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Report of the Workshop on Fisheries Related Anthropogenic Impacts on Silver Eels (WKMAREEL)

20 March–18 April 2017

By correspondence

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1 Introduction

1.1 Purpose of the Workshop (transcribed from the Commission's request to ICES)

In 2016, ICES confirmed again that the status of the stock of European eel remains critical and that recruitment of glass and yellow eels is very low. The perception of the stock status has not changed over the last decade. As a result, ICES advises that "when the precautionary approach is applied for European eel, all anthropogenic impacts (e.g. recreational and commercial fishing on all stages, hydropower, pumping stations, and pollution) decreasing production and escapement of silver eels should be reduced to, or kept as close to, zero as possible".

Given the critical state of the stock, European eel was listed both in CITES Annex II and the IUCN list of endangered species. At the EU level, a specific Regulation was adopted in 2007 to ensure the recovery of the stock. According to this Regulation, Member States (MS) have to establish and implement eel management plans for their river basins that constitute significant eel habitats. The plans must be able to achieve the escapement to the sea of at least 40% of the adult stock biomass that would have escaped without human influence. For marine waters seaward from the area covered by the MS' Eel Management Plans (EMPs), a 50% reduction in catches or effort compared to the 2004–2006 average should be achieved.

While it is MS' obligation to address the anthropogenic impacts on eels in the waters covered by their national EMPs, the request ICES received from the EU Commission for this *ad hoc* request states that the measures to be taken in the marine waters fall under the exclusive competence of the EU.

The main objective of 2013 Common Fisheries Policy is to ensure the sustainable exploitation of marine biological resources, including diadromous species during the marine part of their life cycle. For analytical stocks this means to achieve F_{MSY} by 2020 at the latest, while for data limited stocks the precautionary approach should be followed.

1.2 Request: (transcribed from the Commission's request to ICES)

1) On this basis, ICES is requested to assess whether the 50% reduction either in catches or in effort compared to the 2004–2006 average prescribed in the Eel Regulation is sufficient to achieve the objectives of the 2013 CFP.

2) ICES is also requested to assess the current biomass of escapees by main maritime area (if possible by sea basin, i.e. EU sea basins that have eels: Baltic, North Sea, Atlantic, Mediterranean), more specifically from the boundaries of the EMU to marine waters, in absolute terms and in terms relative to the hypothetical escapement under no human influence.

3) And ICES is requested to assess the extent to which catches of silver eel in marine waters reduce the spawning potential in a manner jeopardising the recovery of the stock.

4) In particular, ICES is requested to assess the impact and effectiveness of the following measures against the objective to increase the glass and yellow eel recruitment (as in consider the potential impact on the SSB of eel) by 2020, provided that these measures remain in place until then:

4.1) Reducing all eel fisheries to 50% of the 2004–2006 average in the Union waters seaward from the baselines ('baselines' here refer to the delimitation of Eel management plans – "seaward of the boundary of Eel Management plans" – article 8 par. 2 of the Eel regulation) as prescribed in the Eel regulation;

4.2) Reducing all eel fisheries to 25% of the 2004–2006 average in the Union waters seaward from the baselines;

4.3) Reducing all eel fisheries to 0% of the 2004–2006 average in the Union waters seaward from the baselines.

5) ICES is requested to further comment on the modalities of the application of the above measures in order to reach the highest effectiveness, e.g. the stages of eels to be subject to the measures mentioned above, the duration of the measures, the seasonal aspect, the geographical area, the gears, the urgency of the need to take the measures etc., taking into account the resulting application of the landing obligation.

6) ICES is also requested to provide comments on other equally effective measures that could be used as alternatives to achieve respective reductions of fisheries in marine waters as in point 4.

7) Finally, ICES is requested to comment on the impact of glass eel fisheries on recruitment and subsequent adult stock biomass.

1.3 Organization of the Work

The Workshop on Eel in the Marine (WKMAREEL) met by correspondence from 20th March to 18th April 2017, under the chairmanship of Alan Walker (UK). Invitations were sent to all members of the EIFAAC/ICES/GFCM Working Group on Eel (WGEEL) to identify experts who were available to contribute. The Workshop was 'attended' by three experts in eel assessment and management: Alan Walker, Willem Dekker (Sweden) and Michael Pedersen (Denmark).

The workshop collated the catch data provided to ICES by the Commission in response to their request for data sent to Member States (February 2017, deadline 31st March 2017), and examined catch data extracted from the FIDES dataset. These data were reported to FAO regions and the workshop aligned these to Eel Management Units (EMUs) and to the four EU sea basins (i.e. Baltic, North Sea, Atlantic and Mediterranean), as well as a fifth category to account for a few EMU that have waters in two sea basins (Mixed basins). The workshop also used data collated by the WGEEL in 2015 and 2016, derived from the MS EMP Progress Report and Country Reports to the WGEEL.

There are 21 EU Member States within the eel distribution area, that border the sea; in total, 88 EMUs. Fifteen of these MSs reported their eel catches to FIDES, a total of 782 t in 2014 (that is: the assessment year of the 2015 Progress Reports). Ten countries responded to the current request for data from the Commission, reporting a total catch (2014) in marine areas of 580 t. Eight MSs did *not* report stock indicators for the 2015 Progress Reports; 13 MSs did report stock indicators, for a total of 77 different EMUs, of which 66 EMUs did include catches in marine areas in their assessments. Because of the apparent incompleteness of all data sources, and the inconsistencies in reporting, the Workshop decided to focus on the most recent data that provided for the current request, supplemented from other data sources for those countries that did not report to the Commission's request.

The workshop report was subject to independent review by two experts appointed by ICES. The report was then updated in response to these reviews; the reviewers' reports are included in an annex, but not the original draft report.

1.4 Structure of the report

This report provides an introduction to European eel biology and the current stock assessment approaches used to support ICES stock advice for the European eel, followed by consideration of the seven questions posed by the Commission. Standard ICES report details are reported in a series of annexes, including a glossary of terms and acronyms.

A draft Advice answering the seven questions was provided as a separate document.

2 Basis of the Advice

2.1 Introduction

European eel life history is complex and atypical among aquatic species, being a long-lived semelparous and widely dispersed stock. The shared single stock is panmictic (Palm *et al*., 2009) and data indicate the spawning area is in the southwestern part of the Sargasso Sea and therefore outside Community Waters (McCleave *et al*., 1987; Tesch and Wegner, 1990). 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. 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 could exceed 50 years) prior to metamorphosis to the silver eel stage and maturation. Age-at-maturity varies according to temperature (latitude and longitude), ecosystem characteristics, and density-dependent processes. The European eel life cycle is shorter for populations in the southern part of their range compared to the north. Silver eels then migrate to the Sargasso Sea where they spawn and die after spawning, an act not yet witnessed in the wild. (ICES, 2014).

The European eel is distributed across the majority of coastal countries in Europe and North Africa, with its southern limit in Mauritania (30°N) and its northern limit situated in the Barents Sea (72°N) and spanning all of the Mediterranean basin (ICES, 2014). At the continental scale, eels have a wide and scattered distribution and are found in virtually all types of waterbodies from rivers and lakes to estuaries and coastal waters. Its distribution area is estimated to be at ca. 90 000 km^2 (Moriarty and Dekker, 1997; Dekker, 2009).

It is not known what areas contribute to successful spawning or to what degree and, therefore, it is not possible to determine the exact number of age groups that contribute successfully to the spawning effort. It seems likely that a considerable number of year classes contribute each year.

Fisheries take place over the whole geographic range, and most often occur as scattered small-scale rural enterprises (Dekker, 2004). Eel are traded both locally and internationally. Total landings and effort data are incomplete. There is a great heterogeneity among the time-series of landings because of inconsistencies in reporting by, and between, countries, as well as incomplete reporting. Changes in management practices have also affected the reporting of non-commercial and recreational fisheries.

