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Agenda Item 24.1.1

PROPOSAL FOR THE INCLUSION OF THE EUROPEAN EEL (*Anguilla anguilla)* ON CMS APPENDIX II

Summary

The Government of the Principality of Monaco has submitted a proposal for the inclusion of the European eel (*Anguilla anguilla*) on CMS Appendix II for the consideration of the 11th Meeting of the Conference of the Parties (COP11), 4-9 November 2014, Quito, Ecuador.

The proposal is reproduced under this cover for a decision on its approval or rejection by the Conference of the Parties.

PROPOSAL FOR INCLUSION OF SPECIES ON THE APPENDICES OF THE CONVENTION ON THE CONSERVATION OF MIGRATORY SPECIES OF WILD ANIMALS

A. PROPOSAL: Inclusion of the European eel (*Anguilla anguilla*) on CMS Appendix II

Summary: The European eel 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 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. A listing on Appendix II of the CMS would provide additional support for improving collaborative management, conservation and monitoring of this species.

The Document is based on the work done by Dr Matthew Gollock and Dr David Jacoby on behalf of the Sargasso Sea Alliance.

B. PROPONENT: Government of the Principality of Monaco

C. SUPPORTING STATEMENT:

1. Taxon

1.1	**Class:**	Actinopterygii
1.2	**Order:**	Anguilliformes
1.3	**Family:**	Anguillidae
1.4	**Genus:**	Anguilla (Schrank, 1798)
	Species:	A. anguilla (Linnaeus, 1758)
1.5	**Common Name:**	English: European eel; Common eel; River eel; Weed eel French: Angèle; Anguille d'Europe; Anguille européenne; Anguille jaune; Civelle; Leptocéphale Spanish: Anguila; Anguila europea; Anguilla

List of regional names adapted from Froese and Pauly (2005).

Genus:	*Anguilla*
Species	*anguilla*
Authority	(Linnaeus, 1758)
Common name	European eel

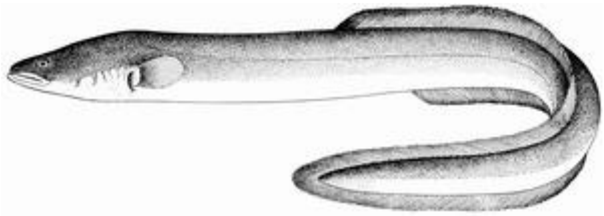

Figure 1. The European eel (*Anguilla anguilla*) – image from FAO.

There are a number of life stages (Figure 2) that have their own terminology and regional vernacular – leptocephalus, glass eel, elver, yellow eel and silver eel.

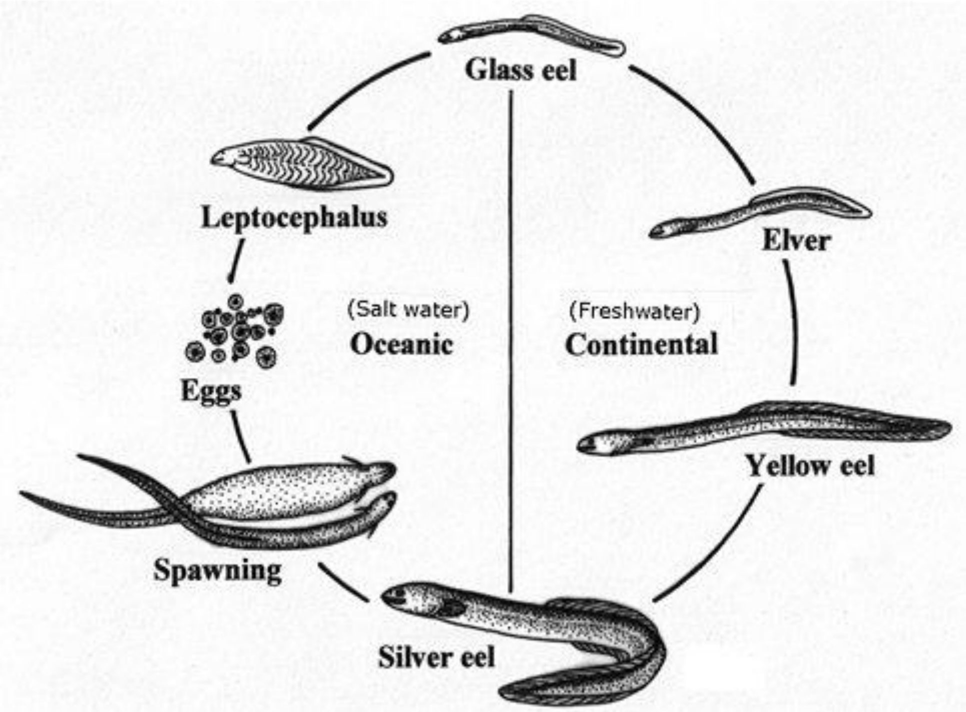

Figure 2. Life cycle of the European eel (created by Rob Slapkauskas).

