Sargasso Sea Commission
and
Convention on the Conservation of Migratory Species of Wild Animals

Workshop of European Eel Range States

Briefing Paper

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1. Background

The European eel (*Anguilla anguilla*) is one of 16 species within the family Anguillidae. It has a wide geographical range from Northern Norway to North Africa and the Mediterranean, and can be found in a broad range of aquatic habitats with varied salinities. Similar to other anguillid eels, they exhibit facultative catadromy; they are also panmictic and semelparous. These life history traits mean that they are susceptible to a range of threats, both in the marine and freshwater environments, and are challenging to manage and conserve. They are exploited from juvenile to adult life stages, however, fisheries are one of a number of proposed threats that also include changes in oceanic currents and/or climatic conditions; barriers to migration (including hydro-power stations which damage and/or kill eels); loss of freshwater habitat; disease (particularly the swimbladder parasite *Anguillicola crassus*); and poor condition of escaping adult eels. There is significant concern of the status of the species due to a decline in recruitment, population and escapement of the species over the past four decades, and it is presently listed as 'Critically Endangered' on the IUCN Red List and Appendix II of CITES. European Union legislation (EU Regulation 1100/2007[1]) was imposed in 2007 to ensure all member states had developed Eel Management Plans, to address these declines; however, to date, there is still great concern relating to the species' abundance amongst stakeholders[2]. Indeed the most recent European Inland Fisheries Advisory Commission (EIFAAC) / International Council for the Exploration of the Sea (ICES) / General Fisheries Commission for the Mediterranean (GFCM) Working Group on Eel (WGEEL) report (ICES, 2016) stated:

- *Based on the stock indicators provided by EU Member States, it was concluded that the stock in most reporting countries/areas was not within the biomass limits of the Eel Regulation and in most management units, anthropogenic mortality is not at a level that can be expected to lead to recovery. The stock in the reporting areas as a whole remains outside biomass limit, as defined in the Regulation, and average mortality over this area was not at a level that can be expected to lead to recovery.*

The Convention on the Conservation of Migratory Species of Wild Animals (CMS) had been identified as a mechanism that could complement the conservation and management of the European eel. CMS is a United Nations Environment Programme treaty that *'provides a global platform for the conservation and sustainable use of migratory animals and their habitats'* through the co-operation of species' 'Range States' that are parties to the convention. Species that are proposed for listing and are of great concern i.e. threatened with extinction, are generally listed on Appendix I. Actions relating to listing on Appendix I involve strict controls on protection, mitigation relating to habitats and movement, and addressing another other impacts on the species. Appendix II is less prescriptive and encourages co-operation between Range States to develop agreements and actions that would benefit the species. 20 species of fish are listed in Appendix I and 49 are listed in Appendix II (19 of which are also listed on Appendix I)[3].

In 2014, the European eel was listed in Appendix II of CMS. A proposal for the listing was submitted which collated existing knowledge on the species and outlined how addition to Appendix II would benefit the species. Within the proposal submitted for listing were three 'co-operative actions' that detailed what next steps might be considered, should the listing occur:

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1 http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32007R1100

2 Please refer to CMS (2014) for a full description of the species' life history, distribution and stock status (at the time), and threats considered to impact them.

3 http://www.cms.int/en/page/appendix-i-ii-cms

1. *The ICES WKEPEMP stated, in relation to EU EMPs "This post-evaluation of the 2012 Progress reports was hampered by the extensive variety of methods used to determine indicators, some of which were incomparable, and the confusing ways in which some data were reported. The standardization and coordination of the data collection, analysis and reporting should be made" (WKEPEMP 2013). ICES is at present trying to address this issue, however, it was felt that a knowledge sharing workshop to bring range states – both with and without EMPs-together to discuss co-operative, coordinated conservation and management activities and agree future collaboration would be hugely beneficial.*

2. *Indeed, due to the trans-boundary migrations this species, both in saline and fresh water, range states that neighbour one another as part of a contiguous coastline and/or river basin district, are encouraged to discuss co-operative management and conservation actions.*

3. *Due to the panmictic nature of the species an MOU/agreement/statement of intent is drafted between concerned states to recognize the importance of the Sargasso Sea as its breeding area, and the region's conservation and management.*

Some of these actions are already occurring to varying degrees and the list above is not proprietary, simply areas where CMS could benefit the species.

The Sargasso Sea Commission and the CMS secretariat have been collaborating to bring European eel Range States together for the knowledge sharing workshop described in Action 1 – both Action 2 and 3 would be expected to be discussed during this meeting. The present briefing note sets the context for discussions relating to specific key threats and associated mitigation, knowledge gaps, and how collaboration between Range States can benefit the conservation of the European eel and their associated habitats. Many of the examples below focus on EU member states and the associated ICES reports which often focus on implementation of EU Regulation 1100/2007 due to the weight of data in these regions, however, it is felt that the discussions are often applicable more broadly and should be view in the context of the species entire range.

The examples and statistics used are by no means exhaustive and have not been chosen to draw attention to particular range states, they have been included to frame the discussion and act as a catalyst for first-steps for potential collaborative management and conservation actions.

2. Potential threats

As previously stated (and discussed in CMS (2014)) there are a range of pressures that are potentially impacting the European eel cumulatively and/or synergistically. While our understanding of these impacts might be limited, there is also a limitation as to how they are practically managed. Below are two tables taken from the ICES review of EU Eel Management Plans (EMPs) (WKEPEMP; ICES, 2013a) indicating where management actions had been implemented by 2013 since EMPs were developed. It is important to state that the presence of an action on the table below does not indicate that it was effective, simply that it was implemented; indeed the lack of evidence for the effects of management measures was highlighted in the report (ICES, 2013a)
It is clear that the majority of these are continental in scope and carrying out any management in the marine environment is extremely challenging. Further, certain impacts, such as climate change, are beyond the scope of a species-specific management action. We recognise that the EU Member States are not the only Range States for the European Eel, and that the associated EMPs are not the only management plans, however, the reporting of them through the joint EIFAAC/ICES/GFCM Working Group on Eel (WGEEL) is the most comprehensive consolidation of eel management data available and as such we will use the above table as a guide for what further actions might feasibly

be developed through co-operation both within and outside of the EU. Further, the WGEEL meetings and associated reports have recently been expanded to include the General Fisheries Commission for the Mediterranean (GFCM) which has allowed input from a number of non-EU range states.

Table 4.1. Evaluation of the implementation status of management actions planned in EMPs, as reported in the 2012 Progress Reports, and summarized according to seven broad categories of action types.

Action type	Fully	Partly	Not	No information	Total
Commercial fishery	204	63	13	5	285
Recreational fishery	78	24	18	2	122
Habitat improvement	53	49	5	1	108
Hydropower and obstacles	158	68	25	2	261
Predator reduction	5	5	4	0	14
Restocking	53	23	11	2	89
Others	205	27	31	2	265
Total	**756**	**259**	**107**	**14**	**1140**

Table 4.2. Evaluation of the implementation status of management actions developed since the approval of EMPs, as reported in the 2012 Progress Reports, and summarized according to seven broad categories of action types.

Action type	Fully	Partly	Not	No information	Total
Commercial fishery	3	4	0	0	7
Recreational fishery	5	1	0	0	6
Habitat improvement	1	11	0	0	12
Hydropower and obstacles	1	2	0	0	3
Predator reduction	0	0	0	0	0
Restocking	3	1	0	0	4
Others	14	1	1	0	16
Total	**27**	**20**	**1**	**0**	**48**

Table 1 – Tables 4.1 and 4.2 from the WKEPEMP (ICES, 2013a) highlighting management actions implemented in EU European eel Range States up to 2013.

2.1 Fisheries and trade

The European eel is exploited from glass eel to silver eel, however, it is the glass eel that has the greatest demand, primarily for farming – 90% of anguillid eel production worldwide come from farming - though it is also essential for re-stocking (Crook and Nakamura, 2013; Shiraishi and Crook, 2015). The glass eel fishery is also arguably the activity that removes the greatest number of eels from the aquatic system. In EU Regulation 1100/2007, it is fisheries and the associated trade that are most focussed upon with regards to explicit management measures:

- *(14) Catches of eels in Community waters seaward of the boundary of eel river basins defined by Member States as constituting natural eel habitats should be reduced gradually by reducing fishing effort or catches by at least 50 % based on the average fishing effort or catches in the years 2004 to 2006.*

- *(16) A control and monitoring system should be established by Member States adapted to the circumstances and to the legal framework already applicable to inland fisheries in consistency with Council Regulation (EEC) No 2847/93 of 12 October 1993 establishing a*

control system applicable to the common fisheries policy. In this context Member States should establish certain information and estimates concerning commercial and recreational fishing activities to support if necessary the reporting and evaluation of Eel Management Plans as well as control and enforcement measures. Member States should furthermore take measures to ensure control and enforcement of imports and exports of eel.