Yellow and silver eel fisheries have been located all over the distribution area of the species, from the Mediterranean basin to northern Scandinavia (Dekker, 2003), with some countries having reduced or closed their fisheries in response to the EU Regulation. Historically, the northern part of the distribution area has provided more complete statistics, of higher catches, than the south. Various types of gear are used in the yellow and/or silver eel fisheries, including different nets, traps, hooks, etc. in both salt- and freshwater (Dekker, 2003). The eel fisheries, located in the coastal and rural areas all over Europe are rather small-scaled; larger-scaled eel fisheries make up less than 5% of the total European eel catch (Dekker, 2002). According to Moriarty and Dekker (1997) these fisheries employed thousands of people across Europe in the 1990s but the number is declining since. In many of the European countries yellow and silver eels are not distinguished in the reported catch (ICES, 2014). Directed fish-

eries for silver eel in coastal waters are most common in the Baltic/Kattegat, where poundnets are used (Dekker, 2003). As the eel densities are low in the northern areas (25 eels/km^2 of land surface), the fishery is concentrated on the emigration period in the late summer and autumn when most of the silver eel is exploited. In contrast, yellow eel fisheries are established in Middle Europe where eel densities per km^2 of land surface are much higher (400 eels/km^2; Dekker, 2003). Yellow and silver eel caught are mainly sold for consumption, either locally or after export to neighbouring countries, in mostly within the EU (ICES, 2015).

In many EU countries, recreational fishery contributes significantly to the total catch. The gear might consist of rod-and-line as well as longlines and nets or traps. Usually a licence or permit is required to be able to fish recreationally, however there are countries where the access to the fishery is free or based on private ownership (Dekker, 2005). Data on recreational fisheries are collected but the inconsistencies in reporting make assessment unreliable (ICES, 2014).

2.2 DG Question 1: On this basis, ICES is requested to assess whether the 50% reduction either in catches or in effort compared to the 2004–2006 average prescribed in the Eel Regulation is sufficient to achieve the objectives of the 2013 CFP

According to the request ICES received from the EU Commission for this *ad hoc* request, the main objective of 2013 Common Fisheries Policy is to ensure the sustainable exploitation of marine biological resources, including diadromous species during the marine part of their life cycle. For analytical stocks this means to achieve F_{MSY} by 2020 at the latest, while for data-limited stocks the precautionary approach should be followed.

The ICES approach to advice on fishing opportunities (ICES General Book) integrates the ecosystem and precautionary approach with the objective of achieving maximum sustainable yield (MSY). The aim is, in accordance with the aggregate of international guidelines, to inform policies for high long-term yields while maintaining productive fish stocks within healthy marine ecosystems.

ICES advice on the status of the European eel stock is an evaluation of the trend in eel recruitment, as this is the most reliable series available (ICES, 2016a). However, this kind of approach does not provide information on the level of management action required to achieve recovery or sustainable exploitation by fisheries (Dekker, 2016). In the case of eel, fisheries are scattered throughout the natural distribution in small-scale fisheries targeting glass eel and/or yellow eel and/or silver eel (Dekker, 2000; 2003). Moreover, unlike other marine species, eel is impacted by many other anthropogenic mortalities (pollution, turbines and pumps, etc.).

The advice rule applied by ICES in developing the advice on fishing possibilities depends on management strategies agreed by relevant management bodies and the information and knowledge available for the concerned stocks. In the case of the European eel, where management plans/strategies have been developed that do not cover the whole stock, and ICES considers the European eel to be a data-limited stock, the advice is based on ICES precautionary approach (ICES, 2016a). In accordance with a precautionary approach (UN Fish Stocks Agreement; UN, 1995), populations need to be maintained within safe biological limits.

For the purposes of identifying the advice rule to be applied when giving advice on fishing possibilities, ICES classifies stocks into six main categories on the basis of

available knowledge. Given a quantitative assessment for the whole stock is not possible, eel falls under Category 3 rules (stocks for which survey-based assessments indicate trends) and particularly in category 3.1.4 (For extremely low biomass, a recovery plan and possibly zero catch is advised (ICES, 2012)).

The European eel stock does not have population estimates from which catch options can be derived using the ICES MSY framework. ICES has developed a precautionary framework for quantitative advice regarding such stocks. The underlying principles of the approach are that (a) the available information should be used, (b) the advice should, where possible, be based on the same principles as applied for stocks with analytical assessments and catch forecasts, and (c) a precautionary approach should be followed. The latter implies that as information becomes increasingly limited, more conservative reference points should be used and a further margin of precaution should be adopted when there is limited knowledge of the stock status. The margin of risk tolerance is a management prerogative.

ICES does not provide quantitative catch advice for European eel, but rather advises in accordance with the precautionary approach, that anthropogenic impacts should be reduced as close to zero as possible (ICES, 2016a). As such, it is difficult to assess reductions in fishing catch or effort of European eel in the marine environment in terms of sustainable exploitation. The precautionary approach applied by ICES is to advise impacts are reduced as close to zero as possible. By implication, any reduction in marine catches less than 100% would fall short of ICES advice, and becomes a political rather than scientific decision.

Considering that many Eel Management Plans were not yet achieving the EC Eel Regulation biomass targets, as reported in 2015, and that exploitation in marine areas is only part of the overall anthropogenic impacts, ICES considers that the 50% reduction in marine catches/efforts is not likely to achieve the objectives for the CFP as they apply to (exploitation by marine fisheries of the) European eel.

2.3 DG Question 2: ICES is also requested to assess the current biomass of escapees by main maritime area (if possible by sea basin, i.e. EU sea basins that have eels: Baltic, North Sea, Atlantic, Mediterranean), more specifically from the boundaries of the EMU to marine waters, in absolute terms and in terms relative to the hypothetical escapement under no human influence

The Regulation (EC 1100/2007: European Council, 2007) sets reporting requirements (Article 9) such that Member States must report on the monitoring, effectiveness and outcomes of EMPs, including the proportion of silver eel biomass that escapes to the sea to spawn, or leaves the national territory, relative to the target level of escapement; the level of fishing effort that catches eel each year; the level of mortality factors outside the fishery; and the amount of eel less than 12 cm in length caught and the proportions utilized for different purposes.

These reporting requirements were further developed (Dekker, 2010; ICES, 2010) and published by the Commission in 2011 as guidance for the production of the 2012 reports. This guidance added the requirement to report fishing catches (as well as effort), and provides explanations of the various biomass, mortality rates and stocking metrics required for international assessment and post-evaluation, as follows:

- Silver eel production (biomass)

- B_0 The amount of silver eel biomass that would have existed if no anthropogenic influences had impacted the stock;
- $B_{current}$ The amount of silver eel biomass that currently escapes to the sea to spawn;
- B_{best} The amount of silver eel biomass that would have existed if no anthropogenic influences, including restocking practices, had impacted the current stock, hence only natural mortality operating on stock.

- Anthropogenic mortality (impacts)
  - 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. It refers to mortalities summed over the age groups in the stock.
- Stocking requirements
  - R(s) The amount of eel (<20 cm) stocked into national waters annually. The source of these eel should also be reported, at least to originating Member State, to ensure full accounting of catch vs. stocked (i.e. avoid 'double banking'). Note that R(s) for stocking is a new symbol devised by the Workshop to differentiate from "R" which is usually considered to represent Recruitment of eel to continental waters.

Mid-2012, Member States first reported on the actions taken, the reduction in anthropogenic mortalities achieved, and the state of their stock relative to their targets in July 2012, and again in July 2015.

To answer the current question from the Commission, current and hypothetical escapement biomasses from EMU waters by maritime area have been calculated from national estimates reported in EMP Progress reports 2015. ICES presents these estimates without prejudice, as the database and methodologies used have not been subject to peer-review.

Table 2.1 summarises these data by sea basin. Most of the 118 EMUs were assigned to the sea basin into which their freshwaters flow, but 13 EMUs belong to/empty into two sea basins and these were given a separate category of 'Mixed basins'.

It should be noted that the silver eels emigrating towards the Sargasso Sea from some countries will pass through the territories of other countries, being exploited there, and therefore there is the risk for these eels to be counted in the estimates of both countries. For instance, the Swedish coastal fishery in the Baltic targets the silver eel passing its coast wherever their origin, and mark-recapture studies in the Swedish fishery thus assess the silver eel run from Swedish waters and other countries in the Baltic combined. The incompleteness of the 2015 reporting for other areas in the Baltic blocks further analysis of this double-counting problem. The Swedish estimates are more than the sum of the reports from other countries, and cover the eel production from a larger area; hence, these estimates will be used here as indicative for the whole Baltic.