It should be noted that there is a hybrid of the European eel and American eel (*Anguilla rostrata*) that is found almost exclusively in Iceland (Albert *et al.*, 2006).

2. Biological data

The anguillid eels (family Anguillidae) are part of the order Anguilliformes, which also includes the conger and moray eels, among others (Obermiller and Pfeiler 2003). There are 16 species of anguillid eels, and molecular analysis indicates that the European eel's closest relative is the American eel (*Anguilla rostrata*) (Teng et al., 2009) – this is unsurprising considering the proximity of their spawning locations (see below). DNA analysis is the best tool to distinguish between European eels and other species, but *A. rostrata* have fewer vertebrae than *A. anguilla* (102-112, usually 106-108, vs. 111-119, usually 114-116).

As stated above, there are a number of phases in an eel's life that have specific terminology and these in turn have a specific morphology (Figure 2). After hatching, the marine larval leptocephalus stage is leaf-shaped and very different from the elongate shape most associated with the anguillids – indeed leptocephali were believed to be a separate species (*Leptocephalus brevirostris*) until 1896 (Grassi, 1896). During the migration the leptocephali grow and elongate to become transparent glass eels upon arrival at the continental shelf. As the glass eels grow and pigment – be it in freshwater or saline waters - they become elvers and then yellow eels; these are morphologically similar, distinguished primarily on size, with a bicolour counter-shade of yellow / brown / green dorsum and lighter ventrum. The final stage is the marine-migratory silver eel which is characterised by a darkened dorsum, silvery counter-shading and large eyes. The 'eel shape' that is associated with the glass eel onwards is characterised by well-developed eyes and jaws with the lower jaw often the longer; a single, long dorsal fin, remote from head; a long anal fin to just behind anus; the caudal fin confluent with both dorsal and anal fins; well-developed pectoral fins; pelvic fins are absent; paired gill openings presenting as small vertical slits at the base of the pectoral fins base; and a smooth tegument (Silvfergrip, 2009).

The European eel has a life history best described as 'facultatively catadromous'. True catadromy could be described as feeding and growing in freshwater, and breeding in the marine environment, however, the European eel's growth phase is often described as 'continental' as they are found in fresh, brackish and coastal waters. As such 'freshwater' is not believed to be essential to the continuation of the species – hence facultative catadromy. Breeding and spawning of the European eel occurs in the marine environment and this element is believed to be essential for the completion of the life cycle. While there is some understanding of the eel's continental life history, relatively little is known about its marine phase.

There are still no exact data about specific spawning sites, however, from, and building upon, work carried out by Johannes Schmidt in the early part of the 20th Century (Schmidt, 1922) it has been deduced that spawning takes place in an elliptic zone, about 2,000 km wide in the Sargasso Sea, in the West Central Atlantic (approximately centred around 26°N 60°W). It should be noted that the American eel (*Anguilla rostrata*) is believed to spawn in a sympatric area of the Sargasso Sea (McCleave et al., 1987). Surveys of *A. anguilla* leptocephali indicate that spawning peaks in early March and continues to July (McCleave, 1993) and that they are <10mm upon hatching (McCleave et al., 1987). Spent adults are assumed to die after spawning.

Leptocephali migrate towards their continental habitat (See section 2.4) and are believed to feed on 'marine snow' – particulate organic matter – during this period (Otake et al., 1993). By the time they reach the continental slope they are as large as 100 mm and have metamorphosed to become elongate, transparent glass eels. The majority of continental landings occur in late-autumn to early-spring in Iberian and Bay of Biscay waters - they are delayed in more northerly sites until temperatures rise in the spring. Sexually undifferentiated glass eels are washed into rivers, estuaries and coastal waters tidally before developing into pigmented elvers (Tesch, 1977) - this is vague term but usually implies an eel above 10-15cm in length. Eels grow and mature over a wide temporal range from anywhere between 5 and 50 years - dependent on environmental conditions, food availability, the sex of the individual and access to and from suitable growth habitat. During this growth period they may migrate within and between freshwater and saline habitats; feed on a broad range of prey including fish, crustaceans, bivalves, shrimp and polychaete worms; and equally, are able to fast for extended periods (reviewed in van Ginneken and Maes, 2005).