Indeed it is stated in WKEPEMP (ICES, 2013a) that '*Most management actions were for commercial and recreational fisheries…*' (see Table 1). However, further analysis in the report indicates the following:

- *Member States were required to report mortality rates due to fisheries (ΣF) and to non-fisheries anthropogenic mortalities (ΣH). These two stock indicators were both reported in at least one year for 43 Eel Management Units (EMU). In 24 of these EMU, the rate due to F was greater than that due to H in the most recent year reported. H was greater than F in 15 EMU, and the two rates were equal in the other 4 EMUs.*

This would suggest that for some EU Member States, explicit fisheries management may not be the most effective to conserve the European eel and this should be considered during the development of future activities and guidance. Regardless, there appear to be fundamental issues relating to the collection of fisheries data (both inside[4, 5] and outside of the EU) and it has been repeatedly stated that it is often incomplete and/or of variable quality (Dekker, 2003; ICES, 2013a,b; 2016). From ICES (2016):

- *The Working Group has repeatedly requested improvements concerning the quality of eel landings data. Even basic data of catch "C" and effort "f" and the main fishery indicators: C total (landings/ fishing mortality), f total, and abundance index (generally cpue) for eel are very often under-evaluated, or even missing in the Country Reports. Moreover, they are not clearly reported by biological stages (glass eel, yellow, silver), by fishing categories or by appropriate management unit, also omitting marine or inland waters.*
  The inaccuracy and poor representativeness of these indicators have so far made it impossible to assess stock-wide plausible total commercial landings as well as catches of recreational and non-commercial fisheries.

As such, the development of range-wide standards to improve data quality and coverage – as opposed to blanket standardisation, which has been highlighted as potentially challenging for a species such as the European eel - would be hugely beneficial (ICES, 2016) and undoubtedly improve management of legal fisheries. From ICES (2016):

- *There is complexity and significant regional differences in eel throughout its distribution range. This is reflected in the different assessment methods and models that have already been developed by Member States in 2012 to derive the stock indicators. Although a single, central stock assessment as used for most marine species may be impractical for eel because of this complexity, being assured of the appropriateness of combining national/regional assessments would be facilitated by review and rationalisation of the methods. This would require:*

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4 It is required under the EC Regulation 199/2008 (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:060:0001:0012:EN:PDF) that an EU-wide data framework – Data Collection Framework (DCF) – relating to the Common Fisheries Policy (CFP) is established and input to; the European eel is explicitly mentioned in the regulation.

5 A recent document has updated the requirements for EC Regulation 199/2008: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016D1251&qid=1473240901058&from=en

1) *Ensure the quality of the methodologies (input data, model structure, data and model uncertainties, etc.) used by the MS to derive the stock indicators,*

2) *Consider the level of redundancy in the currently applied suit of models, consider generalisations of existing models, and/or inter-calibrate the different models,*

3) *Evaluate the sensitivity of results towards input data, assumptions and estimates of model parameters, in the context of the precautionary approach.*

This can only be achieved by an international steering and coordination process, not by uni-national initiatives.

In relation to trade of legally exploited European eels, the species was listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix II[6] in 2007 and the listing came in to force in 2009. The listing does not prevent trade, simply requires '*that trade will not be detrimental to the survival of the species in the wild*' and in 2010, the EU banned export outside of member states as it decided this requirement, referred to as a non-detriment finding (NDF), was not being met due to the beleaguered state of the European eel stock. As such, trade of European eels either occurs between EU members states or between non-EU member states, be they European eel range states or otherwise (Crook, 2011). The CITES Science Review Group (SRG) has a watching brief on the European eel and reviewed the export ban in 2014. It was subsequently stated that:

- *The SRG re-assessed the situation for export of European eels: it was agreed that the situation remained critical and that it was not possible to perform a "non-detriment finding" for the European eels, i.e. that it was not possible for the SRG to advise that the capture or collection of European eel specimens in the wild for their export will not have a harmful effect on the conservation status of the species or on the extent of the territory occupied by the relevant population of the species. The SRG would reassess the situation when significant new information becomes available.*[7]

Since this time, the EU has taken steps to put measures into place to assess the impact of trade on the European eel, most recently through a workshop to define criteria for determining an NDF European eels (ICES, 2015). These criteria were welcomed by the SRG, however, they reiterated the above statement in 2015[8], and the ban remains in place at the time of writing. International trade, by its nature requires trans-boundary co-operation, and as such exploring ways to strengthen enforcement and monitoring of trade would be of enormous value.

Despite the EU export ban, there is a still a demand for European eel in the key import and consumer markets in East Asia (Shiraishi and Crook, 2015). Some of the demand has been met through the opening and/or expansion of non-EU European eel markets in North Africa and through increased exploitation and export of other species, particularly *A. rostrata* and *A. bicolor*, however, there is concern that a significant black market exists (Crook, 2014; Shiraishi and Crook, 2015). Anecdotally, and in the media[9,10], illegal trade of European eels is frequently discussed; however, empirical data relating to illegal trade are scant (ICES, 2016):

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6 https://cites.org/eng/disc/text.php#IV

7 https://circabc.europa.eu/sd/a/a0c4f3e6-6862-46cb-8c95-8f7c78ff962e/69_summary_srg%20rev.pdf

8 https://circabc.europa.eu/sd/a/1e2aa226-4ea3-42f1-a5ff-2b868a7dde12/73_summary_srg%20rev.pdf

9 https://www.theguardian.com/environment/world-on-a-plate/2016/feb/09/illegal-eel-black-market-continues-to-taint-europes-eel-fishery

- *The limited data that were presented were judged insufficient to draw conclusions on the level of misreporting or illegal fishing.*

Further, a recent report by TRAFFIC (Shiraishi and Crook, 2015) stated the following in relation to trade of anguillids generally, while making specific reference to the European eel:

- *The report identified many data discrepancies; however the grounds for many of these are unclear. Possible reasons for differences in production data sources include the number of intermediaries through which production data are passed prior to official reporting and under/over-reporting of glass eel input and/or production due to illegal sourcing of glass eels. Differences in exporter and importer data can be a result of incomparability, lack of clarity over taxon-designation or misuse of Customs codes (trade reported as* Anguilla *in fact being of another eel species) or illegal trade.*

  Illegal trade in Anguilla *eels is a prevalent concern, not only affecting the lucrative glass eel commodity, but also eel products for the end consumer. Many records of live eel fry imports into East Asia over the past decade have no corresponding records in exporter data and a number of eel seizures have been reported by European and Asian authorities supporting the fact that illegal trade in* Anguilla *spp. is ongoing and illegally-sourced glass eels are being used in East Asian farms. Doubts over the legality of* A. anguilla *eels grown out in mainland China farms exist, as they continue to be re-exported many years after glass eels could be legally sourced from the EU.*

  Information on trade in eel products is generally not available to the species level. This makes it difficult to identify to what extent A. anguilla *or other eel species have been imported…*

Seizures of illegally exported European eels do occur but they are believed to be intercepting only a small proportion of the estimated illegal trade (Crook, 2014; Shiraishi and Crook, 2015). As such, opportunities to improve enforcement of trade regulations and increase seizures and prosecutions would be valuable. A recent paper has shown how genetics can be used to support customs seizures (Stein et al, 2016a), and while these techniques can be relatively costly, increased collaboration between exporting and importing nations could spread this cost. Further, collaboration could encourage innovation which in turn could both reduce costs of existing methods, and develop new technologies for impacting illegal trade.