As enabled in the Eel Regulations, most national EMPs cover marine waters within the national territories, but not all do. Most national assessments reported in 2015 cover marine waters, but not all do. The data reported under the current Commission

request in some cases cover only the marine areas outside the EMP, but in most cases also cover the catches within the area covered by the EMP. The workshop felt unable to sort out all these potential data mismatches, and hence presents an analysis of the latest data, as reported to in response to the Commission request. Hence, the results reported here may not strictly represent the "current biomass of escapees by main maritime area …. from the boundaries of the EMU to marine waters".

In accordance with the EU Eel Regulation, EMPs have been developed for EMUs (countries or specific water basins); assessments have been made for these EMUs; and reported stock indicators have been compiled at the international level (ICES, 2013b; 2016c). However, not all Member States have reported, and of the reporting ones, some have reported incompletely. Though the reported indicators allow for an evaluation of the status of the local stock and its protection status within each EMU, the sum of the reported indicators is incomplete, and might give an incorrect picture of the overall stock and its protection status. Below, we report and analyse the available information at face value, ignoring the non-reported areas. For the Baltic, major areas have not been reported; the Swedish assessment, for biological reasons, estimated the escapement from the Baltic as a whole, but assessed the impacts of the Swedish fisheries only; that is: some of the reported indicators apply to the whole Baltic, others to the Swedish coast only. Integration of the Baltic assessments will be required, to derive a set of meaningful stock indicators. The coastal fisheries on eel all over Europe being predominantly concentrated in the Baltic (Table 2.1), this hampers the overall evaluation of the impact of coastal fisheries considerably.

Table 2.1. Present and hypothetical escapement of silver eels, in tonnes, by sea basins. Note that this table sums all reported data, ignoring the non-reporting areas. Data from ICES (2016c). The $B_{current}$ column provides the current biomass of escapees by main maritime areas, and the B_0 column provides the hypothetical escapements under no human influence, assuming that, without human influence, recruitment would return to historical high values. Column $B_{current}/B_0$ provides that comparison in percentage terms. Additional estimates are provided for estimates of potential escapement under present conditions if human impacts were eliminated (B_{best}) in the current situation of low recruitment, and mortality rates due to all human impacts (∑A, fishing and non-fishing).

	Current (2014) escapement	Current potential escapement	Pristine escapement, hypothetical	Current, as percentage of pristine	Current, as percentage of potential, %SPR	Lifetime anthropogenic mortality
	$B_{current}$	B_{best}	B_0	$B_{current}$ / B_0	$B_{current}$ / B_{best}	∑A
Basin	t	t	t	%	%	
Baltic	3557	3770	12 500	28	94	0.06
North Sea	2977	3376	17 489	17	88	0.13
Atlantic	1501	20 775	71 814	2	7	2.63
Mediterranean	1480	2137	10 868	14	69	0.37
mixed basins	508	622	1378	37	82	0.20
Total reported	10 022	30 680	114 049	9	33	1.12

2.4 DG Question 3: And ICES is requested to assess the extent to which catches of silver eel in marine waters reduce the spawning potential in a manner jeopardising the recovery of the stock

Eels are semelparous and undergo a final seaward spawning migration. The silver eel run is composed of multiple year classes and variable sex ratios that differ between locations. The mechanism behind the silvering process from yellow eel to seaward migrating silver eel is poorly understood and production (numbers or biomass) of silver eel is likely to be related to a combination of stock abundance and location growing conditions. During their migration silver eels are affected by inland and coastal fisheries, and by a variety of anthropogenic factors such as hydropower turbines, pumps, etc., leaving a final escapement to the ocean. It is this escapement ($B_{current}$) relative to pristine production (B_0) that is required to be quantified under the EU Regulation.

Catches of European eel in marine waters by EU Member States have been compiled from the data MS reported to the Commission in response to the request for data (February 2017, deadline 31st March 2017), and we included all data provided to the Workshop until 11th April (inclusive). In addition, information on catches in marine waters have been derived from the Fishery Data Exchange system of the European Commission (Fides). Table 3.1 compares these information sources, for the year 2014. Though the Commission's request for the data asked for all marine catches, the questions addressed here refer to catches outside the areas covered by EMPs, most likely, the data obtained are somewhat inconsistent. The Fides data, in contrast, encompass all catches in marine areas, irrespective of the presence of EMPs. Four countries (Sweden, Germany, Denmark, France) dominate, representing 98% (data request) or 91% (Fides) of the reported total marine catch. For each of these four countries, the marine areas are included in their EMPs, and both data sources do include all their catches in marine waters.

Table 3.1. Catches of eel from marine areas, as reported to the current data request or Fides, in tonnes. These data refer to the year 2014, the year stock status indicators were assessed (2015 post-evaluation of the Eel Regulation).

Basin	Member State	data-request	Fides
Baltic	Sweden	208.881	208.881
	Finland		0.855
	Estonia	1.056	1.055
	Latvia	0.154	0.200
	Lithuania	0.000	0.002
	Poland	0.018	39.458
	Denmark	283.100	281.227
Baltic Total		493.209	531.678
North Sea	Sweden	0.242	0.242
	Denmark	33.800	33.463
	Netherlands	3.579	0.630
	United Kingdom		0.766
	France		0.028
North Sea Total		37.621	35.129
Atlantic	Denmark		
	United Kingdom		0.517
	France		55.239
	Spain	0.000	5.988
	Portugal		5.959
Atlantic Total		0.000	67.703
Mediterranean	France		129.861
	Spain	0.000	1.443
	Croatia		0.516
	Greece	2.699	14.998
	Cyprus		0.529
Mediterranean Total		2.699	147.347
Mixed basins	Germany	46.700	
Total reported		580.229	781.857

Based on this information, the total catch in marine areas in 2014 is estimated at 580 or 782 t, of which at least 573 t or 709 t is from areas under an EMP. That is: total reported marine catches are in the order of magnitude of 6–8% of the current escapement, and catches made outside EMPs are less than 1% of current escapement. Current escapement of silver eel biomass towards the sea - for the areas reporting - is estimated at 33% of the current potential, or 9% of the pristine escapement (Table 2.1, above).

Although scientific knowledge is not sufficient to express this impact in regard to the extent to which it jeopardises the recovery of the stock, it is apparent that the marine fishery (like all other mortalities) makes an impact on the stock, reducing the chance of stock recovery.

2.5 DG Question 4: In particular, ICES is requested to assess the impact and effectiveness of the following measures against the objective to increase the glass and yellow eel recruitment (as in consider the potential impact on the SSB of eel) by 2020, provided that these measures remain in place until then:

a) Reducing all eel fisheries to 50% of the 2004–2006 average in the Union waters seaward from the baselines ('baselines' here refer to the delimitation of Eel management plans - "seaward of the boundary of Eel Management plans" - article 8 par. 2 of the Eel regulation) as prescribed in the Eel regulation;

b) Reducing all eel fisheries to 25% of the 2004–2006 average in the Union waters seaward from the baselines;

c) Reducing all eel fisheries to 0% of the 2004–2006 average in the Union waters seaward from the baselines.

The EU Eel Regulation has adopted a management target of 40% of the pristine silver eel production. ICES has not evaluated this management target for its conformity with the precautionary approach.

In the absence of a quantified stock–recruit relationship for European eel, it is not possible to estimate the effect of marine-caught eels on subsequent recruitment. However, none of these options (a-c) will is or would be enough to achieve the 40% escapement biomass target of the Eel Regulation for any sea basin in the short term. As the generation time for eel is greater than three years, this circumstance will not change materially by 2020. Stock recovery is a long-time process, and reducing marine catches could be just one contribution to that. However, we note that, in qualitative terms at least, reductions in fishing mortality (or other mortality factors) at a late life stage probably has a greater benefit than reducing mortality by the same amount at an early life stage, and reductions in silver eel mortality in particular should confer the most rapid potential improvements in amount of spawners.

2.6 DG Question 5: ICES is requested to further comment on the modalities of the application of the above measures in order to reach the highest effectiveness, e.g. the stages of eels to be subject to the measures mentioned above, the duration of the measures, the seasonal aspect, the geographical area, the gears, the urgency of the need to take the measures etc., taking into account the resulting application of the landing obligation

Fisheries have taken place over the whole geographic range, and most often occur as scattered small-scale rural enterprises (Dekker, 2004). Various types of gear are used in the yellow and/or silver eel fisheries, including different nets, traps, hooks, etc. in both salt- and freshwater (Dekker, 2003). In many EU countries, a recreational fishery contributes significantly to the total catch. The gear might consist of rod-and-line as well as longlines and nets or traps. Usually a licence or permit is required to be able to fish recreationally, however there are countries where the access to the fishery is free or based on private ownership (Dekker, 2005). Commercial and recreational fisheries are typically seasonal in timing, but those seasons depend on the availability of the target life stage which varies geographically.