Sex determination is principally driven by environmental factors with density dependence producing more males at high densities (Davey and Jellyman, 2005). Males grow faster than females, however, females achieve a greater age and size than males when sexually mature - fat stores are used to fuel the migration to the Sargasso, and in the case of females, produce eggs (Svedäng and Wickström, 1997). Yellow eels that are ready for the seaward migration undergo morphological and physiological changes to become silver eels (Tesch, 1977). The age at which silver eels mature and undertake their spawning migration is hugely variable and dependent on latitude and temperature of the environment in which they have grown, physical barriers that block migration routes, growth rate and sex differences. From the data available, lower bound estimates for average length of the continental growth phase are approximately 3-8 years for males and 4-5 years for females and upper bound estimates are approximately 12-15 years for males and 18-20 for females (Acou et al., 2003; Froese and Pauly, 2005; Durif et al., 2009). However, data is lacking from some parts of its range and there is no threshold size or age before initiation of silvering occurs this occurs - what triggers this process is still not known (Svedang et al., 1996). Once eels have begun silvering, initiation of the 'downstream' migration of anguillids is believed to be triggered by lunar stage and atmospheric conditions (Todd, 1981). The silver eels then begin the migration to the Sargasso which may take up to 6 months depending on the location of the river that they are migrating from (Kettle et al., 2011). Eels are not believed to feed during the oceanic migration and their alimentary tract degenerates (Pankhurst and Sorensen, 1984), and it is only during this migration that full sexual maturity is believed to occur, but our understanding of this process is poor. In recent years, researchers have been successful in attaching satellite tags to large female silver eels and this work has given us a new insight into the spawning migration of the European eel (Aarestrup et al., 2009). The eels swam towards the Canary and Azores currents exhibiting a diel vertical migration (Castonguay and McCleave, 1987; see section 2.4). It has been proposed that eels that spawn in the Sargasso Sea (i.e. American and European eels), locate their spawning ground using the convergence of currents in the region (Kleckner and McCleave 1988; Miller and McCleave 1994) – sometimes referred to as the North Atlantic Subtropical Convergence Zone. Eels have also been found to have a magnetic sense (Durif et al., 2013) which may play a role in the migration. Once mature eels reach the Sargasso Sea, spawning occurs and the life cycle continues with fertilised eggs hatching to produce leptocephali.

2.1 Distribution

Due to the unusual nature of this species' life history the distribution primarily refers to the continental growth stage – the yellow eel – which is known to occur in freshwater bodies, estuaries and coastal waters of the range states (Moriarty and Dekker 1997; ICES, 2009). It is important to highlight that a proportion of some *Anguilla anguilla*'s life – both the adult spawning migration and the subsequent larval migration – occurs in the open ocean, both in range state's Exclusive Economic Zones (EEZ) and the High Seas (see section 5), though these movements are poorly understood. *A. anguilla* are thought to spawn in the Sargasso Sea in the West Central Atlantic between late winter and early spring, before eggs hatch and leptocephalus larvae migrate, on oceanic currents, back across the Atlantic to begin the continental phase of their life history (Schmidt, 1922; Aarestrup et al., 2009).

The common name of *A. anguilla* - the European eel – indicates the majority distribution of the species, however, it is also found outside of Europe in adjacent regions. Its range is described as the North Cape in Norway, southwards along the coast of Europe, all coasts of the Mediterranean and on the North African Coast, as well as Iceland (Figure 3.) (Schmidt, 1922; Dekker, 2003). It is occasionally found entering the White and Barents seas, and has been recorded eastward to the Pechora River in northwest Russia. The species occurs in low abundance in the Black Sea where it migrates east to the Kuban drainage (occasional individuals reach the Volga drainage through canals), in northern Scandinavia and Eastern Europe. Historically, its range may have been wider.