2.2 Barriers to migration

Dams and other barriers to migration can have significant impacts on freshwater systems and the associated species (Liermann et al, 2012) and the number of obstructions has increased rapidly (e.g. Figure 1; Miller et al, 2016). A global analysis of the impact of barriers on freshwater systems indicated that the range of the European eel was significantly impacted by dam construction (Figure 2; Liermann et al, 2012). After commercial fisheries, barriers to migration were the threat that was identified as having the most mitigating actions implemented in the WKEPEMP (see Table 1 / ICES, 2013a). These may take many forms as both upstream and downstream migration of eels can be impacted by barriers, and depending on where they are in the watershed, these could impact recruitment of glass eels and/or elvers, escapement, and/or migration of yellow eels within freshwater catchments during the growth stage – an assessment of passability was carried out for

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10 https://www.theguardian.com/environment/world-on-a-plate/2016/mar/31/illegal-eel-who-is-pilfering-europes-catch

the American eel in the St Lawrence catchment by Trembley et al (2016). Further, barriers can potentially cause an increase in density of eels in the waters below them which can impact condition, predation and sex ratio – it is generally believed that males predominate in higher density areas (Davey and Jellyman, 2005).

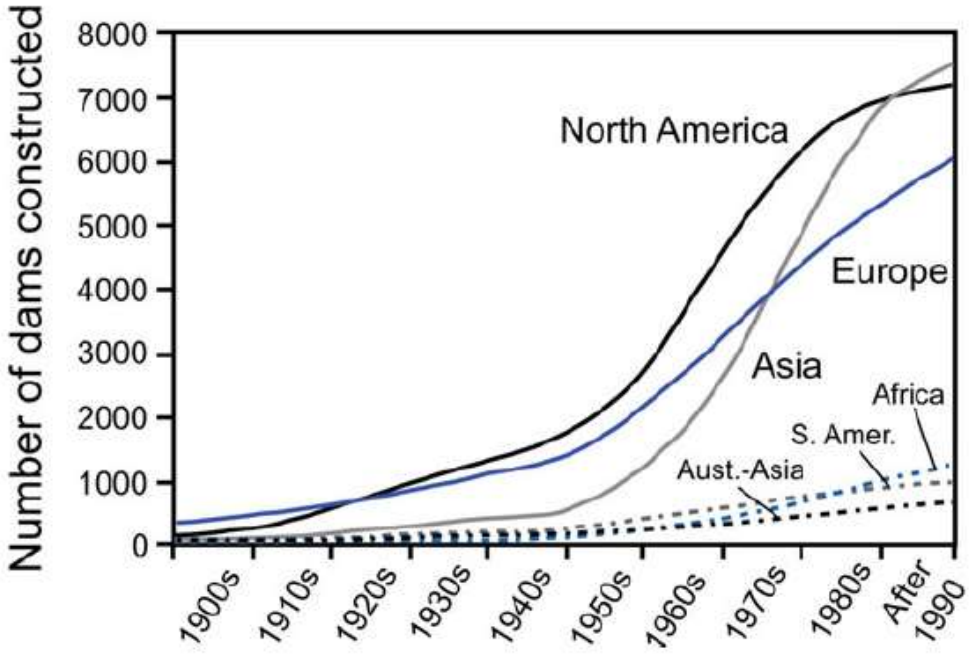

Figure 1. Plots of the cumulative number of dams constructed by region - excluding China which currently has more than 20,000 dams. From Miller et al (2016).

In addition to acting as a barrier to migration, hydro-power dams can be a significant cause of mortality of escaping silver eels, due to the elongate nature of the species – a study carried out in Sweden indicated that mortality through the turbines of a single facility was 74% (Calles et al, 2010). When this figure is applied to watersheds that have multiple facilities, escapement levels will quickly become negligible. Ensuring safe passage to achieve the 40% escapement target would seem a high priority in regions where hydro-power is planned and/or prevalent – e.g. in Turkey 575 hydropower projects are under construction or in planning (ICES, 2016) – as if one assumes the fish are exposed to other threats during the migration the mortality rate would undoubtedly increase.

There are measures that can be applied to barriers and/or hydro-power facilities in order to ease passage – these are often some form of eel pass, which will be designed to take factors such as life stages affected and whether it is a new structure or a retro-fitted solution into account (reviewed by Nieminen et al, 2016). These have been shown to facilitate movement past barriers, however, it is important to ensure that monitoring of mitigation actions occurs to determine their effectiveness. For example, a study at a Danish hydro-power station indicated that escaping silver eels spent extended periods locating the downstream passes – which could potentially increase the chances of predation – and ultimately only 37% of tagged eels made it past the barrier during the study (Pederson et al, 2012). Several papers have indicated that silver eel migration in freshwater may be punctuated, possibly over multiple years, due to a range of environmental factors (Durif et al, 2003; 2006; Bultel et al, 2014; Stein et al, 2016b) which may partially account for the above behaviour, and being aware of studies that broaden our understanding of eel biology is important in developing management actions. An alternative to easement is to collect the fish and move them past the barrier – known as 'trap and transport'. This can be effective, especially for silver eels, but is potentially costly (Nieminen et al, 2016).

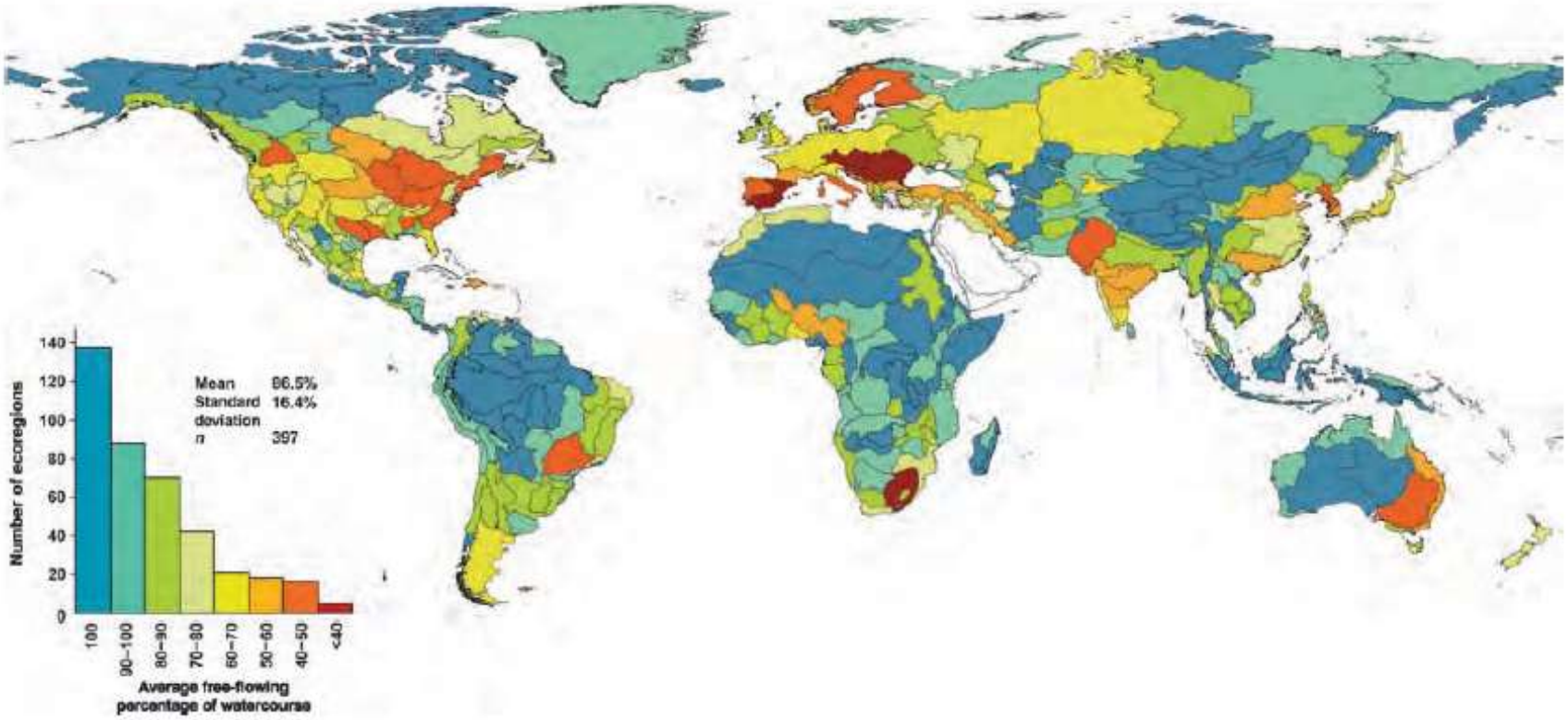

Figure 2. Distribution of the average free-flowing percentage of watercourse length among the 397 freshwater ecoregions with available data. The data are skewed; the five longest watercourses of approximately half of all of the ecoregions (n = 215) retained an average of 90%–100% of their watercourse distance as free flowing. The white areas indicate a lack of sufficient data for analysis. No dams were identified on the five longest watercourses of 137 ecoregions (indicated by the darkest blue).From Liermann et al, (2012).

