related questions.

Requirements: A series of meetings/workshops to design Data Call, integrate and analyse data and build two databases.

7.2.4 Assessment

Relates to: Kick-off meeting to define steps required; Model development project; Model development; Test model robustness; Benchmark.

Rationale/Used in: The ambition behind the development of an assessment model is to generate a tool that utilizes and combines the available data and derives a holistic description of the stock dynamics, including a spatialised approach (i.e. providing data on subunits of the stock, e.g. EMUs).

Improvements: The development of the **Spatial Stock Assessment Model** will provide both trends in species abundance and trends in mortality, which are currently missing in the advice. Moreover, if spatialised, the model would provide spatially disaggregated estimates. Though the advice would remain based on the status at the population scale, the estimates would be useful for managers as a basis for EMP implementation. In the long-term, it is a step towards the estimation of biological reference points, which are also currently missing.

Requirements: An effort in data collection is required to improve data quality and provide insights on the effects of different sources of mortality (Project 1), and consequently to achieve more holistic advice (even if it remains trend-based advice). This will also allow better account for spatial heterogeneity traits in eel life history that will feed the **Spatial Stock Assessment Model**. The model development is beyond the scope of WGEEL or ICES workshops and will require a dedicated project and thus funding.

7.3 How the above will respond to expectancies of end-users?

The improvements described above are consistent with most expectancies expressed by end-users in Chapter 6. The effort of data collection through different Data Calls, workshops and projects directed towards all countries within the natural range of European eel will hopefully address "*the greater examination of data inconsistencies*" and "*lack of reporting data by some countries*". Among this effort in data collection, data collected in the context of the WFD will be handled during a dedicated workshop and successive Data Calls, and as such will "*be incorporated into the analysis that informs the advice*" during the modelling exercise. The WFD data may provide information on eel abundance, but also on habitat quality (specific Data Call) which will be supplemented by a Data Call on HP/P and barriers, with the final aim of better assessing the effect of "*known threats*", including "*non-fishery impacts*", potentially by using these data in the stock assessment model.

The stock assessment model will provide mortality estimates and will be used in the long-term work on biological reference points, which can be seen as "*mortality targets*" and to depict "*signs* *of recovery*". Finally, the estimation of mortality and abundance potentially disaggregated at a spatial scale more consistent with the management framework will provide "*evidence base for the specified actions would make it more directly useable*".

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Annex 2: Acronyms and Glossary

Acronyms

Acronyms	Definition
ACFM (ICES)	Advisory Committee on Fisheries Management
ACOM (ICES)	Advisory Committee on Management
CITES	Convention on International Trade in Endangered Species of Flora and Fauna
CMS	Convention on the Conservation of Migratory Species of Wild Animals
CPUE	Catch per unit of effort
DCF	Data Collection Framework of the European Union
DG ENV	Directorate-General for Environment is the European Commission department responsible for EU policy on the environment.
DG MARE	Directorate-General for Maritime Affairs and Fisheries, European Commission
EC	European Commission
EDA	Eel Density Analysis (model, France)
EIFAAC	European Inland Fisheries & Aquaculture Advisory Commission
EIFAC	European Inland Fisheries Advisory Commission – became EIFAAC in 2008
EMP	Eel Management Plan
EMU	Eel Management Unit
EU	European Union
EU MAP	The European Multi-Annual Plan
FAO	Food and Agriculture Organisation
GFCM	General Fisheries Commission of the Mediterranean
GEREM	Glass Eel Recruitment Estimation Model
GIS	Geographic Information Systems
GLM	Generalised Linear Model
HP/P	Hydropower Plant
ICES	International Council for the Exploration of the Sea
IUCN	International Union for the Conservation of Nature
IUU	Illegal, Unreported and Unregulated fisheries

Acronyms	**Definition**
MS	Member State, typically used in reference to EU Member States but not only
MSY	Maximum Sustainable Yield
NAO	North Atlantic Oscillation
PA	Precautionary Approach
RBD	River Basin District, typically as defined according to the EU Water Framework Directive
SAC	The GFCM Scientific and Advisory Committee on Fisheries
SCICOM	The Science Committee of ICES
SGAESAW	Study Group on anguillid eels in saline waters 2009
SUDOANG	An Interreg SUDOE project promoting sustainable and concerted eel stock management in the European Sud west area.
SPR	Estimate of spawner production per recruiting individual.
SSB	Spawning–stock biomass
ToR	Terms of Reference
WG	Working Group
WFD	Water Framework Directive, European Directive
WGEEL	Joint EIFAAC/ICES/GFCM Working Group on Eels
WKEELMIGRATION	Workshop on the Temporal Migration patterns of European Eels 2020
WKEMP	Workshop on Evaluating Management Plans – 2018
WKESDCF	Workshop on Eels and Salmon in the Data Collection Framework 2012
WKFEA	Workshop on the Future of Eel Advice 2021
WKSTOCKEEL	Workshop on Eel Stocking 2016