Given the diversity of fisheries methods practised, in our view there is no one-size-fits-all approach to designing effective fishery control measures.

If the landing obligation is applied to catches of eel by targeted fisheries, the comparison with the 2004–2006 landings effectively sets a quota for eel catch. Presumably therefore targeted fisheries would have to cease fishing upon meeting that quota.

2.7 DG Question 6: ICES is also requested to provide comments on other equally effective measures that could be used as alternatives to achieve respective reductions of fisheries in marine waters as in point 4

Considering that fishing is expected to be the dominant anthropogenic impact on the eel stock in marine waters (though small in comparison to impacts in non-marine waters), ICES could not identify any other 'non-fisheries' measures that could be taken in the marine environment seaward of EMUs to protect silver eel escapement and the recovery of the stock.

However, several MS reported to the Commission a bycatch of European eel from other fisheries. Therefore, measures might be designed to reduce or eliminate that bycatch. For example, introduce a derogation for European eel from the landing obligation and ensure that bycatch is returned alive to marine waters. Note that the survivability of European eel after catch and release by marine fisheries has not been tested, to our knowledge.

2.8 DG Question 7: Finally, ICES is requested to comment on the impact of glass eel fisheries on recruitment and subsequent adult stock biomass

The glass eel fisheries are mainly concentrated around SW England, the Bay of Biscay area (Dekker, 2003) and along the Mediterranean coasts of Spain and Italy (ICES, 2012b). Being executed in the estuaries and river mouths, these fisheries capitalize on the natural concentration of glass eels in the area (Dekker, 2003). The exploitation of glass eels takes place in winter and early spring when they arrive on the European coast. The glass eel fishing gear consists of both active and passive gears. The active gear includes different hand-held or ship-borne nets while passive gear is composed of traps and fykenets kept fixed in a stream (Dekker, 2002). The glass eels caught are used for stocking, aquaculture or local consumption (ICES, 2013b); additionally, a considerable quantity has been illegally exported in recent years (ICES, 2016b). The EU Regulation (Article 7.1) states that 60% of the eels less than 12 cm in length caught annually should be reserved for stocking.

The glass eel catch for 2016 was estimated by WGEEL to be 59.3 tonnes (ICES, 2016b: Table 2.9). As the Regulation requires that 60% of this catch must be made available for restocking, we assume simplistically that 23.7 tonnes of glass eel is retained for consumption. This may be an overestimate as some of these glass eels may have supplied aquaculture and subsequently be restocked.

There are few national, and no international, assessments that estimate the impact of glass eel catch on recruitment and subsequent adult biomass. At best for the international (sea basin) scale, an estimate can be made of the equivalent amount of silver eel derived from a quantity of glass eel; indeed, this is the basis of some national eel stock assessments. Tentative calculations indicate a potential silver eel production in the order of a few thousand tonnes, but these estimates are highly uncertain. More essentially, this tentative calculation ignores the existing human-induced mortalities

such as yellow and silver eel fisheries, turbines and pumps, etc. and therefore, should be considered as indicative only: it does not relate to the actual state of the stock and impacts in any EMU.

2.9 References

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

Dekker W. (ed.) 2002. Monitoring of glass eel recruitment. Report C007/02-WD, Netherlands Institute of Fisheries Research, IJmuiden, 256 pp.

Dekker W. 2003. Status of the European eel stock and fisheries. In: Aida K., Tsukamoto K. and Yamauchi K. (eds.), Eel Biology. Springer-Verlag, Tokyo, pp. 237–254.

Dekker, W. 2004. Slipping though our hands; population dynamics of the European eel. Faculteit der Natuurwetenschappen. 186 pp.

Dekker W. (ed.) 2005. Report of the Workshop National Data Collection European eel, Sånga Säby (Stockholm, Sweden), 6–8 September 2005.

Dekker W. 2009. A conceptual management framework for the restoration of the declining European eel stock. Pages 3–19 in J.M. Casselman and D.K. Cairns, editors. Eels at the Edge: science, status, and conservation concerns. American Fisheries Society, Symposium 58, Bethesda, Maryland.

Dekker, W. 2010. Post evaluation of eel stock management: a methodology under construction. IMARES report C056/10, 67 pp.

Dekker W. 2016 Management of the eel is slipping through our hands! Distribute control and orchestrate national protection. ICES Journal of Marine Science, 73(10), 2442–2452.

European Council. 2007. Council Regulation (EC) No 1100/2007 of 18 September 2007 establishing measures for the recovery of the stock of European eel. Official Journal of the European Union L248/17: 1–7.

ICES. 2010. Report of the Study Group on International Post-Evaluation on Eels (SGIPEE), 10–12 May 2010, Vincennes, France. ICES CM 2010/SSGEF:20, 42 pp.

ICES. 2012. ICES Implementation of Advice for Data-limited Stocks in 2012 in its 2012 Advice. ICES CM 2012/ACOM 68. 42 pp.

ICES. 2013a. Report of the Workshop on Guidelines for Management Strategy Evaluations (WKGMSE). ICES CM 2013 ACOM 39. 121 pp.

ICES. 2013b. Report of the Joint EIFAAC/ICES/GFCM Working Group on Eel, 18–22 March 2013 in Sukarrieta, Spain, and 4–10 October in Copenhagen, Denmark. ICES CM 2013/ACOM:18. 851 pp.

ICES. 2014. Report of the Joint EIFAAC/ICES/GFCM Working Group on Eel, 3–7 November 2014, Rome, Italy. ICES CM 2014/ACOM:18. 203 pp.

ICES. 2015. Report of the Workshop on Eel and CITES (WKEELCITES), 10–12 March 2015, Copenhagen, Denmark. ICES CM 2015/ACOM:44. 57 pp.

ICES. 2016a. European eel (*Anguilla anguilla*) throughout its natural range. ICES Advice on fishing opportunities, catch, and effort, Northeast Atlantic, ICES Advice 2016, Book 9, Published 28 October 2016.

ICES. 2016b. Report of the Working Group on Eels (WGEEL), 15–22 September 2016, Cordoba, Spain. ICES CM 2016/ACOM:19. 107 pp.

ICES. 2016c. Report of the Joint EIFAAC/ICES/GFCM Working Group on Eel (WGEEL), 24 November–2 December 2015, Antalya, Turkey. ICES CM 2015/ACOM:18. 130 pp.

ICES. 2016d. Report of the Workshop on Eel Stocking (WKSTOCKEEL), 20–24 June 2016, Toomebridge, Northern Ireland, UK. ICES CM 2016/SSGEPD:21. 75 pp.

McCleave, J.D., R.C. Kleckner and M. Castonguay. 1987. Reproductive sympatry of American and European eels and implications for migration and taxonomy. American Fisheries Society Symposium, Vol.1, pp. 286–297.

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

Palm, S., Dannewitz, J., Prestegaard, T., Wickstrom, H. 2009. Panmixia in European eel revisited: no genetic difference between maturing adults from southern and northern Europe. Heredity, 103, 82–89.

Tesch, F.-W. and Wegner, G. 1990. The Distribution of Small Larvae of *Anguilla* sp. Related to Hydrographic Conditions 1981 between Bermuda and Puerto Rico. Int. Revue ges. Hydrobiol. Hydrogr., 75: 845–858. doi: 10.1002/iroh.19900750629.