2.3 Continental habitat loss

Eels are known to be able to exist in a wide range of habitats as part of both their migratory and growth stages. However, this section will be limited to areas that can realistically be managed by range states e.g. fresh waterbodies and estuaries.

As stated above, barriers will ultimately limit the amount of available growth habitat, and the methods described will potentially increase the wetted area available to eels. There are other anthropogenic activities that have been proposed to impact habitat availability and/or quality for eels however empirical evidence for this, and the associated mitigation, is limited as indicated as stated in the 'Habitat' section of the WKEPEMP (ICES, 2013a):

- *The descriptions of the actions taken, as well as the expected impact on escapement or mortality were often unspecific, vague and lacking specific reference to eel-specific habitats. Most measures on habitat improvement were related to the implementation of the Water Framework Directive and therefore not specifically related the EMP.*

  To assess the effect of actions taken, monitoring data and process knowledge are required.

Studies have indicated that habitat modifications such as embankment creation, river course modification, wetland drainage/land reclamation, and/or urbanisation has reduced available habitat to both European and Japanese eel (Kettle et al. 2011; Chen et al, 2014) and bankside development has been showed to negatively correlate with eel catches in Japan (Itakura et al, 2014). A fuller understanding of the impacts of these activities would be of value through habitat mapping and correlation with available eel data.
There are examples of habitat creation that appear to benefit the European eel, for example, a study of a 'controlled reduced tide' (CRT) scheme in the River Schelde, Belgium, indicated that eels populated newly-created tidal marshland (Van Liefferinge et al., 2012). Projects such as this could offer opportunities for mitigating against habitat loss.

2.4 Pollutants

It has been highlighted that the effects of pollutants might be particularly of concern to eels due to the lipophilic nature of many chemicals and the reliance of the species on using fat stores to migrate and, in the female, produce eggs (Belpaire and Goemans, 2007; Geeraerts and Belpaire, 2010; Brinkmann et al, 2015). A number of potentially damaging pollutants have been banned due to their effects on the natural environment, however, due to their persistence, residues are still found in aquatic systems (Geeraerts and Belpaire, 2010), and fisheries in a number of European rivers have ceased due to the high levels of contaminants (ICES, 2012; 2013b). There have been a number of studies that have examined the effects of specific pollutants on eels (reviewed most recently in Geeraerts and Belpaire, 2010), but this only begins to address the impacts, both individually and synergistically and/or cumulatively, of the multitude of chemicals that are found in both marine and freshwater environments. Additionally, identification of new pollutant threats and an improved understanding of the impacts of pollutants can have on the European eel have been raised as points of concern (ICES, 2016):

- *There has been recent concern about pollutants impacting organisms via changes in gene expression. The presence of pollutants may lead to an increase in the transcription of genes involved in detoxification, but at a cost of the reduced expression of genes involved in vital organism processes, such as respiratory and lipid metabolism. (ICES 2013b; Pujolar et al., 2013; Marohn et al., 2008). This may have implications for eels.*

Microplastics are a potential problem for aquatic species as they are incorporated at the base of the food chain (Andrady, 2011). They can have a mechanical effect (on digestion and buoyancy of autotrophs) but are also loaded with heavy metals which ac-cumulate in organisms (Cole et al., 2011). We have currently no idea how this might affect the early life stages of eels, and there are no microplastics data for freshwater systems so this remains an area to be investigated.

A recent study used modelling to determine the impacts of specific pollutants on the European eel (Brinkmann *et al*., 2015). When applied to a broader suite of pollutants, it may allow a better understanding of their effects on the European eel and to focus efforts to manage the input of chemicals into the aquatic environment more broadly.

3. Transboundary collaboration

As stated in the proposal to list the species on CMS Appendix II (co-operative action 2) it is was considered that collaboration between range states, particularly those with contiguous coastlines or river basin districts. There are general tools for transboundary assessment – i.e. http://www.geftwap.org/ - but below are areas that have been raised in other fora and/or discussed in the threat section above where it is felt that the greatest impact on the status of the European eel could be made.

Again, the short summaries below are by no means exhaustive and have been prepared to stimulate discussion. The content of each section broadly reflects the state of our knowledge of each theme.

3.1 Fisheries and Trade

The issues around both legal and illegal fisheries and trade were briefly addressed in section 2.1. Due to the range of the European eel incorporating both EU and non-EU member states, the management of fisheries and trade is complex in light of the EU export ban. While there are issues that will affect only EU states and vice-versa, there are undoubtedly overlaps that require collaboration between all range states, and importantly, in relation to trade, with import nations outside of the species range, both in relation legal and illegal trade. Chains of custody are often extended and complex and multi-national which can complicate traceability, and the following has been suggested in relation to the EU, but would be applicable more broadly (ICES, 2016):

- *There is still an urgent need for a traceability system to meet the requirements of Article 12 of the EU Eel Regulation, as identified in the WGEEL Reports from 2009, 2011 and 2012 regarding specifically both trade and the actual use of glass eels. Concerning trade there is an obvious mismatch between "export" and "import" in the trade of glass eels within (and outside EU).*

  It has been recommended that all countries put in place a system which will:

  1) *permit cross-checking of imports and exports between countries for each batch of glass eel exported;*

  2) *be able to identify the quantity of glass eel which is supplied to aquaculture but subsequently stocked;*

3) *allow for each batch of glass eel exported, the date, the amount, the price, the destination EMU and final fate (stocking/aquaculture/consumption), and the EMU of origin to be recorded and made available to the appropriate regulatory authority.*

In relation to the EU, as stated above, many of the EMP management actions relate to commercial fisheries, however, how many of these have been successfully implemented and if so have these lessons been shared nationally and internationally is still unclear. Again, the statement below was made by the WGEEL in the relation to the EU but the advice is broadly applicable (ICES, 2016):

- *The Working Group has repeatedly requested improvements concerning the quality of eel landings data. Even basic data of catch "C" and effort "f" and the main fishery indicators: C total (landings/ fishing mortality), f total, and abundance index (generally cpue) for eel are very often under-evaluated, or even missing in the Country Reports. Moreover, they are not clearly reported by biological stages (glass eel, yellow, silver), by fishing categories or by appropriate management unit, also omitting marine or in-land waters.*
  The inaccuracy and poor representativeness of these indicators have so far made it impossible to assess stock-wide plausible total commercial landings as well as catches of recreational and non-commercial fisheries.

This workshop provides an excellent opportunity to share successes and failures on activities that have clearly required time, effort and resources to implement. Further, the WKEPEMP (ICES, 2013a) indicated that fisheries may not be the greatest impact on the European eel in 15 out of 43 range states and as such, updated guidance on the implementation of EU Regulation 1100/2007 and the associated EMPs would be of value.

Across all the range states that are exploiting the European eel, a number of management measures would benefit from discussion and assessment. While they may not apply to all range states, points that are frequently raised of being of interest, include:

- Metrics
  - How is data relating to fisheries collected?
  - Is it effective in determining impact upon the stock?
  - Is a metric of effort collected?
  - Is fisheries dependent data correlated with fisheries independent data?

- Quotas
  - Are they working?
  - Are they scientifically informed?
  - How do they compare to demand/export and natural recruitment?

- Traceability
  - Is there a clear chain of custody within range states and with export nations?
  - Have efforts been made to standardise metrics between import and export nations?

- Enforcement
  - Are fisheries and any associated trade enforced appropriately?
  - Is the scale of any illegal trade understood and how is it being addressed?

Additionally, while it is not specifically related to the European eel, the recommendations provided by Shiraishi and Crook (2015) relating to trade in anguillids, contains an excellent summary of

measures that would increase our understanding and ability to manage both legal and illegal trade (Appendix 1).