Glossary

Anthropogenic	Caused by humans
Assisted migration	The practice of trapping and transporting eel within the same river catchment to assist their migration at difficult or impassable barriers, without significantly altering the production potential (B_{best}) of the catchment
Catch	The WGEEL uses the term catch(es) to mean fish that are caught but not necessarily landed. See landings below
Depensation	The effect on a population when a decrease in spawners leads to a faster decline in the number of offspring than in the number of adults.
Eel River Basin or Eel Management Unit	"Member States shall identify and define the individual river basins lying within their national territory that constitute natural habitats for the European eel (eel river basins) which may include maritime waters. If appropriate justification is provided, a Member State may designate the whole of its national territory or an existing regional administrative unit as one eel river basin. In defining eel river basins, Member States shall have the maximum possible regard for the administrative arrangements referred to in Article 3 of Directive 2000/60/EC [i.e. River Basin Districts of the Water Framework Directive]." EC No. 1100/2007.
Elver	Young eel, in its first year following recruitment from the ocean. The elver stage is sometimes considered to exclude the glass eel stage, but not by everyone. To avoid confusion, pigmented 0+cohort age eel are included in the glass eel term.
Escapement	The amount of eel that leaves (escapes) a waterbody, after taking account of all natural and anthropogenic losses. Most commonly used with reference to silver eel – silver eel escapement.
Glass eel	Young, unpigmented eel, recruiting from the sea into continental waters. WGEEL consider the glass eel term to include all recruits of the 0+ cohort age group, including some pigmented eel.
ICES advice (*ad hoc*)	Advice provided by ICES to answer special requests.
ICES advice (recurrent)	Advice provided by ICES on a recurrent basis
ICES advice on fishing opportunities	Refers to the headline of the advice
ICES advice sheet	Full text provided by ICES for each stock subject to recurrent advice. It contains different parts: The Advice (the section currently called 'ICES advice on fishing opportunities') and sections related to stock status, quality and issues relevant for the management.
Index river	Index rivers are intensively monitored systems that employ a variety of sampling methods to produce census and other biological data of a given fish species.
Landings	The WGEEL uses the term landings to mean fish that are brought ashore and killed, i.e. landed.
Leptocephalus	Flat and transparent marine larval stage of eel, on migration from spawning ground to continental waters; life stage between pre-leptocephalus and metamorphosis to glass eel
Life stage	Defined stage in the life cycle of eel, whether leptocephalus, glass eel, yellow eel or silver eel.
Limit reference point	A Limit Reference Point indicates a state of a fishery and/or a resource which is considered to be undesirable and which management action should avoid.

Anthropogenic	**Caused by humans**
Portfolio effect	"The portfolio effect (derived from stock market terminology) refers to the dampening of variance caused by use of a diversity of habitats or resources. Eel use of both fresh and saline growth habitats can be viewed as a portfolio effect." (ICES, 2009)
Pre-leptocephalus	First larval stage of eel, between hatching from ovum and the leptocephalus life stage.
Production	The amount of fish produced from a waterbody. For silver eel sometimes referred to in terms of escapement + anthropogenic losses, or production – anthropogenic losses = escapement.
River Basin District (RBD)	The area of land and sea, made up of one or more neighbouring river basins together with their associated surface and groundwaters, transitional and coastal waters, which is identified under Article 3(1) of the Water Framework Directive as the main unit for management of river basins. The term is used in relation to the EU Water Framework Directive.
Restocking	The practice of adding fish [eels] to a waterbody from another source, to supplement existing populations or to create a population where none exists.
Silver eel	Migratory phase following the yellow eel phase. Eel in this phase are characterized by darkened back, silvery belly with a clearly contrasting black lateral line, enlarged eyes. Silver eel undertake downstream migration towards the sea, and subsequently westwards. This phase mainly occurs in the second half of calendar years, although some are observed throughout winter and following spring.
Storage effect	"The storage effect refers to a long segment of a life cycle which has relatively low variation in survival, in contrast to a short segment which has high variability. In eels, the storage stage is the yellow stage due to its larger size and attributes that adapt it to seasonal and spatial environmental changes" (ICES, 2009).
Target reference point	A Target Reference Point indicates to a state of fishing and/or a resource which is considered to be desirable and at which management action, whether during development or stock rebuilding, should aim. (FAO, 1995).
To silver (silvering)	Silvering is a requirement for downstream migration and reproduction. It marks the end of the growth phase and the onset of sexual maturation. This true metamorphosis involves a number of different physiological functions (osmoregulatory, reproductive), which prepare the eel for the long return trip to the Sargasso Sea. Unlike smoltification in salmonids, silvering of eels is largely unpredictable. It occurs at various ages (females: 4–20 years; males 2–15 years) and sizes (body length of females: 50–100 cm; males: 35–46 cm) (Tesch, 2003).
Trap and transport	Capturing downstream migrating silver eel for transportation around hydropower turbines and subsequent release.
Yellow eel	Life-stage resident in continental waters. Often defined as a sedentary phase, but migration within and between rivers, and to and from coastal waters occurs; includes young pigmented eels (elvers and bootlace).