UN. 1995. United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks.
http://www.un.org/Depts/los/convention_agreements/convention_overview_fish_stocks.htm

Annex 1: Master dataset used in this report, showing the countries assigned to sea basins, summarising the eel management units (EMUs) and eel stock indicators (from 2015 Progress Reports), and the catch data submitted to the Commission request

		Number of Eel Management Units						Stock indicators, ignoring non-reporting EMUs							
		WITHOUT INDICATORS	WITH INDICATORS	INDICATORS COVER	MARINE AREAS	LISTED IN DATA REQUEST	DATA CALL OVERLAPS EMU	$B_{current}$	B_{best}	B_0	$B_{current}$ / B_0	$B_{current}$ / B_{best}	∑A	CATCH, DATA REQUEST, 2014	CATCH /$B_{current}$
BASIN	COUNTRY	2015	2015					T	T	T	%	%		T	%
Baltic	SE		1	1	1	1		3 557	3 770	12 500	28	94	0.06	209	6
	FI	1												1	
	EE	2			2	2								1	
	LV	1			1									0	
	Lt		1	1	1	1		9	18	87	10	48	0.74	0	
	PL		2	2	2			91	475	2 954	3	19	1.65	0	
	DE		3	3				2 662	2 706	3 005	89	98	0.02		
	DK														
Baltic	total	4	7	7	7	4		3 557	3 770	12 500	28	94	0.06	211	6
North Sea	SE	1			1									0	
	DE		6	6				1 623	1 122	5 988	27	145	-0.37		
	DK														
	NL		1	1	1	1		1 057	1 697	10 400	10	62	0.47	4	
	BE		2					24	47	239	10	51	0.67		
	UK		3	3				189	472	731	26	40	0.91		
	FR		2	2				84	38	131	64	219	-0.79		
North Sea	total	1	14	12	2	1		2 977	3 376	17 489	17	88	0.13	4	0.1

		Number of Eel Management Units						Stock indicators, ignoring non-reporting EMUs							
		WITHOUT INDICATORS	WITH INDICATORS	INDICATORS COVER	MARINE AREAS	LISTED IN DATA REQUEST	DATA CALL OVERLAPS EMU	$B_{CURRENT}$	B_{BEST}	B_0	$B_{CURRENT}$ / B_0	$B_{CURRENT}$ / B_{BEST}	∑A	CATCH, DATA REQUEST, 2014	CATCH /$B_{CURRENT}$
BASIN	COUNTRY	2015	2015					T	T	T	%	%		T	%
Atlantic	IE		6	6				326	340	590	55	96	0.04		
	UK	1	9	9				411	1 376	6 315	7	30	1.21		
	FR		6	6				583	18 687	64 481	1	3	3.47	55	9
	ES	1	4		4			181	372	429	42	49	0.72	0	
	PT	1												6	
Atlantic	total	3	25	21	4			1 501	20 775	71 814	2	7	2.63	25	2
Mediterranean	FR		2	2				112	194	669	17	58	0.55	130	54
	ES	1	4		4			761	1 010	6 613	12	75	0.28	0	
	IT		20	20				585	876	3 408	17	67	0.40		
	GR	1	3		3			22	57	178	12	39	0.95	3	11
Mediterranean	total	2	29	22	7			1 480	2 137	10 868	14	69	0.37	133	8
mixed basins	DK	1	1		1			132	168	1 110	12	79	0.24		
	DE				9									47	
	UK		1	1				376	454	268	140	83	0.19		
	FR														
mixed basins	total	1	2	1	10			508	622	1 378	37	82	0.20	47	49
Total reported		11	77	63	30	5		10 022	30 680	114 049	9	33	1.12	819	6

Annex 2: Participants

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Annex 3: Acronyms and Glossary of terms used in the report

ACRONYM	DEFINITIONS
DLS	Data-Limited Stocks
EIFAAC	European Inland Fisheries & Aquaculture Advisory Commission
EMP	Eel Management Plan
EMU	Eel Management Unit
GFCM	General Fisheries Commission of the Mediterranean
ICES	International Council for the Exploration of the Sea
MSY	Maximum Sustainable Yield
RBD	River Basin District
SGIPEE	Study Group on International Post-Evaluation on Eels
SPR	Estimate of spawner production per recruiting individual
SSB	Spawning–Stock Biomass
WGEEL	Joint EIFAAC/ICES/GFCM Working Group on Eel

Glossary

Eel River Basin or Eel Management Unit: "Member States shall identify and define the individual river basins lying within their national territory that constitute natural habitats for the European eel (eel river basins) which may include maritime waters. If appropriate justification is provided, a Member State may designate the whole of its national territory or an existing regional administrative unit as one eel river basin. In defining eel river basins, Member States shall have the maximum possible regard for the administrative arrangements referred to in Article 3 of Directive 2000/60/EC

[i.e. River Basin Districts of the Water Framework Directive]." EC No. 1100/2007.

River Basin District: The area of land and sea, made up of one or more neighbouring river basins together with their associated surface and groundwaters, transitional and coastal waters, which is identified under Article 3(1) of the Water Framework Directive as the main unit for management of river basins. The term is used in relation to the EU Water Framework Directive.

Eel reference points/population dynamics:

- Silver eel production (biomass)
  - B_0 The amount of silver eel biomass that would have existed if no anthropogenic influences had impacted the stock;
  - $B_{current}$ The amount of silver eel biomass that currently escapes to the sea to spawn;
  - 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.
- Anthropogenic mortality (impacts)

- 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. It refers to mortalities summed over the age groups in the stock.

- Stocking requirements
  - R(s) The amount of eel (<20 cm) stocked into national waters annually. The source of these eel should also be reported, at least to originating Member State, to ensure full accounting of catch vs. stocked (i.e. avoid 'double banking'). Note that R(s) for stocking is a new symbol devised by the Workshop to differentiate from "R" which is usually considered to represent Recruitment of eel to continental waters.

Spawner per recruitment (SPR): Estimate of spawner production per recruiting individual. %SPR Ratio of SPR as currently observed to SPR of the pristine stock (B_0), expressed in percentage. %SPR is also known as Spawner Potential Ratio.

Annex 4: Reviewer Reports

Reviewer 1

My task as a reviewer is to evaluate how well the paper meets what is asked for in the official Request. However, I'm having some trouble determining what is actually wanted. The Request's title (Fisheries related anthropogenic impacts on silver eels) suggests that the Request is for information about silver eel fisheries impacts. The last two paragraphs of the Background section refer to eels while they occupy marine waters. Marine waters can be occupied by glass, yellow, and silver eels. There is no indication in the Background that the Request pertains only to silver eels; although one might guess that this is the case due to references to spawning escapement in earlier paragraphs of the Background. Most of the questions appear to be oriented towards marine areas, but it is unclear if the interest is limited to silver eels or also includes yellow eels. Question 7 refers specifically to glass eels.

Since the overall orientation of Request seems to be toward areas that are seaward of areas covered by Eel Management Plans, it's important to understand what is meant by this. Question 4a refers to Article 8, part 2 of the EU Regulation as the authority for definitions.

Article 8, part 2, says "For the purposes of paragraph 1, Community waters are those waters seaward of the boundary of those eel river basins which constitute natural eel habitats as defined by Member States according to Article 2(1)." Article 2, part 1, says "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."

These regulatory clauses provide no enlightenment on the nature of habitat beyond EMP seaward boundaries, because a member state can define the area covered by an EMP in whatever way it chooses. The Report's answer to Question 2 notes that "most national EMPs cover marine waters within the national territories, but not all do." It would be useful for the Report to include ecological context for such habitats, based on salinity, tidal regime, and degree of shelter from the open sea. Given the variable way in which EMP zones are mapped, such generalizations may be difficult. Nevertheless, it should be possible to give a maximum extent to such zones, based on the limit of "national territories," provided that there is a standard definition of "national territories," e.g. within a certain distance from the coast.

Even if "national territories" include open coastal waters, yellow eels may be present in the waters beyond. The ICES report on eels in saline waters (http://www.ices.dk/sites/pub/CM%20Doccuments/CM-2009/DFC/SGAESAW09.pdf) documented large (or at least formerly large) yellow eel populations in waters many km from the shore, in the southeast and southwest North Seas (cf. Helgoland trawl fishery, Willem Dekker's analysis of North Sea beam trawl data). This should be noted, as well as any other pertinent information that has come to light since the saline report.

To the extent possible, the Report should make general comments on whether fisheries in waters seaward of EMP boundaries typically catch both yellow and silver eels, or silver eels alone. In the Baltic Sea, especially near its exit, there are fisheries which

target silver eels as they migrate along the coast. Are fisheries which intercept coastal migrants unique to the Baltic, or do they occur elsewhere in the EU?

The question of what waters are covered and not covered is a source of confusion in both the Request and the Report. I suggest that the authors add a section in the Introduction, or perhaps a separate section after the Introduction, which deals with this. It would help if a word (possibly "maritime) is introduced and assigned the meaning of the waters outside the seaward boundary of an EMP. It would be emphasized that such a definition is administrative, and not based on normal biological or oceanographic meaning. Once the term is defined, it would be used consistently throughout the Report.