3.2 Restocking

Restocking of eels in to the aquatic environment is a management practice that has been promoted in relation to the restoration of the eel stock. For example, EU Regulation 2007/1100 states:

- *(12) Special measures to increase the numbers of eels less than 12 cm in length released into European waters as well as for the transfer of eel less than 20 cm in length for the purpose of restocking should therefore be implemented as part of an Eel Management Plan.*

  (13) By 31 July 2013, 60 % of eels less than 12 cm in length caught annually should be reserved for restocking. The evolution of market prices for eel less than 12 cm in length should be monitored annually. In the event of a significant decline in average market prices for eels less than 12 cm in length used for restocking in eel river basins as defined by Member States, compared to the price of eels less than 12 cm in length used for other purposes, the Commission should be authorised to take appropriate measures which may include a temporary reduction in the percentage of eels less than 12 cm in length to be reserved for restocking.

During the WKEPEMP it was determined that 16 range states had utilised stocking as a management measure, however, only six had reached their stocking targets due to the cost of the practice (ICES, 2013b; 2014) raising the question whether the purchase, grow-out and dispersal of eels is the most effective use of limited resources. Pedersen and Rasmussen (2015) found that, in relation to yield per recruit, there was no advantage in using larger aquaculture-reared eels for stocking in a Danish fjord. It was suggested that the longer they are on artificial food, the longer it will take to establish a foraging strategy in the wild and smaller eels that have spent less time reared artificially may adapt faster to natural prey. Further, Simon and Dörner (2014) indicate that, stocking of 'wild' glass eels over farmed eels could have equivalent survival and faster growth at a lower cost. They state:

- *The observed differences in growth and survival of eels stocked as glass and farm eels can possibly be attributed to a variety of factors such as the quality of the original glass eels, food adaptation problems of farm eels after stocking and size grading of farm eels in the fish farms prior selling and stocking.*

  Furthermore, it cannot be excluded that non- or slow-growing eels were sorted out in the eel farms after size grading and subsequently sold as stocking material. The prime economic interest of the farm companies focuses on the production of fast-growing eels for human consumption. Thus, the selling of non- or slow-growing eels for stocking purposes may be an additional source of income but it may potentially impact on the quality of the stocking material.

Some range states have determined that water bodies within their require re-stocking to achieve EU escapement targets (Brämick et al, 2014) while others have been identified as at carrying capacity and therefore could act as donor rivers (Acou et al, 2011). A very recent paper indicated that stocking in a Swedish lake may result in migration failure and/or poor conditioned eels (Sjöberg et al, 2016). These studies are helpful in determining where stocking might be most beneficial, but a recent paper from Canada has indicated that translocation of glass eels to areas with conspecifics that have marked difference in life history could result in a failure to migrate and spawn (Stacey et al, 2015) though has never been seen in the European eel. Indeed, it is important to consider that

while a study has indicated that the early stages of the spawning migration of stocked eels mirrors that of wild eels (Westerburg et al, 2014) escapement is not equivalent to successful spawning.

Ultimately there is still a great deal of uncertainty relating to the effectiveness of restocking as a management practice. For example, the ICES WGEEL stated (ICES, 2014):

- *Concerns about current eel stocking practices have been expressed and its effective contribution to ensure increased silver eel production has been raised. It has been recommended that there should be a co-ordinated marking programme of stocked eel and thereby separable from wild eel in subsequent sampling.*

  …there is evidence that translocated and stocked eel can contribute to yellow and silver eel production in recipient waters, but that evidence of further contribution to actual spawning is limited (by the general lack of knowledge of the spawning of any eel).

As such it is essential stocking of waterbodies is carried out on a case by case basis, and that further research is carried out to determine how to both economically and biologically optimise the practice for the benefit of European eel stocks. Knowledge sharing of range states on stocking and a cost-benefit analysis of the activity compared to other management actions across the species range would be of huge value. It has also been suggested that regional co-ordination of marking of all stocked eels (e.g. strontium, oxytetracycline) would help to determine how successful the practice is (ICES, 2016; Sjöberg et al, 2016). A review of the EU escapement targets, which many of the species' range states are bound to achieve, and the best way to ensure they are met, in the context of restocking and the associated requirement of glass eels being made available for the practice, would also be of enormous value. Finally the ICES WGEEL has also laid out what it considers essential research in relation to restocking (ICES, 2016):

- *An assessment of the success of stocking measures (ICES, 2008, 2010),*

  Comparing the reproductive fitness of silver eels originating in stocking programs vs. that of native-origin eels (ICES, 2010, 2013b),

  Investigating the impact of holding and maintenance feeding of elvers in aquaculture with regard to a possible adaptation to culture conditions and their subsequent suitability for conservation stocking (ICES, 2013b),

  A whole eel distribution approach to assessing stocking and determining net benefit to the stock including an evaluation of the mortality of the stocked fish in relation to the mortality the fish would have experienced if left in situ *(ICES, 2008, 2012, 2013b, 2014).*

3.3 Barriers to migration

Easing of barriers appears to be a relatively achievable management action in relation to the European eel. However, the process requires site prioritisation to ensure it has the maximum benefit for the stock. This needs to be carried out at an international level in the case of transboundary rivers. To date there are national databases and studies relating to migration barriers but collating these in the context of transboundary rivers would be hugely valuable. Further, sharing lessons learned on what methods for mitigation have and haven't worked would improve success and optimise resource use. In addition to this, a recent study (Sjöberg et al, 2016) proposed that in the presence of barriers, eels may simply use estuarine habitat – increasing our understanding of the utilisation of brackish and marine waters by eels would be hugely valuable.

3.4 Continental habitat loss

Despite 'habitat loss' - and the secondary effects relating to resource competition, body condition and predation - being referred to as a concern relating to European eel stocks the number of studies that explicitly examine the effects of impacts such as bankside modification and development, and water abstraction, are limited and improving our understanding of these generally, and in the context of transboundary watercourses would help to prioritise mitigation for threats to the European eel. A key question relating to this prioritisation is to determine what the importance and, if any, the compensating effect, of estuarine/saline waters is in light of reduced habitat quality/availability in freshwater (see section 3.3; Sjöberg et al, 2016). This was reviewed in 2009 (ICES, 2009) but there are still large knowledge gaps and this would be especially important for range states with contiguous coastlines.

3.5 Pollutants

The recent paper by Brinkmann et al (2015) offers an interesting approach to the possibility of standardising the approach to determining the impacts of pollutants on the European eel in specific waterbodies. Exploring the application of a standardised approach to the impacts of contaminants across the species range would be of value. More broadly the WGEEL stated the following (ICES, 2016):

- …recommended the initiation of an internationally coordinated re-search project, in order to improve the understanding and quantification of the effects of contaminants on the reproductive success of the European eel, for integration in stock wide assessments (WGEEL, 2013b).

This international effort would be particularly timely in relation to the 'new emerging contaminants' reference in section 2.4 above.

3.6 Marine Protection

This is dealt with more fully in the companion briefing note and as such the section below is relatively brief.

As previously described, the European eel is facultatively catadromous and it is the marine spawning phase and associate migrations that are ultimately the obligate elements of the life history. While breeding of European (or American) eels has never been observed, all research, and associated data, points to areas within the Sargasso Sea as being the seat of spawning activity, and as such this could be a candidate for protection from anthropogenic activity. The Sargasso occupies an area that is contained within the North Atlantic Sub-Tropical Gyre (Laffoley et al, 2011) but due to the variations in current boundaries it is difficult to apply specific metrics[11] (Figure 4). The majority of the Sargasso is in the 'high seas' or Areas Beyond National Jurisdiction (ABNJ) while a smaller proportion is found within the 200 nautical mile Exclusive Economic Zone (EEZ) of Bermuda, a UK Overseas Territory. A non-binding agreement, termed the Hamilton Declaration on Collaboration for the Conservation of the Sargasso Sea was signed by the Governments of Bermuda (UK), Azores (Portugal), Monaco, UK,

[11] An assessment commissioned by the Sargasso Sea Alliance (Laffoley et al, 2011) stated the following: *The Sargasso occupies ~ 4,163,499 km^2 of the Atlantic Ocean in an area extending between 22^o–38^{o}N, 76^o–43^{o}W and centred on 30^{o}N and 60^{o}W that is contained within the North Atlantic Sub-Tropical Gyre*.