Stock Reference Points

Age	The age of eel in years, with part years as plus growth (e.g. 0+, 1+), starting at recruitment to coastal waters. Glass eel are defined as 0+.
A_{lim}	Limit anthropogenic mortality: Anthropogenic mortality, above which the capacity of self-renewal of the stock is considered to be endangered and conservation measures are requested (Cadima, 2003).
A_{pa}	Precautionary anthropogenic mortality: Anthropogenic mortality, above which the capacity of self-renewal of the stock is considered to be endangered, taking into consideration the uncertainty in the estimate of the current stock status.
Aquaculture production	The biomass of eel harvested in aquaculture during a time frame, e.g. a year.
$B_{current}$ or B_{curr}	The current escapement biomass: the amount of silver eel biomass that currently escapes to the sea to spawn, corresponding to the assessment year.
B_{best}	The amount of silver eel biomass that would have existed if no anthropogenic influences had impacted the current stock, included restocking practices, hence only natural mortality operating on stock. The best achievable escapement biomass under present conditions: escapement biomass corresponding to recent natural recruitment that would have survived if there was only natural mortality and no restocking, corresponding to the assessment year.
B_0	The amount of silver eel biomass that would have existed if no anthropogenic influences had impacted the stock. Reference point for the theoretical maximum quantity of silver eel expressed as biomass that would have escaped from a defined eel producing area, in the absence of any anthropogenic impacts.
B_{lim}	Limit reference point for spawning–stock biomass. In terms of eel, spawner escapement biomass, below which the capacity of self-renewal of the stock is considered to be endangered and conservation measures are requested (Cadima, 2003).
B_{MSY}	Spawning–stock biomass (SSB) that is associated with the Maximum Sustainable Yield.
$B_{MSY-trigger}$	Value of spawning–stock biomass (SSB) which triggers a specific management action, in particular: triggering a lower limit for mortality to achieve recovery of the stock.
B_{pa}	Precautionary spawner escapement biomass: The spawner escapement biomass, below which the capacity of self-renewal of the stock is considered to be endangered, taking into consideration the uncertainty in the estimate of the current stock status.
Commercial fisheries	Fisheries with sale of catch for commercial gain
Coastal waters	Coastal waters as defined according to the WFD in each Member State
Eel management unit (EMU)	Eel management unit defined in an Eel Management Plan under the Eel Regulation 1100/2007.
F	Fishing mortality rate
FAO areas	See http://www.fao.org/fishery/area/search/en
F_{lim}	F_{lim} is a limit reference point for the fishing mortality which in the long term will result in an average stock size at B_{lim}.
Fpa	Precautionary reference point for fishing mortality (mean over defined age range)

F-rec	Recreational fishing mortality, per reporting year, in kg.
Freshwaters	Waters with zero salinity
FMSY	Fishing mortality consistent with achieving Maximum Sustainable Yield (MSY).
G	Code in Data Call for data comprising glass eel only as defined in Glossary.
G+Y	Code in Data Call for data comprising a glass eel with yellow eel mix.
Glass eel recruitment series	Time-series enumerating glass eel recruiting from the sea into continental waters.
GLM	Generalized linear model (used by ICES to predict and fill in gaps in the data).
Habitat	Waters occupied by eel, whether fresh, transitional, coastal or marine.
ICES statistical rectangles	See http://gis.ices.dk/sf/index.html?widget=StatRec
Inland waters	Freshwaters, not under the jurisdiction of marine fisheries management (i.e. the CFP).
Landings from fisheries	Commercial landings include any eel taken from the water, landed and put on the market. Recreational landings include any eel taken from the water by recreational fisheries. Other landings include eel caught for assisted migration and translocation.
M	Natural mortality
North Sea	For the purposes of ICES eel management, taken as ICES sea areas IV_a, IV_b, IV_c and inflowing freshwater systems.
Marine waters	(Abbreviated MO) Open marine waters
Fisheries - Recreational	Recreational (= non-commercial) fishing is the capture or attempted capture of living aquatic resources mainly for leisure and/or personal consumption.
Releases	Eel released to the wild after capture
R_{target}	For eel, the Geometric Mean of observed recruitment between 1960 and 1979, periods in which the stock was considered healthy.
S	Code in Data Call for data comprising silver eel
Silver eel abundance series	Time-series of abundance of silver eel determined by consistent regular count or survey (usually by capturing migrating silver eel).
SPR	Spawner per recruit: estimate of spawner production per recruiting individual.
%SPR	Ratio of SPR as currently observed to SPR of the pristine stock, expressed in percentage. %SPR is also known as Spawner Potential Ratio.
Standing stock	The total stock of eel present in a waterbody at a point in time, expressed as a number of individuals or total biomass.
sumA	Total anthropogenic mortality, per reporting year, in kg.
sumF	Total fishing mortality per reporting year, in kg.
sumH	Total non-fishing anthropogenic mortality, per reporting year, in kg.