The question of how marine/non-marine habitat is classified also enters into interpretation of the two competing landings series, i.e. Fides and responses provided by member states to the EU. I suggest that an introductory section would also be the best place to clarify this issue.

Question 1: The Report addresses this question by pointing out how complexities and data limitations make it difficult to provide a full answer. This is all true. However, a simple empirical analysis may also be possible. This would be done by comparing catch data and effort data from 2004–2006 with corresponding data for the most recent available period. One would then look at changes in glass eel recruitment indices over the same interval. The hypothesis would be that falling catch and effort levels would correspond to increasing recruitment indices. If marine fisheries are mostly silver eels (not certain if this is the case), then the time-lag should be only a year. Hence if there is a cause-and-effect relation between marine catch and effort and subsequent recruitment, it should be evident in this comparison. This is hardly a strong or tight method of analysis. However, if catch and effort decline over the study period, and recruitment also declines, this would support a negative answer to Question 1.

Question 3: I'm confused whether Question 1 and Question 3 refer to the same or different mortality factors. Question 1 refers to catches and effort, with the prefix "on this basis" seeming to refer to a previous paragraph that refers to marine habitat. The Request title implies that only silver eels are considered, but the text is silent on what phase is intended to be included. Question 3 refers to silver eels in marine waters, but I don't know if "marine" is used in its oceanographic or administrative (i.e. beyond the bounds of EMP) sense. If Questions 1 and 3 are both intended to deal with silver fisheries mortality in marine waters, then they are essentially asking the same question, although the criteria for judging the response differ ("sufficient to achieve the objectives of the 2013 CFP" vs. "manner jeopardising the recovery of the stock.").

Question 5 asks about effectiveness of conservation measures in relation to eel stages that are targeted, and Question 7 asks about impacts of glass eel fisheries. I think it would be useful to make one point here. There are literature indications that natural mortality in eels has some degree of density-dependence. Density-dependence may occur at early continental stages and yellow stages due to limitations of habitat and food. Density-dependent mortality is unlikely to occur in silver eels, because silver eels do not eat. This means that impacts of a given fishing mortality may vary with the stage that is fished. If 50% of recruiting glass eels are removed, then the reduction in the number of spawners reaching the spawning ground is probably something less than 50%. But if 50% of a run of silver eels is taken, then the number of spawners reaching the spawning ground will probably be reduced by a full 50%. The data on density-dependence may not be sufficiently firm to set this up in a quantitative basis.

However, the Report should note, in a qualitative sense, that reducing fishing mortality at a late life stage probably has a greater benefit than reducing mortality by the same amount at an early life stage.

The following is a point that is outside all the Questions asked, but nevertheless affects all of them. The whole apparatus of ICES analysis of European Eel status works with eels within EMPs. There may be substantial populations of yellow eels in open marine waters outside EMPs (I'm not sure of this). If this is the case, are these "extra-national" eels considered in ICES models? If they are not, then this should be flagged in the report.

Reviewer 2

ICES recently confirmed that the European eel remains in the critical zone. The EU Common Fisheries Policy indicates that for data-limited stocks such as the European eel, the Precautionary Approach should be applied. The Precautionary Approach dictates that all mortality sources (fisheries or otherwise) reducing escapement of silver eels should be reduced to as close to zero as possible. The EU asked ICES to answer seven questions on this topic which form the basis of this report.

DG Question 1

A reference should be provided to support the statement that ICES considers European eel to be a data-limited stock.

I agree that a 50% reduction in marine catches/effort is not sufficient to achieve the objectives of the 2013 Common Fisheries Policy to exploit the eel stock sustainably in the short term. Although it was not specifically requested, the answer could also highlight that there are silver eel mortality factors that are much more difficult to mitigate than others and that management actions should focus on mortality factors that the EU can control. Decreasing silver eel mortalities due to hydro dams or pollution would be a difficult task, if at all feasible.

DG Question 2

$\mathbf{B}_{best}$ is not clearly defined with respect to restocking. It seems like restocking is excluded from the **Bbest** calculation. I wonder how such a calculation is performed, as excluding the effect of restocking on silver eel production seems hard to quantify. Please clarify.

Are $\mathbf{\Sigma A} = \mathbf{\Sigma F} + \mathbf{\Sigma H}$ all instantaneous rates?

I find it quite unfortunate that countries MUST meet requirements regarding stocking. At best, the “jury is still out” on the usefulness of restocking for conservation purpose. There is mounting evidence of intra-generational spatially variable selection fine-tuning the genome of elvers such that they are closely adapted (e.g. with respect to sex ratio and growth) to the continental habitat where they live (Côté *et al*., 2009; Côté *et al*., 2015; Pavey *et al*., 2015; and Mateo *et al*., 2017). Restocking destroys such genetic fine-tuning and likely decreases the fitness of stocked eels, and also possibly the fitness of natural eels inhabiting the same watersheds. The Precautionary Approach would dictate prudence with this measure. It seems to me that the last thing a management body would want to do is to force countries to meet restocking targets. I realize this comment is somewhat beside the point, but this is an issue worth raising.

Regarding Table 2.1, it would be useful to add a column showing the fraction of non-reporting EMUs by sea basin. This would give the reader a better sense of the potential impact of missing data on escapement calculations by sea basin.

Regarding Table 2.1 again, please explain how the total reported **ΣA** is calculated. I imagine it is an average by sea basin weighted by current escapement.

DG Question 3

I agree that catches in the order of 6–8% make an impact on the stock, further reducing the chance of recovery. However ICES should point out that silver eel mortality is not like any other source of mortality. Unlike mortality reductions on other life stages, reducing silver eel mortality directly increases escapement to the Sargasso Sea spawning site and hence spawning–stock biomass (and hopefully glass eel recruitment, depending on the stock–recruitment relationship). Management actions targeting reductions in silver eel mortalities are the actions most likely to bring a rapid benefit to the population.

DG Question 4

In relation to my point above, bringing a rapid benefit to the population through reducing silver eel mortalities close to zero would not in itself possibly allow to achieve the 40% virgin biomass escapement by 2020. As the authors point out, recovering eel populations will be a long-term process that will require long-term sustained management plans.

Like most collapsed marine or diadromous fish stocks, European eel is likely in a linear portion of the stock–recruitment relationship close to the origin where the quantity of spawning–stock biomass does affect the number of recruits. If management actions on silver eel mortality were to bring $\mathbf{B}_{current}$ close to $\mathbf{B}_{best}$ (i.e. aiming at tripling escapement as per Table 2.1), the benefit in terms of recruitment would be felt more rapidly than mitigation measures on other life stages. Hence a substantial reduction of silver eel mortality could have a rather quick benefit. However fishing mortality is only one part of anthropogenic mortality on silver eels, and mortality not due to fishing is much harder to mitigate.

DG Question 5

I completely agree with the answer.

DG Question 6

I agree that regulations of marine fisheries that capture silver eels as bycatch should be amended such that silver eel bycatch is returned alive to the sea. Eels are robust fish and I surmise that the survival rate would be quite high. It would be a good idea to develop studies to quantify this.

However I find this answer quite short on details. What are the main marine fisheries reporting eel bycatch? What types of fishing gears are used mostly: fixed or mobile gears? Any idea of quantities of bycatch?

DG Question 7

The possible deleterious effects of restocking on the eel population should also be discussed as per my comment on restocking for Question 2.

I find a natural mortality of 0.01 for glass eels rather impossible. I would like the authors to add a reference specifically citing this value.

4.2.1 References

Côté, C., M. Castonguay, G. Verreault, and L. Bernatchez. 2009. Differential effects of origin and salinity rearing conditions on growth of glass eels of the American eel *Anguilla rostrata*: implications for stocking programmes. J. Fish Biol. 74: 1934–1948.

Côté, C.L., S.A. Pavey, J.A. Stacey, T. Pratt, M. Castonguay, C. Audet, and L. Bernatchez. 2015. Growth, female bimodality and sex ratio variability in American Eel (*Anguilla rostrata*) of different origins in both controlled conditions and the wild: Implications for stocking programs. Trans. Am. Fish. Soc. 144: 246–257.

Mateo, M., P. Lambert, S. Tétard, M. Castonguay, B. Ernande, and H. Drouineau. 2017. Cause or consequence? Exploring the role of phenotypic plasticity and genetic polymorphism in the emergence of phenotypic spatial patterns of the European eel. Can. J. Fish. Aquat. Sci. In press. doi: 10.1139/cjfas-2016-0214.