USA and British Virgin Islands (UK) on 11th of March 2014[12]. This agreement applies to the area defined by Laffoley et al (2011) but not the Bermudan EEZ.

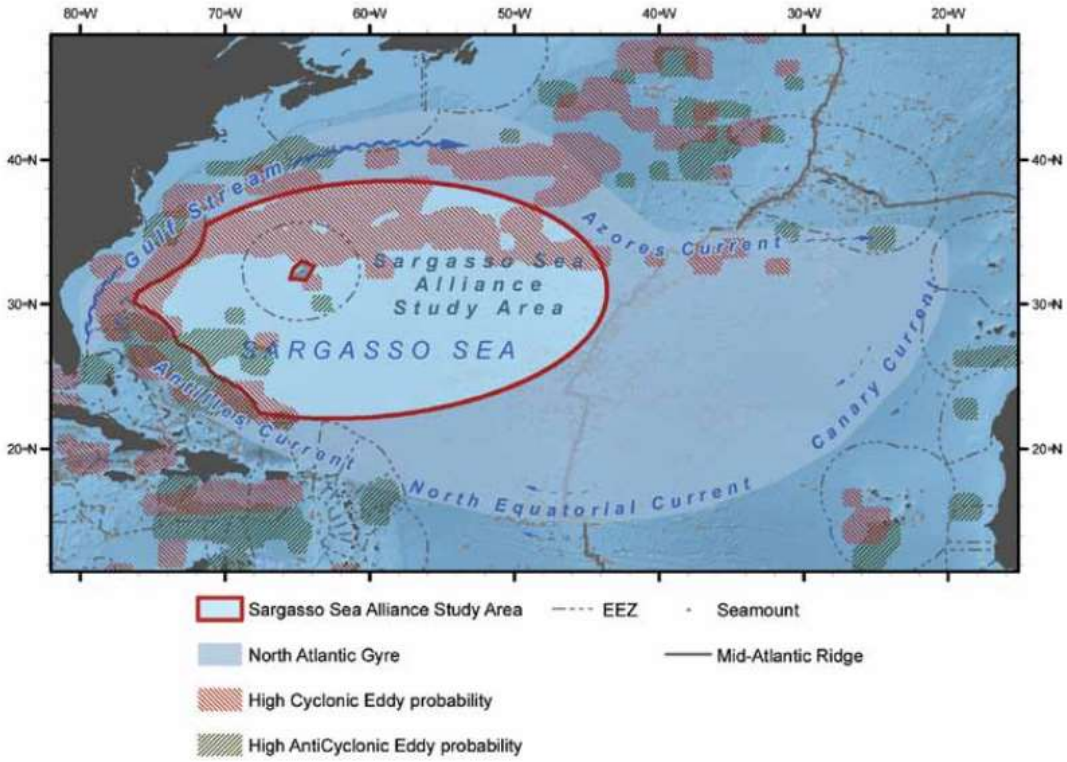

Figure 4. A recent map, commissioned by the Sargasso Sea Alliance, describing the area covered by the Sargasso Sea (from Laffoley et al, 2011).

While it could be argued that certain activities in the Sargasso do not directly impact European eels, there is a strong argument for reducing the human impact on the region as whole while strengthen the ecosystem and its associated biodiversity more generally, which will indirectly benefit many species, including the two species of anguillid eel that are believed to spawn there. Indeed, under the Convention of Biological Diversity (CBD), the Sargasso has been identified as meeting the criteria[13] to be designated as an Ecologically or Biologically Significant Marine Area (EBSA)[14]. Under the CBD, stakeholders are encouraged to collaborate to improve conservation and management of EBSAs [15].

At present, management of any ABNJ is under the United Nations (UN) and particularly UN Convention on the Law of the Sea (UNCLOS) – which also applies to catadromous species such as the European eel[16] - however, it has been argued that this was not a specific enough instrument to manage these common resources and in recent years there have been steps towards establishing a centralised body, better tailored for this role. For example, the UN recently established PrepCom[17], which has been tasked with overseeing '*Development of an international legally binding instrument*

12 http://www.sargassoseacommission.org/storage/documents/Hamilton_Declaration_with_signatures_March_2016_revised.pdf

13 https://www.cbd.int/doc/meetings/mar/ebsaws-2014-01/other/ebsaws-2014-01-azores-brochure-en.pdf

14 https://chm.cbd.int/database/record?documentID=200098

15 https://www.cbd.int/decision/cop/?id=12295

16 Article 67 - http://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf

17 http://www.un.org/depts/los/biodiversity/prepcom.htm

under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction'. Attendance at the inaugural meeting (28/3-8/4/2016) indicated that the majority of European eel range state were represented[18]. This process is in the very early stages of development but management of the eel's proposed spawning grounds in the Sargasso Sea will be affected by any decisions made and as such it is vital that range states are engaged.

It is important to highlight that as we better understand the oceanic migrations of the European eel, there could be opportunities for temporal protection of distinct identified pathways and/or 'pinch points' e.g. the Gibraltar Strait (Righton et al. 2016) and the Skagerrak / Kattegat (Westerberg et al, 2014).

3.7 Policy

Outside of already defined policy that relates to the European eel, EU Regulation 1100/2007 specifically states the following in relation to trans-boundary issues:

- *10. Within a river basin where fisheries and other human activities affecting eels may have transboundary effects, all programmes and measures should be coordinated for the whole of the relevant river basin. However, coordination must not take place at the expense of the rapid introduction of the national parts of Eel Management Plans. For river basins extending beyond the boundaries of the Community, the Community should endeavour to ensure appropriate coordination with the third countries concerned.*

  11. In the context of transboundary coordination, both within and outside the Community, special attention should be devoted to the Baltic Sea and European coastal waters falling outside the scope of Directive 2000/60/EC. However, the need for such coordination should not prevent urgent action being taken by Member States.

These guidelines highlight the importance of transboundary collaboration for the success EU EMPs, and this will undoubtedly apply to any management plans of other range states. To date, activities have focussed on national actions rather than transboundary initiatives – there was no explicit reference to collaborative management actions in the WKEPEMP report (ICES, 2013a). At present there is no policy relating to management of the European eel that applies to all range states, but there is a legislative mandate for EU member states to develop co-operative actions.

The CITES Appendix II listing applies to all range states, and the recent development of criteria that can be used to determine an NDF in the European eel (ICES, 2015) offers an opportunity for non-EU range states to ensure they are trading in accordance with the criteria of the listing. Further, a document submitted to the CITES CoP 17 (2016) by Australia[19], encourages the sharing of NDF assessment for the benefit of other species range states and the management of the species across its range. Data sharing is a fundamental requirement of the co-operative actions and this would be a valuable exercise. Further, the EU have submitted a document to CoP 17 that relates to trade of anguillids more broadly[20], the outcome of which would be result in improved understanding of trade in the European eel and how this impacts trade in other anguillid species, and vice versa.

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18 http://www.un.org/depts/los/biodiversity/prepcom_files/Final_List_of_Participants_BBNJ.pdf
19 https://cites.org/sites/default/files/eng/cop/17/WorkingDocs/E-CoP17-78.pdf
20 http://ec.europa.eu/environment/cites/pdf/cop17/eels.pdf

3.8 Region-wide co-ordination of data management

The fundamental tenet of the co-operative actions is regional co-ordination, and all of the activities and knowledge gaps highlighted in the document will require range states to work together for the benefit of the European eel. Below are several additional areas relating to data collection and management that fall outside of the limited selection of themes that have been addressed in this briefing document that have been highlighted as of importance to address (ICES, 2016):

- Quality control
- Appropriate spatial coverage of monitoring / data collection
- Temporal continuity of monitoring / data collection
- Standardisation of eel quality, stock and mortality indicators
- Collection of data relating to marine stages – maturing adults / larvae / eggs
- Collection of data relating to predators, and parasites and disease
- National and regional databases of collected data

4. Prioritisation

Prioritisation of management actions for the European eel will ultimately occur at multiple levels from local to global. In the context of CMS co-operative actions it is important to consider this is in the context of trans-boundary collaboration, which will therefore mean, depending on the issue, discussions between all range states, and/or range states who have common and/or contiguous natural resources i.e. coastlines and/or freshwater rivers and lakes. Producing specific priorities is not the aim of this document as ultimately it is for the range states to determine what national and international priorities are and how they can be achieved through regional co-operation, however, below are broad themes that have been raised in the sections above which could be considered during discussions:

- Improved co-ordination
  - EU and non-EU range states
  - Monitoring and associated data collection
    - Alignment of methods and data standards
  - Stock assessment
  - Threat mitigation
  - Policy development
  - Fisheries management and enforcement
  - Restocking

- Knowledge gaps
  - Individual and synergistic impacts of threats
  - Restocking
  - Importance and biology of non-freshwater continental populations
  - Scale of illegal trade
  - Impacts of habitat loss

5. Key stakeholders

There are a number of potential stakeholders that would play key roles in the development and implementation of any future co-operative actions. These have been listed under three broad headings below but ultimately there will be overlap in their remits and variation in the importance of their role depending on the issue discussed.