sumF_com	Mortality due to commercial fishery, summed over age groups in the stock.
SumF_rec	Mortality due to recreational fishery, summed over age groups in the stock.
SumH_hydro	Mortality due to hydropower (plus water intakes, etc.) summed over the age groups in the stock (rate).
SumH_habitat	Mortality due to anthropogenic influence on habitat (quality/quantity) summed over the age groups in the stock (rate).
SumH_other	Mortality due to other anthropogenic influence summed over the age groups in the stock (rate).
SumH_release	Mortality due to release summed over the age groups in the stock (rate: negative rate indicates positive effect of release).
Transitional waters	WFD definition of transitional waters, implies reduced salinity.
ΣF	The fishing mortality rate, summed over the age-groups in the stock.
ΣH	The anthropogenic mortality rate outside the fishery, summed over the age groups in the stock.
ΣA	The sum of anthropogenic mortalities, i.e. ΣA = ΣF + ΣH.
Y	Code in Data Call for data comprising yellow eel only
Yellow eel abundance series	Time-series of abundance of yellow eel determined by consistent regular count or survey.
Yellow eel recruitment series	Time-series enumerating yellow eel where this life stage is first observed at a site or is the stage at which eel enter freshwaters.
Yellow eel standing stock series	Time-series of abundance of yellow eel determined by consistent regular count or survey.
3Bs & ΣA	Refers to the 3 biomass indicators (B_0, B_{best} and $B_{current}$) and total anthropogenic mortality rate (ΣA).
40% EU target	From the Eel regulation (1100/2007): “The objective of each Eel Management Plan shall be to reduce anthropogenic mortalities so as to permit with high probability the escapement to the sea of at least 40% of the silver eel biomass relative to the best estimate of escapement that **would have existed if no** anthropogenic influences had impacted the stock”. The WGEEL takes the EU target to be equivalent to a reference limit, rather than a target.

Annex 3: Participants list

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Annex 4: Scientific information potentially challenging the recurrent ICES advice rationales

Table 2. Scientific information potentially challenging the recurrent ICES advice rationales.

Category	Type of scientific information	Potential consequence on the recurrent ICES advice	Status of the information	Are we able to account for the information at the population scale?
1. Is escapement a reliable proxy of SSB?	Predation of silver eels during the oceanic migration.	If the predation has increased through time, this would invalidate the use of the escapement as a proxy of SSB. This would not be precautionary: current escapement would produce a lower SSB than in the past so that the stability of the escapement might hide a decrease in SSB.	While the predation of tagged eels has been observed (Wahlberg *et al.*, 2014; Righton *et al.*, 2016), data are too limited and too recent to conclude on the existence of a temporal trend.	A proportion of predated eels can be estimated (at least for the beginning of the migration, and if we assume that the tagging does not increase predation risk) but the number of observations is still limited. And the required number of spawners is not known, so any estimate of predation loss cannot be analysed in terms of whether it is too much or not material.
	Sub-lethal injury during escapement	It is likely that we are underestimating hydropower mortality (obstacle induced impacts on escapement) due to delayed mortality. This raises a precautionary concern: the "conversion rate" between escapement and SSB would have decreased which might hide a decrease in the latter.	There is an understanding of how passage through hydro turbine/pumping stations can impact silver eels that survive (Durif *et al.*, 2003; Bruijs and Durif, 2009; Drouineau *et al.*, 2017), but there are many forms this can take and it is difficult to quantify these. There is also a question of delayed mortality vs reduced fitness.	Although the turbine designs and therefore the effects on individual eels of passing through turbines should be similar between sites, total mortality rates at a power station area depend on 1) the proportion of eel moving into the power station intake, 2) the mortality rate of those moving into the power station (turbine mortality, impingement on bar racks, etc.), and 3) the mortality rate of those using alternative routes (bypass channels, old river bed, etc.) (see Chapter 4 of the WGEEL report (ICES, 2019a) for more discussion).
	Quality of spawners (contamination/parasitism/condition)	Quality of escapees/spawners is thought to have decreased because of contamination/parasitism and a potential decrease in fat content that could affect migration success, fecundity and/or larval survival (e.g. transfer of contaminants). This may invalidate using escapees as a direct proxy of SSB and impact the SSR, requiring a change of reference points. This would not be precautionary:	There are many observations on contamination and parasitism (Kirk, 2003; Belpaire *et al.*, 2011). While there are elements at the individual scale, the consequence at the population scale is more speculative.	Limited data across the geographical and temporal range, and a limited understanding of conversion factors for oceanic swimming and/or gametogenesis. Moreover, respective effects of parasitism, contamination and fat content are difficult to disentangle.