Pavey, S.A., J. Gaudin, E. Normandeau, M. Dionne, M. Castonguay, C. Audet, and L. Bernatchez. 2015. RAD-sequencing highlights polygenic discrimination of habitat ecotypes in the panmictic American eel (*Anguilla rostrata*). Current Biology 25: 1666–1671.

Annex 5: Response to Reviewers

Response to Reviewers (27/04/2017)

Thanks to the two reviewers for their time and considerations.

We shared the reviewers' difficulties in answering some of the questions asked by the Commission using the marine eel catch data reported by Member States either in response to the Commission's request for national data or in data submitted to FIDES. We assumed there was not sufficient time available to make a new request for national data and still meet the Advice Delivery date, so we worked with what data and information were available to us at the time.

We would like to make it clear that the workshop focused specifically on the questions asked by the Commission, and refrained from considering wider issues.

Our responses to the points raised by the reviewers are inserted after those points (underlined for clarity), and shown in italics.

An updated WK report accompanies this document, with changes made in response to reviewers' comments shown by track changes.

Reviewer 1

ICES recently confirmed that the European eel remains in the critical zone. The EU Common Fisheries Policy indicates that for data-limited stocks such as the European eel, the Precautionary Approach should be applied. The Precautionary Approach dictates that all mortality sources (fisheries or otherwise) reducing escapement of silver eels should be reduced to as close to zero as possible. The EU asked ICES to answer seven questions on this topic which form the basis of this report.

DG Question 1

A reference should be provided to support the statement that ICES considers European eel to be a data-limited stock.

Response: a citation has been inserted for the ICES Advice on European eel (2016a) where it is stated that the eel is Stock Category 3.

I agree that a 50% reduction in marine catches/effort is not sufficient to achieve the objectives of the 2013 Common Fisheries Policy to exploit the eel stock sustainably in the short term. Although it was not specifically requested, the answer could also highlight that there are silver eel mortality factors that are much more difficult to mitigate than others and that management actions should focus on mortality factors that the EU can control. Decreasing silver eel mortalities due to hydro dams or pollution would be a difficult task, if at all feasible.

Response: we agree with the reviewer but, as noted, this wider discussion was not requested.

DG Question 2

B_{best} is not clearly defined with respect to restocking. It seems like restocking is excluded from the B_{best} calculation. I wonder how such a calculation is performed, as excluding the effect of restocking on silver eel production seems hard to quantify. Please clarify.

Response: The estimate of B_{best} should be independent of restocking. The definition provided in the reported has been adjusted to make this more clear. Member States use a range of methods to estimate B_{best} however and so it is not possible to include a succinct description within this report.

Are ΣA = ΣF + ΣH all instantaneous rates?

I find it quite unfortunate that countries MUST meet requirements regarding stocking. At best, the "jury is still out" on the usefulness of restocking for conservation purpose. There is mounting evidence of intra-generational spatially variable selection fine-tuning the genome of elvers such that they are closely adapted (e.g. with respect to sex ratio and growth) to the continental habitat where they live (Côté *et al*., 2009; Côté *et al*., 2015; Pavey *et al*., 2015; Mateo *et al*., 2017). Restocking destroys such genetic fine-tuning and likely decreases the fitness of stocked eels, and also possibly the fitness of natural eels inhabiting the same watersheds. The Precautionary Approach would dictate prudence with this measure. It seems to me that the last thing a management body would want to do is to force countries to meet restocking targets. I realize this comment is somewhat beside the point, but this is an issue worth raising.

Response: as the reviewer states, this matter is outside the remit of the task set the WK and therefore, although we appreciate the comment, we do not respond.

Regarding Table 2.1, it would be useful to add a column showing the fraction of non-reporting EMUs by sea basin. This would give the reader a better sense of the potential impact of missing data on escapement calculations by sea basin.

Response: We assume that the reviewer refers to the non-reporting of marine catches (including nil returns) in response to the request by the Commission. The table in Annex 1 provides this information for Member State EMUs grouped into each sea basin, and those units that span two basins. As the EMUs are not standard in size or productive output or capacity, and that not all of them have reported the biomass and/or mortality indicators, we do not believe that reporting a fraction of them would be informative to answering the questions posed by the Commission.

Regarding Table 2.1 again, please explain how the total reported ΣA is calculated. I imagine it is an average by sea basin weighted by current escapement.

Response: For basins other than the Baltic, total ΣA is simply the average of national ΣA estimates, weighted by B_{best} (which is equivalent to $-ln(B_{current}/B_{best})$ for the summed $B_{current}$ and B_{best}). For the Baltic, total biomass estimates were estimated by Sweden because their estimates encompass the escapement of all others, including the non-reporting areas. As a consequence, the ΣA covers the Swedish fishery only. The Baltic clearly needs a better integrated assessment.

DG Question 3

I agree that catches in the order of 6–8% make an impact on the stock, further reducing the chance of recovery. However ICES should point out that silver eel mortality is not like any other source of mortality. Unlike mortality reductions on other life stages, reducing silver eel mortality directly increases escapement to the Sargasso Sea spawning site and hence spawning–stock biomass (and hopefully glass eel recruitment, depending on the stock–recruitment relationship). Management actions targeting reductions in silver eel mortalities are the actions most likely to bring a rapid benefit to the population.

Response: We note the reviewer's comments and similar comments of the second reviewer, and have inserted a sentence to reflect both points in the answer to DG Question 4.

DG Question 4

In relation to my point above, bringing a rapid benefit to the population through reducing silver eel mortalities close to zero would not in itself possibly allow to achieve the 40% virgin biomass escapement by 2020. As the authors point out, recovering eel populations will be a long-term process that will require long-term sustained management plans.

Like most collapsed marine or diadromous fish stocks, European eel is likely in a linear portion of the stock–recruitment relationship close to the origin where the quantity of spawning–stock biomass does affect the number of recruits. If management actions on silver eel mortality were to bring $B_{current}$ close to B_{best} (i.e. aiming at tripling escapement as per Table 2.1), the benefit in terms of recruitment would be felt more rapidly than mitigation measures on other life stages. Hence a substantial reduction of silver eel mortality could have a rather quick benefit. However fishing mortality is only one part of anthropogenic mortality on silver eels, and mortality not due to fishing is much harder to mitigate.

Response: we appreciate the reviewer's comments but note no action suggested of the WK. ICES advice on eel has been to reduce anthropogenic impacts to a minimum, which encompasses minimising mortality on silver eel.

DG Question 5

I completely agree with the answer.

DG Question 6

I agree that regulations of marine fisheries that capture silver eels as bycatch should be amended such that silver eel bycatch is returned alive to the sea. Eels are robust fish and I surmise that the survival rate would be quite high. It would be a good idea to develop studies to quantify this.

However I find this answer quite short on details. What are the main marine fisheries reporting eel bycatch? What types of fishing gears are used mostly: fixed or mobile gears? Any idea of quantities of bycatch?

Response: The WK did not have access to data from which to answer the questions posed by the reviewer.

DG Question 7

The possible deleterious effects of restocking on the eel population should also be discussed as per my comment on restocking for Question 2.

Response: As we understood the question from the Commission to be considering catch vs. not-catch, the subsequent fate of the glass eel catch would not be relevant. Therefore, we do not agree with the reviewer.

I find a natural mortality of 0.01 for glass eels rather impossible. I would like the authors to add a reference specifically citing this value.

Response: We have revised this section of the report after drafting a suggested advice, and the mortality rate is no longer reported.

References

Côté, C., M. Castonguay, G. Verreault, and L. Bernatchez. 2009. Differential effects of origin and salinity rearing conditions on growth of glass eels of the American eel *Anguilla rostrata*: implications for stocking programmes. J. Fish Biol. 74: 1934–1948.

Côté, C.L., S.A. Pavey, J.A. Stacey, T. Pratt, M. Castonguay, C. Audet, and L. Bernatchez. 2015. Growth, female bimodality and sex ratio variability in American Eel (*Anguilla rostrata*) of different origins in both controlled conditions and the wild: Implications for stocking programs. Trans. Am. Fish. Soc. 144: 246–257.