The list is not mean to be exhaustive:

Governments

- Range states
  - Relevant government departments and agencies
  - CMS Focal Point
  - Customs authorities
  - CITES
    - Management Authority
    - Scientific Authority
- Import / transit nations
  - Customs authorities
  - CITES
    - Management Authority
    - Scientific Authority
- Other anguillid range states[21]
- Government of Bermuda

- European Union
  - DG MARE
  - DG ENVIRONMENT
  - CITES SRG

Inter-governmental Organisations

- United Nations
  - Food and Agriculture Organization
  - UN/UNCLOS and the ABNJ PrepCom
  - CMS Secretariat
  - CITES Secretariat
- Regional Fisheries Bodies
  - ICES
  - EIFAC
  - GFCM
  - North East Atlantic Fisheries Commission (NEAFC)
  - Western Central Atlantic Fishery Commission (WECAFC)

Commerce / Industry

- Fisheries[22]
  - Fishers
  - Traders and exporters
  - Farms and producers
  - Processers
  - Sellers
  - Points of sale

[21] In the context of the document submitted by the EU to CITES CoP 17 (2016) this is of relevance: http://ec.europa.eu/environment/cites/pdf/cop17/eels.pdf

[22] This should include non-range states in some instances, particularly after export has occurred.

    - Industry coalitions e.g. DUPAN; Sustainable Eel Group
- Hydropower companies
- Agriculturalists
- Industries requiring freshwater input/uptake

<u>Conservation / Science / Advocacy</u>

- Relevant Academic Institutions
- TRAFFIC
- International Union for the Conservation of Nature (IUCN)
- Sargasso Sea Commission
- High Seas Alliance

References

Acou, A., Rivot., E., Van Gils, J.A., Legault, A., Ysnel, F. and Feunteun, E. (2011) Habitat carrying capacity is reached for the European eel in a small coastal catchment: evidence and implications for managing eel stocks. *Freshwater Biology* 56: 952–968.

Amilhat, E., Aarestrup, K., Faliex, E., Simon, G., Westerberg, H and Righton, D. (2016) First evidence of European eels exiting the Mediterranean Sea during their spawning migration. *Scientific Reports* **6**, Article number: 21817 (2016).

Belpaire, C., and Goemans, G. (2007) Eels: contaminant cocktails pinpointing environmental contamination. *ICES Journal of Marine Science*, **64**: 1423–1436.

Brämick, U., Fladung, E. and Simon, J. (2016) Stocking is essential to meet the silver eel escapement target in a river system with currently low natural recruitment. *ICES Journal of Marine Science* **73**: 91–100.

Brinkmann, M., Freese, M., Pohlmann, J-D., Kammann, U., Preuss, T.G., Buchinger, S., Reifferscheid, G., Beiermeister, A., Hanel, R. and Hollert, H. (2015) A physiologically based toxicokinetic (PBTK) model for moderately hydrophobic organic chemicals in the European eel (*Anguilla anguilla*). *Science of the Total Environment* **536**: 279–287.

Bultel, E., Lasne, E., Acou, A., Guillaudeau, J., Bertier, C. and Feunteun, E. (2014) Migration behaviour of silver eels (Anguilla anguilla) in a large estuary of Western Europe inferred from acoustic telemetry. *Estuarine, Coastal and Shelf Science* **137**: 23–31.

Calles, O., Olsson, I.C., Comoglio, C., Kemp, P.S., Blunden, L., Schmitz, M. and Greenberg, L.A. (2010) Size-dependent mortality of migratory silver eels at a hydropower plant, and implications for escapement to the sea. *Freshwater Biology* **55**: 2167–2180.

Chen, J-Z., Huang, S-L. and Han, Y-S. (2014) Impact of long-term habitat loss on the Japanese eel *Anguilla japonica. Estuarine, Coastal and Shelf Science* **151**: 361–369.

CMS (2014) Proposal for the inclusion of the European eel (*Anguilla anguilla)* on CMS Appendix II UNEP/CMS/COP11/Doc.24.1.18 Rev.1

Crook, V. (2011) Trade in European Eels: Recent Developments under CITES and the EU Wildlife Trade Regulations. *TRAFFIC Bulletin* **23(2)**: 71-74.

Crook, V. and Nakamura, M. (2013) Glass eels: Assessing supply chain and market impacts of a CITES listing on *Anguilla* species. *TRAFFIC Bulletin* **25(1)**: 24-30.

Davey, A.J.H. and Jellyman, D.J. (2005) Sex determination in freshwater eels and management options for manipulation of sex. *Reviews in Fish Biology and Fisheries* **15**: 37-52.

Dekker, W. (2003). On the distribution of the European eel (*Anguilla anguilla*) and its fisheries. *Canadian Journal of Fisheries and Aquatic Sciences* **60**:787–799.

Durif, C., Elie, P., Gosset, C., Travade, F. and Rives, J. (2003) Behavioral study of downstream migrating eels by radio-telemetry at a small hydroelectric power plant. *American Fisheries Society Symposium* **33:** 343-356

Durif, C., Dufour, F. and Elie, P. (2006) Impact of silvering stage, age, body size and condition on reproductive potential of the European eel. *Marine Ecology Progress Series* **327**: 171–181.

Geeraerts, C. and Belpaire, C. (2010) The effects of contaminants in European eel: a review. *Ecotoxicology* **19**: 239–266

ICES (2008) The report of the 2008 Session of the Joint EIFAC/ICES Working Group on Eels, September 2008; ICES CM 2008/ACOM:15. 192 pp. and Country Reports.

ICES (2009) Report of the Study Group on Anguillid Eels in Saline Waters (SGAESAW), 16–18 March 2009, Sackville, Canada; 3–5 September 2009, Gothenburg, Sweden. ICES CM/DFC:06. 183pp.

ICES (2010) The report of the 2010 Session of the Joint EIFAC/ICES Working Group on Eels, September 2010; ICES CM 2009/ACOM:18. 198 pp. and Country Reports.

ICES (2012) Report of the 2012 Session of the Joint EIFAAC/ICES Working Group on Eels, Copenhagen, Denmark, 3–9 September 2012; ICES CM 2012/ACOM:18, EIFAAC Occasional Paper 49, 828 pp.

ICES (2013a) Report of the Workshop on Evaluation Progress Eel Management Plans (WKEPEMP), 13–15 May 2013, Copenhagen, Denmark. ICES CM 2013/ACOM:32. 757 pp.

ICES (2013b) Report of the Joint EIFAAC/ICES Working Group on Eels (WGEEL), 18–22 March 2013 in Sukarietta, Spain, 4–10 September 2013 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 (2016) 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.

Itakura, H., Kitagawa, T., Miller, M. J. and Kimura, S. (2014) Declines in catches of Japanese eels in rivers and lakes across Japan: have riverbank and lakeshore revetments reduced fishery catches? *Landscape Ecology Engineering* **11**: 147–160.

Kettle, A. J., Vøllestad, L. A. and Wibig, J. (2011) Where once the eel and the elephant were together: decline of the European eel because of changing hydrology in southwest Europe and northwest Africa? *Fish and Fisheries* **12**: 380–411.