Category	Type of scientific information	Potential consequence on the recurrent ICES advice	Status of the information	Are we able to account for the information at the population scale?
		current escapement would produce a lower SSB than in the past so that the stability of the escapement might mask a decrease.	The same stands for changes in fat content (Belpaire *et al.*, 2009).	
2. Is the shape of the SSB-R relationship correct?	Potential regime shift in the SSB-R	A shift in oceanic conditions in the late 1970s might have played a role in the recruitment collapse (Castonguay *et al.*, 1994; Bonhommeau *et al.*, 2008a). Such a regime shift would challenge the "unicity" of the SSB-R. In such a situation, using the pre-1980s as a reference period, i.e. when the conditions were more favourable, is precautionary but might lead to "setting the bar too high"	Speculative. Synchrony in the collapse of temperate anguillid eel species around the world suggests the role of large-scale factors (Castonguay *et al.*, 1994; Bonhommeau *et al.*, 2008a). Change in oceanic circulation might have impaired larval drift (Castonguay *et al.*, 1994) though this was not observed with a simulation model of larval drift (Pacariz *et al.*, 2014). A shift in the planktonic community in the Sargasso Sea is suspected to have led to a decrease of the survival of larvae (Bonhommeau *et al.*, 2008b; Miller *et al.*, 2016).	If a shift indeed occurred, fitting separate SSR before and after the shift would be required. Intents have been made by WGEEL (ICES, 2012; 2013) and preliminary results were not conclusive. The main problem is the lack of reliable SSB index.
	Potential allee effect in the SSR.	An allee effect would change the shape of the SSR (Figure 2) and postulates the existence of an inflexion point at low SSB under which the collapse in recruitment accelerates. It can seriously accelerate population decline and drive a population to extinction, or at least heavily hamper its ability to recover (Walters and Kitchell, 2001). The implication of an allee effect has been discussed by WGEEL (ICES, 2012; 2013): it leads to a shift of B_{lim} to B_{stop}. If an allee effect exists, not taking it into account is not precautionary.	Speculative. The potential existence of an allee effect in eel population was first proposed by Dekker (2004) and latter explored by WGEEL (ICES, 2012; 2013). In the absence of SSB indicator, landings (or reconstructed landings) were used as a proxy of SSB. However, historic landings data are of poor quality and exploitation rate was not constant through time. In fishery science, the existence of an allee effect has rarely been observed but the absence of evidence does not mean that it does not exist (Hutchings, 2014) and eel is in a rare situation of extremely low recruitment in which such an allee effect could have a significant effect.	The main problem to explore the existence of an allee effect lies in the absence of SSB indicator over a sufficient period of time.

Category	Type of scientific information	Potential consequence on the recurrent ICES advice	Status of the information	Are we able to account for the information at the population scale?
	Spatial patterns in sex ratio, both at distribution area and basin scale.	It may invalidate the assumption that 1 kg of silver eels has an equal contribution to SSB across the distribution. If males are limiting, as proposed by Kettle *et al.* (2011), using SSB as an indicator is not precautionary since males are lighter than females.	Existing observations support the existence of a spatial pattern over latitudes (Kettle *et al.*, 2011) but we don't know whether males or females are limiting the reproduction.	No. Achieving a sex-disaggregated SSB estimate would probably require spatialised analysis and supporting biometry data are heterogeneous. An understanding of the necessary ratio of female to male spawners would also be required.
3. Can we miss long-term changes population by focusing on SSB or recruitment?	Potential existence of both spatially variable selection and genetic expression profiles correlated to habitat use.	This would invalidate the assumption of total equivalence of 1 kg of silver eels. This could mean the risk of long-term loss of genetic diversity. While this does not question the use of SSB, it might not prevent long-term changes in the population and may take time to be detected with recruitment.	Still speculative. Ecotypes and spatially variable selection have been proposed recently for American eel (Gagnaire *et al.*, 2012; Pavey *et al.*, 2015) but are less studied in Europe (Ulrik *et al.*, 2014). The existence of different genetic expression profiles in Europe has been shown in a few rivers and correlated with behaviours and habitat use (Podgorniak *et al.*, 2016a; 2016b). Some studies on the theoretical consequences of ecotypes have been produced (Mateo *et al.*, 2017b; 2017a).	Data are too scarce and preliminary to go further than theoretical analysis.
	Age-at-silvering varies between latitudes and habitats.	Though linked to length-at-silvering, the existence of variable age-at-silvering is thought to generate storage and portfolio effects and be a source of resilience for the population. Not considering age-at-silvering would hinder possible patterns in mortality rates and be a threat to storage and portfolio effect. The use of SSB does not prevent long-term changes on the population, and it might take time to be detected with recruitment.	The patterns in age at silvering are well documented (Vøllestad, 1992). The portfolio and storage effects have only been demonstrated theoretically (ICES, 2009).	This is a difficult task. Detecting differences in mortality rates correlated with age-at-silvering (e.g. to check whether anthropogenic pressures affect fast and slow maturing eels differently) would require a spatialised analysis. Quantifying the effect on portfolio and storage effect would require multi-generational analysis.
3. Can we miss long-term changes population by focusing on SSB or recruitment?	Effect of habitat loss.	The direct effect of habitat loss or indirect effects of changes in habitat (productive) quality on growth or survival would not change the relevance of SSB (but perhaps would create a regime shift). However, it has been proposed that habitat loss can also indirectly modify life history traits and have asymmetrical effects on ecotypes. While this does not question the use of SSB, it might not	Habitat loss is difficult to quantify (Clavero and Hermoso, 2015; ICES, 2020a). WGEEL conducted a review of the effects of habitat loss, modification or degradation (ICES, 2020a): while it is thought to increase predation (Mouton *et al.*, 2011), cannibalism (Sinha and Jones, 1967; Wattendorf, 1979), modifies sex ratio (Davey and Jellyman,	No: currently, data on habitat loss and habitat quality are too limited. Knowledge on their effects is speculative.