Mateo, M., P. Lambert, S. Tétard, M. Castonguay, B. Ernande, and H. Drouineau. 2017. Cause or consequence? Exploring the role of phenotypic plasticity and genetic polymorphism in the emergence of phenotypic spatial patterns of the European eel. Can. J. Fish. Aquat. Sci. In press. doi: 10.1139/cjfas-2016–0214.

Pavey, S.A., J. Gaudin, E. Normandeau, M. Dionne, M. Castonguay, C. Audet, and L. Bernatchez. 2015. RAD-sequencing highlights polygenic discrimination of habitat ecotypes in the panmictic American eel (*Anguilla rostrata*). Current Biology 25: 1666–1671.

Reviewer 2

My task as a reviewer is to evaluate how well the paper meets what is asked for in the official Request. However, I'm having some trouble determining what is actually wanted. The Request's title (Fisheries related anthropogenic impacts on silver eels) suggests that the Request is for information about silver eel fisheries impacts. The last two paragraphs of the Background section refer to eels while they occupy marine waters. Marine waters can be occupied by glass, yellow, and silver eels. There is no indication in the Background that the Request pertains only to silver eels - although one might guess that this is the case due to references to spawning escapement in earlier paragraphs of the Background. Most of the questions appear to be oriented towards marine areas, but it is unclear if the interest is limited to silver eels or also includes yellow eels. Question 7 refers specifically to glass eels.

Since the overall orientation of Request seems to be toward areas that are seaward of areas covered by Eel Management Plans, it's important to understand what is meant by this. Question 4a refers to Article 8, part 2 of the EU Regulation as the authority for definitions.

Article 8, part 2, says "For the purposes of paragraph 1, Community waters are those waters seaward of the boundary of those eel river basins which constitute natural eel habitats as defined by Member States according to Article 2(1)." Article 2, part 1, says "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."

These regulatory clauses provide no enlightenment on the nature of habitat beyond EMP seaward boundaries, because a Member State can define the area covered by an EMP in whatever way it chooses. The Report's answer to Question 2 notes that "most national EMPs cover marine waters within the national territories, but not all do." It would be useful for the Report to include ecological context for such habitats, based on salinity, tidal regime, and degree of shelter from the open sea. Given the variable way in which EMP zones are mapped, such generalizations may be difficult. Nevertheless, it should be possible to give a maximum extent to such zones, based on the limit of "national territories," provided that there is a standard definition of "national territories," e.g. within a certain distance from the coast.

Response: We appreciate the reviewer's comments and desire for clarity, which highlight the most difficult element of the task faced by the WK. Our report does highlight these challenges. Unfortunately, there are no standard (or otherwise) definitions of national territories, and no concise inventory of marine habitats inside vs. outside EMUs from which to succinctly address the reviewer's request. To our knowledge, marine catches outside national territorial waters are negligibly small. The Doggerbank has none, in the southern North Sea catches are made in-shore, the German fishery around Heligoland has come to an end long ago, and the Baltic fisheries are all in-shore.

Even if "national territories" include open coastal waters, yellow eels may be present in the waters beyond. The ICES report on eels in saline waters (http://www.ices.dk/sites/pub/CM%20Doccuments/CM-2009/DFC/SGAESAW09.pdf) documented large (or at least formerly large) yellow eel populations in waters many kilometres from the shore, in the southeast and southwest North Seas (cf. Helgoland trawl fishery, Willem Dekker's analysis of North Sea beam trawl data). This should be noted, as well as any other pertinent information that has come to light since the saline report.

To the extent possible, the Report should make general comments on whether fisheries in waters seaward of EMP boundaries typically catch both yellow and silver eels, or silver eels alone. In the Baltic Sea, especially near its exit, there are fisheries which target silver eels as they migrate along the coast. Are fisheries which intercept coastal migrants unique to the Baltic, or do they occur elsewhere in the EU?

Response: There was no information available to the WK to examine whether eels caught seaward of EMUs were yellow or silver stage. Noting the likely negligibly small magnitude of these catches, it will be hard and expensive to find evidence on their precise life stage.

The question of what waters are covered and not covered is a source of confusion in both the Request and the Report. I suggest that the authors add a section in the Introduction, or perhaps a separate section after the Introduction, which deals with this. It would help if a word (possibly "maritime) is introduced and assigned the meaning of the waters outside the seaward boundary of an EMP. It would be emphasized that such a definition is administrative, and not based on normal biological or oceanographic meaning. Once the term is defined, it would be used consistently throughout the Report.

Response: We appreciate the comment and thought we had made clear that because of the uncertainties over catch data we have focused on all marine waters, not being able to discriminate between catches inside or outside EMUs.

The question of how marine/non-marine habitat is classified also enters into interpretation of the two competing landings series, i.e. Fides and responses provided by member states to the EU. I suggest that an introductory section would also be the best place to clarify this issue.

Response: Unfortunately, the issue cannot be clarified and hence we focused on all marine waters.

Question 1: The Report addresses this question by pointing out how complexities and data limitations make it difficult to provide a full answer. This is all true. However, a simple empirical analysis may also be possible. This would be done by comparing catch data and effort data from 2004–2006 with corresponding data for the most recent available period. One would then look at changes in glass eel recruitment indices over the same interval. The hypothesis would be that falling catch and effort levels would correspond to increasing recruitment indices. If marine fisheries are mostly

silver eels (not certain if this is the case), then the time-lag should be only a year. Hence if there is a cause-and-effect relation between marine catch and effort and subsequent recruitment, it should be evident in this comparison. This is hardly a strong or tight method of analysis. However, if catch and effort decline over the study period, and recruitment also declines, this would support a negative answer to Question 1.

Response: The analysis proposed by the reviewer was made by WGEEL in 2013. It was expected that the very first protective measures (for silver eel), taken in 2009, could affect incoming glass eel recruitment by 2011/2012 - when an increase in recruitment was observed indeed. Looking more closely, however, the increase in silver eel escapement due to protective measures was counteracted by the ongoing decline related to past recruitment decline, and temporal variation was far smaller than data deficiencies/uncertainties. Hence, this tentative analysis ended inconclusively.

Question 3: I'm confused whether Question 1 and Question 3 refer to the same or different mortality factors. Question 1 refers to catches and effort, with the prefix "on this basis" seeming to refer to a previous paragraph that refers to marine habitat. The Request title implies that only silver eels are considered, but the text is silent on what phase is intended to be included. Question 3 refers to silver eels in marine waters, but I don't know if "marine" is used in its oceanographic or administrative (i.e. beyond the bounds of EMP) sense. If Questions 1 and 3 are both intended to deal with silver fisheries mortality in marine waters, then they are essentially asking the same question, although the criteria for judging the response differ ("sufficient to achieve the objectives of the 2013 CFP" vs. "manner jeopardising the recovery of the stock.").

Response: We understand the confusion, and we have tried to reflect that and the challenges posed in this work because of inconsistencies in the manner of reporting catches in relation to EMU boundaries, and the poor understanding of the proportion of silver vs. yellow eel in catches in marine waters. We appreciate that the questions appear similar, but we answered each question separately.

Question 5 asks about effectiveness of conservation measures in relation to eel stages that are targeted, and Question 7 asks about impacts of glass eel fisheries. I think it would be useful to make one point here. There are literature indications that natural mortality in eels has some degree of density-dependence. Density-dependence may occur at early continental stages and yellow stages due to limitations of habitat and food. Density-dependent mortality is unlikely to occur in silver eels, because silver eels do not eat. This means that impacts of a given fishing mortality may vary with the stage that is fished. If 50% of recruiting glass eels are removed, then the reduction in the number of spawners reaching the spawning ground is probably something less than 50%. But if 50% of a run of silver eels is taken, then the number of spawners reaching the spawning ground will probably be reduced by a full 50%. The data on density-dependence may not be sufficiently firm to set this up in a quantitative basis. However, the Report should note, in a qualitative sense, that reducing fishing mortality at a late life stage probably has a greater benefit than reducing mortality by the same amount at an early life stage.

Response: Noted and a sentence inserted to that effect in answer to DG Question 4.

The following is a point that is outside all the Questions asked, but nevertheless affects all of them. The whole apparatus of ICES analysis of European Eel status works with eels within EMPs. There may be substantial populations of yellow eels in open marine waters outside EMPs (I'm not sure of this). If this is the case, are these "extra-

national" eels considered in ICES models? If they are not, then this should be flagged in the report.

Response: We appreciate the point raised but, to our knowledge, there are none; see our response to the introduction of reviewer 2, above.