Laffoley, D.d'A., Roe, H.S.J., Angel, M.V., Ardron, J., Bates, N.R., Boyd, I.L., Brooke, S. Buck, K.N., Carlson, C.A., Causey, B., Conte, M.H., Christiansen, S., Cleary, J., Donnelly, J., Earle, S.A., Edwards, R., Gjerde, K.M., Giovannoni, S.J., Gulick, S., Gollock, M., Hallett, J., Halpin, P., Hanel, R., Hemphill, A., Johnson, R.J., Knap, A.H., Lomas, M.W., McKenna, S.A., Miller, M.J., Miller, P.I., Ming, F.W., Moffitt, R., Nelson, N.B., Parson, L., Peters, A.J., Pitt, J., Rouja, P., Roberts, J., Roberts, J., Seigel, D.A., Siuda, A.N.S., Steinberg, D.K., Stevenson, A., Sumaila, V.R., Swartz, W., Thorrold, S., Trott, T.M. and Vats, V. (2011) The protection and management of the Sargasso Sea: The golden floating rainforest of the Atlantic Ocean. Summary Science and Supporting Evidence Case. Sargasso Sea Alliance, 44 pp.

Liermann, C.R., Nilsson, C., Robertson, J. and Ng, R.Y. (2012) Implications of dam obstruction for global freshwater fish diversity. *BioScience* **62**: 539–548

Miller, M. J., Feunteun, E., and Tsukamoto, K. (2016) Did a "perfect storm" of oceanic changes and continental anthropogenic impacts cause northern hemisphere anguillid recruitment reductions? *ICES Journal of Marine Science* **73**: 43–56.

Nieminen, E., Hyytiäinen, K. and Lindroos, M. (2016) Economic and policy considerations regarding hydropower and migratory fish*. Fish and Fisheries* DOI: 10.1111/faf.12167
Pedersen, M.I., Jepsen, N., Aarestrup, K., Koed, A., Pedersen, S. and Okland, F. (2012) Loss of European silver eel passing a hydropower station. *Journal of Applied Ichthyology* **28**: 189–193.

Pedersen, M. I. and Rasmussen, G. H. (2016) Yield per recruit from stocking two different sizes of eel (*Anguilla anguilla*) in the brackish Roskilde Fjord*. ICES Journal of Marine Science* **73**: 158–164.

Shiraishi, H. and Crook, V. (2015) *Eel market dynamics: an analysis of* Anguilla *production, trade and consumption in East Asia.* TRAFFIC. Tokyo, JAPAN

Simon, J. and Dörner, H. (2014) Survival and growth of European eels stocked as glass- and farm-sourced eels in five lakes in the first years after stocking. *Ecology of Freshwater Fish* **23**: 40–48.

Sjöberg, N.B., Wickström, H., Asp, A. and Petersson, E. (2016) Migration of eels tagged in the Baltic Sea and Lake Mälaren—in the context of the stocking question. *Ecology of Freshwater Fish* doi:10.1111/eff.12296

Stacey, J.A., Pratt, T.C., Verreault, G. and Fox, M.G. (2015) A caution for conservation stocking as an approach for recovering Atlantic eels. *Aquatic Conservation: Marine and Freshwater Ecosystems* **25**: 569–580.

Stein, F.M., Wong, J.C.Y, Sheng, V., Law., C.S.W., Schröder, B. and Baker, D.M. (2016a) First genetic evidence of illegal trade in endangered European eel (*Anguilla anguilla*) from Europe to Asia. *Conservation Genetics Resources*: DOI 10.1007/s12686-016-0576-1

Stein, F*.,* Doering-Arjes, P*.,* Fladung, E*.,* Brämick, U*.,* Bendall, B. and Schröder, B. (2016b) Downstream migration of the European eel (*Anguilla anguilla*) in the Elbe River, Germany: Movement patterns and the potential impact of environmental factors. *River Research and Applications* **32**: 666–676*.*

Tremblay, V., Cossette, C., Dutil, J-D., Verreault, G. and Dumont, P. (2016) Assessment of upstream and downstream passability for eel at dams. *ICES Journal of Marine Science* **73**: 22–32.

Van Liefferinge, C., Dillen, A., Ide, C., Herrel, A., Belpaire, C., Mouton, A., de Deckere, E. and Meire, P. (2012) The role of a freshwater tidal area with controlled reduced tide as feeding habitat for European eel (*Anguilla anguilla*, L.). *Journal of Applied Ichthyology*, **28**: 572–581.

Westerberg, H., Sjöberg, N., Lagenfelt, I., Aarestrup, K. and Righton, D. (2014) Behaviour of stocked and naturally recruited European eels during migration. *Marine Ecology Progress Series* **496**: 145-157.

APPENDIX 1 – Recommendations from Shiraishi and Crook (2015) relating to global anguillid eel trade.

RECOMMENDATIONS

Data collection, monitoring, reporting and analysis

Fisheries and Customs authorities across East Asia, in collaboration with local governments, fishermen, eel farmers and fisheries/farming/trade associations, are urged to:

- Investigate and address the reasons for the data discrepancies identified throughout this report, including the large difference between production data reported to FAO and released along with the "Joint Statement", and differences between reported exports and imports of prepared eel from mainland China to Taiwan.

- Develop and share standardized methods for data collection (catch, farm input, farming production), and for estimating production (based on the most up to date information on survival and growth rates, grow-out sizes and periods) when actual production data cannot be obtained.

- Collect, record and make publically available data on glass eel catch, farming input and production to the species level, as a minimum differentiating between *A. japonica, A. anguilla*, *A. rostrata* and tropical species such as *A. bicolor* and *A. marmorata*.

- Provide FAO with the most accurate production data possible, preferably to the species level, to enable more accurate global analyses of eel production.

- Regularly monitor and inspect eel farms and examine any discrepancies between actual and reported/estimated eel fry farm input and production.

- Co-ordinate any future changes to Customs codes used for *Anguilla* spp. at national levels, to ensure these are comparable across the region, for example, if new species-specific codes are introduced in Japan or South Korea (such as those designated for tariffs in mainland China), and/or if mainland China or Japan introduce codes for different sizes of live eel fry (such as those already in existence in Taiwan and South Korea). Ideally, standardised eel codes would be introduced across East Asia.

- Make the most detailed Customs data publically available for analysis, such as the 10-digit species-specific codes for mainland China, and work with processing industries to collect information to establish appropriate conversion factors for all eel products to live weight.

- Allocate resources and carry out research into consumption, in particular in mainland China, and in improving the transparency of the eel trade chain including potential traceability schemes, and make the results publically available.

Legislation and enforcement

Fisheries, CITES, Customs, Police and other authorities across East Asia are encouraged to:

- Enhance national enforcement effort, carry out risk/intelligence analysis and establish enforcement priorities for eel fishing and trade in East Asia, in particular focusing on illegal fishing of *A. japonica*, illegal trade of *A. anguilla* eel fry from the European Union and of *A. japonica* eel fry within East Asia; in addition to increasing controls and checks of re-exports of *A. anguilla*, in particular from mainland China.

- Carry out capacity-building/training in national and local legislation, inspection procedures for farming operations and species identification and share information on illegal fishing and trade, including peak seasons, modus operandi, mis-labelling and main trade routes.

- Regularly analyse and investigate discrepancies in trade and CITES permit data for potential illegal trade.

- Co-operate and share intelligence and information with *Anguilla* source countries/territories, in particular in Europe, the Americas and South-East Asia; including keeping up to date with changes in national export regulations.

- Raise awareness and provide information to importers on the various international and national regulations in place, such as export bans for eel fry from the Philippines and Indonesia, and the total ban on export of *A. anguilla* from the European Union.

Additional research, collaboration and consultation with stakeholders

All eel stakeholders in East Asia, including fisheries, Customs and CITES authorities, fishermen, eel farmers, fisheries/farming/trade associations, traders, retailers and researchers, are urged to cooperate and:

- Together analyse all available data sources and collaboratively develop management decisions and traceability systems for the East Asian eel industry, with a particular focus on ensuring legality and sustainability of sourcing of glass eels and eliminating illegally sourced eel products from the supply chain.

- Exchange experiences and information with other *Anguilla* spp. range States to ensure conservation and management measures are complementary and adaptable to the changing circumstances across the globe.

- Carry out further research and initiate dialogue with potentially important emerging markets such as Russia.

- Encourage international organisations involved in setting up systems for reporting of fisheries data to specify, where possible, the genus/species to be reported under designated codes; for example request that FAO adds the genus “Anguilla” to categories such as “River Eels Nei” (FAO production) and World Customs Organization (WCO) adds “Anguilla” to the new HS code for prepared/preserved eels introduced in 2012.

- Raise food industry, retail and consumer awareness with regards to eel legality and sustainability issues and potentially suitable traceability schemes.