Category	Type of scientific information	Potential consequence on the recurrent ICES advice	Status of the information	Are we able to account for the information at the population scale?
		prevent long-term changes in the population and may take time to be detected with recruitment.	2005), and to have contributed to the collapse of the population (Feunteun, 2002), quantitative information on effect at the population scale is scarce. Some theoretical simulations have been carried out that show that indirect effects can mean that using SSB as a unique indicator of population state is flawed (Mateo *et al.*, 2017b).	
4. Unknown effect	Spatial variation in length at silvering.	Regarding length at silvering, since SSB is in kg, this does not necessarily have a major consequence. However, Clevestam *et al.* (2011) showed that – after subtraction of migration costs – the longer females have a relatively higher energy reserve available for reproduction.	Spatial patterns are well documented (Vøllestad, 1992)	If we only focus on effect on SSB, this would already account for length-at-silvering variations.
	Existence of several trends in recruitment.	This does not invalidate the advice since different indicators are produced per zone (North Sea, Elsewhere Europe) to account for these differences.	Recruitment trends are different among regions (ICES, 2020a). However, lunar compass-recruitment relationship (Cresci *et al.*, n.d.) may help to understand the proportion of glass eels entering different regions. There is no clear explanation on the underlying drivers e.g. changes in oceanic circulation?	Already accounted for in the GLM model.

Annex 5: Available data and potential use to support the recurrent ICES advice

Table 4. Available data and potential use to support the recurrent ICES advice.

Information	Data type	Usage by WGEEL	(Would) inform on?	Suitability (protocol, scales, quality…)	Need for methods to analyse the data	Does it provide information at the population scale?
Population characteristics	biometry (length, weight, sex-ratio)	Some data collected by WGEEL. Exploratory analysis in the WGEEL report.	Spatial distribution of life history traits if these aspects are thought to be relevant for the advice.	Protocols are very heterogeneous with different selectivity. Results depend on sampling protocols, environmental conditions (habitats), anthropogenic actions, but this information is not always available in the metadata to take it into account in the analyses. Data are still spatially scarce but that can be extended by using EU MAP data that can also inform on other traits (e.g. fat content)	Currently not. Analysing the data would require a method that takes into account all the sources of heterogeneity.	At present not, given the lack of method to analyse the data
Anthropogenic pressure	Commercial landings	Data are collected, presented in the advice, but mainly as additional information.	A source of anthropogenic mortality.	Data not available for all the distribution area and there are some questions over data quality. Great effort to standardise the data collection by the WGEEL.	These data was used as a proxy of spawning biomass but are not relevant anymore given the decline in fishing effort. Trends in GE landings can already be used and compared to trends in recruitment to derive in trend in exploitation rate. For standing stock, a method to analyse trend in standing stock abundance is required first.	At present - No. It perhaps has the potential to provide data at the population scale if all countries were to report good data, but that is unlikely.
Anthropogenic pressure	sigmaF, sigmaH per EMU	Data are collected by WGEEL and have been used to derive a precautionary diagram in the report. They are not used in the advice. They	Would allow the comparison of sources of mortality per EMU and potentially at the EU scale.	Methods are heterogeneous impairing comparisons. Time-series are short. Data analysis and reporting are not always consistent among countries and complex because of the multiplicity of scales - life stage, habitats, EMU. All sources of mortality are rarely included.	Methods are heterogeneous impairing comparisons. Time-series are short. Data reporting is not always consistent among countries and complex because of the multiplicity of scales - life stage, habitats, EMU. Few data reported outside EU. Aggregating mortalities	Only EU MS, plus a few others, provide these estimates

Information	Data type	Usage by WGEEL	(Would) inform on?	Suitability (protocol, scales, quality…)	Need for methods to analyse the data	Does it provide information at the population scale?
		have been used in other ad hoc requests (eg (ICES, 2018)			requires that reliable biomass estimates are available.	
	Recreational landings	Data are collected, presented in the advice, but mainly as an illustration	A source of anthropogenic mortality.	Not all countries report data, and data are partial even in countries that indeed report. National interpretation of "recreational" varies among countries.	The method to analyse data is adequate, but spatial coverage of data is incomplete and even when/where reported it is thought the data are incomplete.	At present - No. It perhaps has the potential to provide data at population scale if all countries were to report good data, but that is unlikely.
	Contamination data	An eel quality database has been developed (Belpaire *et al.*, 2011) but the data are not used in the advice	Inform on the impact of an anthropogenic pressure	Efforts have been made to collect the data into a database, but they are still spatially and temporally limited and not including all sources of contaminant (which would be impossible). Data consists mostly of individual observations and extrapolation to the population scale is difficult.	Methods to express impacts on individuals at the population scale are missing, as are thresholds of contaminant levels impacting spawners, both individual and cumulative impacts. Effort should be made to update and extend the Eel Quality Database.	While we suspect that contamination can impair migration success and/or reproduction success (Robinet and Feunteun, 2002; Geeraerts *et al.*, 2011), this is speculative and cannot be quantified, so extrapolation of effect at the population scale is difficult.
Anthropogenic pressure	Mortality at hydropower and pumping stations.	Some data exists at specific sites or in river basins. They are not routinely collected by the WGEEL. Some assessment at larger scales (EMU or countries) have been carried out (e.g. (Briand *et al.*, 2018))	The impact of anthropogenic pressure	The precise location of hydropower dams and/or pumping stations and their characteristics is not known though some progress has been made (e.g. AMBER and SUDOANG projects. Observations consist mainly of direct mortality, i.e. neglecting indirect effects, and at specific sites.	First, an effort should be made to collect data on the location of hydropower plants/pumping stations and on their characteristics e.g. positions in the basin, turbines, waterfall, passage facility etc. Then models should be used to predict direct mortality based on these characteristics, and to predict the distribution of eels within the basin to extrapolate the impact at larger scale e.g. SUDOANG project. Such models already have been applied in some countries (Briand *et al.*, 2018; DEFRA, 2018) but application to new regions would need the collection of site-specific impact characteristics.	

Information	Data type	Usage by WGEEL	(Would) inform on?	Suitability (protocol, scales, quality…)	Need for methods to analyse the data	Does it provide information at the population scale?
	Habitat loss	Some data have been collected by the WGEEL but they are not really used in the report or in the advice.	Production potential of the habitat compared to the reference period - if habitat is limiting, how does that affect practical gain.	Wetted area data have good spatial coverage in some countries, less in others. Mapping scale differs, e.g. 1:50,000 vs 1:250,000, and this affects the amount of wetted area estimated. Wetted area does not equal eel habitat, but knowledge is insufficient to describe eel habitat suitability in consistent and specific terms, so wetted area accessible from the sea might be the only data available. Historic data are scarce.	Yes, but standardised data across the international scale is the first priority. Then standardising data internationally for the reference period.	Not at present because of data gaps, but it would if data were available. However, the direct and indirect effects of habitat loss are still poorly known and consequently, the effect on the population dynamics is difficult to quantify, and historic data on wetted area are scarce.
Anthropogenic pressure	Reduced habitat quality	Not collected by WGEEL.	Production potential of the habitat compared to the reference period - if habitat is limiting, how does that affect practical gain.	Similar comments to Habitat Loss, but even less good data on how suboptimal habitat quality affects eel production, or what measures we have to say a habitat is suboptimal.	Data are the first priority, but then would need a method to measure the influence of habitat quality on eel production.	Not at present because of data gaps, but it would if data were available.
	Parasitism / disease	Not collected despite the eel quality database.	Inform on the potential reduction of migration and spawner success.	While the occurrence of *A. crassus* is documented in most countries, data are too scarce to quantify prevalence and intensity at the distribution area scale, and does not inform on the long-term and chronic impact of infection. Data on diseases are limited.	The method would require an estimation of prevalence and a quantification of the effect on migration success. Ideally a non-destructive method to avoid killing eels. Not available yet. Effort should be made to update the Eel Quality Database and to include indices of swimbladder damage (Lewin *et al.*, 2019).	Not given the previous point. Developing an index of swimbladder function/state of silver eels would potentially be useful.
Unclear	Climate change	Various indicators of climate change are available. Currently, the effect of climate change is not routinely considered in	Effect of climate change on the SSR and on habitat quality. The potential for a regime shift, in the past or in the future.	For reproduction, the effect of climate change is not clear. For habitat quality, modification of temperature and discharge can affect habitat quality and migration, but climate change has long-term effects that are difficult to disentangle from other pressures.		Perhaps, at least in terms of changes in the ocean, if climate change in the past and future could be linked to regime shifts that affected production in a quantifiable manner.

Information	Data type	Usage by WGEEL	(Would) inform on?	Suitability (protocol, scales, quality…)	Need for methods to analyse the data	Does it provide information at the population scale?
		the report and not considered in the advice at all.				
	Stocking data	Data are collected and included in the report but not used in the advice.	It potentially informs on the relevance of a management measure, but this would be complex and has never been done. It is used to correct stock indicators (sigmaA and $B_{current}$) to avoid "double-banking".	Sometimes problem of consistency in the way data are reported if eels are kept in aquaculture before being re/stocked.	The effect of restocking in stock indicators have been detailed (ICES, 2018). Regarding the effect of the management measure, is this the aim of the advice?	Does not inform the population status but should be taken into account in the computation of stock indicators at local scale.
Unclear	Aquaculture	Collected and reported in WGEEL but not used in the advice	While aquaculture data are used to implement fishery regulation in Japan (wild glass eels are grown in aquaculture before consumption) this would not be possible in Europe. Such data are probably more pertinent for managers (to inform on the market and destination of landings) than for the ICES advice.			
Unclear	Recruitment abundance indices	Main source of information in the advice.	Trend in recruitment, and a proxy index for spawning stock trend.	Protocols are heterogeneous and time-series are not representative of all the range states. There are some quality doubts e.g. commercial landings, modification of elver traps. The implementation of fishery regulations affects the use of commercial landings/CPUE as consistent abundance indices over time. Hopefully, most of time-series provide	two methods already used	trends are assumed to inform on the population trend

Information	Data type	Usage by WGEEL	(Would) inform on?	Suitability (protocol, scales, quality…)	Need for methods to analyse the data	Does it provide information at the population scale?
				consistent trends, but care should be taken with potential differences among regions – series are not immune to local influences. The effect of environmental conditions – discharge, temperature, etc. - is considered to be noise around the overall trend, but this assumption may be violated in the context of climate change.		
	Standing stock abundance indices (yellow and silver eel)	Collected by WGEEL and analysed in the report in 2020 but not used in the advice.	Trend in standing stock, combined with trend in recruitment would inform the trend in growth rate of the population during the continental stage.	Protocols are heterogeneous and meta data are missing. Trends are both the results of global factors - trend in recruitment - and local factors - environmental conditions, anthropogenic actions. Data are not evenly distributed across the range. Some countries provide data at the sampling site scale while others report data aggregated at the river scale after a pre-treatment.	A DFA has been proposed to compare trends, but more robust methods taking into account environmental conditions, sampling protocols and anthropogenic actions would be required. Some countries already apply such methods in their rivers, but consistency among countries needs to be confirmed.	These time-series primarily inform on trends at local scale. Given their spatial heterogeneity, a spatialised, statistical or mechanistic, model would be required. The DFA carried out by the WGEEL (ICES, 2020a is a first step and confirmed the heterogeneity among time-series.
Unclear	B_0, $B_{current}$ and B_{best}	Collected and reported (precautionary diagram) but not used in the advice.	This can inform the trend in SSB, on the situation at the EMU scale. By comparing with recruitment trend, it can inform on growth/survival during the continental stage.	Methods and reference period are heterogeneous impairing comparisons. Time-series are short. Data reporting is not always consistent among countries and complex because of the multiplicity of scales - life stage, habitats, EMU. Few data reported outside EU.	In most cases, deriving estimates at the population scale is just summing EMU estimates, but the main problem is the consistency among EMUs, and scarcity of data outside the EU. There is need for a validation of these estimates, an agreement on the reference period and on how habitat loss should be accounted for (B_0). And ideally, non-EU countries should also report similar indicators	Only EU MS, plus a few others, provide these estimates

Annex 6: Recommendations

Recommendations	Addressed to
WKFEA highlighted parts of the advice that need clarification and awareness from ACOM when drafting future advice for eel (see 4.1.3.2. for a detailed list of the points to be clarified).	ADGEEL, ACOM
WKFEA asks ACOM to consider, comment on, and further promote the proposed road map.	ACOM
WKFEA recommends to the WGEEL to propose the inclusion in the ToR of its annual meetings the work assigned to it in the road map until the benchmark is held.	WGEEL
WKFEA recommends that all the data compiled during the road map implementation are to be hosted by ICES. This will require liaison between the WGEEL, the data providers and the ICES Data Centre.	WGEEL, ICES Data Centre