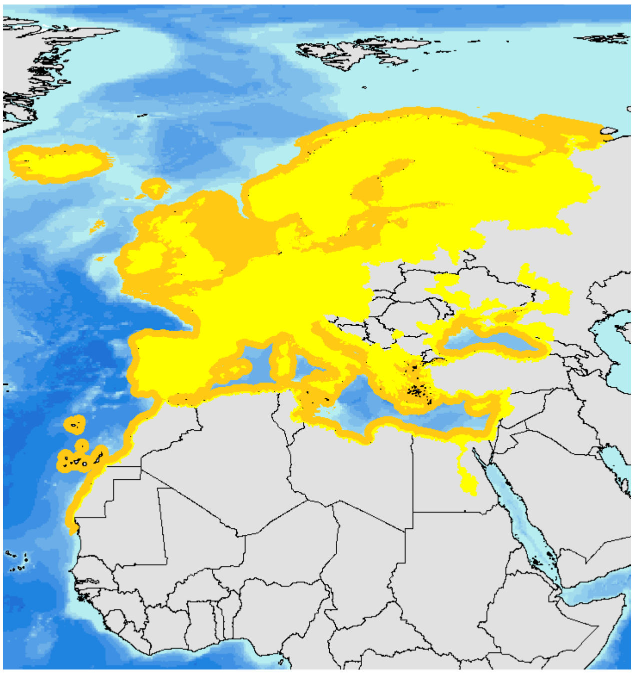

Figure 3. Continental distribution of the European eel: yellow = freshwater; orange = estuarine/marine.

The European eel is considered 'introduced' in East Asia where it was exported for stocking eel farms (Ringuet et al., 2002) – almost exclusively as glass eels – until 2010 when a ban was imposed on trade of the species outside of the EU. It is believed to have been found in watercourses in Asia – either through escape or release from farms - however, due to the specific breeding location and associated migration of silver eels of this species, these are not thought to have successfully populated the region over subsequent generations.

2.2 Population

There are a number of metrics that are commonly used when estimating the abundance of this species. 'Population', in relation to anguillid species, is generally associated with the continental yellow eel stock. 'Recruitment' refers to returning juveniles or glass eels that will subsequently replenish the population, and 'escapement' refers to the silver eels that leave the continental habitat to make the spawning migration to the Sargasso Sea. The latter is ultimately the closest metric we are able to gather in relation to an actual spawning stock, however, the percentage of escapees that complete the migration and successfully spawn is unknown – indeed for all intents and purposes it is assumed that practically nothing is known about the dynamics of the oceanic phase of *A. anguilla* (ICES, 2013a).

Determining changes in the international stock in the European eel is hampered by limited data and the poor understanding of the relationship between recruitment, continental populations and escapement. There is a significant time lag between the recruitment of glass eels and the subsequent escapement of silver eels, i.e. the period defined as 'population' but, from the little data we have, there appears to be differences in the severity of the declines that have been observed in each of these life stages over the past 30 years. This would indicate that the relationship between these metrics is not linear. Further, given that *A. anguilla* are panmictic, escapement from one region does not translate directly into returning larval recruitment at the same locality. There is also considerably more data available for *A. anguilla* in northern, central and southern European countries compared to North Africa. This is potentially of concern as it has been suggested that males may migrate primarily from North Africa (Kettle et al., 2010), however, this has still to be proven.

Arguably the best studied population metric is recruitment – both of glass eels and juvenile yellow eels/elvers - and the joint European Inland Fisheries and Aquaculture Advisory Commission (EIFAAC) and International Council for the Exploration of the Sea (ICES) eel working group (WGEEL) has been analysing recruitment data from continental Europe for many years. Since the early 1980s, a steady and almost continent-wide decline of ~90% has been observed in the recruitment of glass eels (Figure 3) – in some catchments this has been as high as 99% (Gollock et al., 2011). In 2009 the WGEEL recruitment index dropped to its lowest historical level, less than 1% for the North Sea and 5% elsewhere in the distribution area (ICES, 2013a). Strong language has been used in light of these findings e.g. recruitment was 'outside its safe biological limits' and as such efforts should be made to 'reduce all anthropogenic impacts to as close to zero as possible' (ICES, 2006). In the last three years however, the recruitment index has increased to 1.5% of the 1960–1979 reference level in the 'North Sea' series, and to 10% in the 'Elsewhere' series, but both remain far from 'healthy' (ICES, 2013a). This could possibly be in response to the closure of silver eel fisheries across Europe in 2009, although this increase is within the natural variation of historical records (ICES, 2012). Whilst data from catch returns indicate this increase in recruitment, the impact of the overall decline will continue to influence adult stock for at least one generation length (ICES, 2012). For the North African range of the population there is considerably less information. A regional Red List assessment in North Africa suggests that *A. anguilla* is 'Endangered' due to a decline in recruitment of 50% in the last 10 years with annual catches declining by between 10 and 25% since the 1980s, and by more in Tunisia alone (Azeroual, 2010).

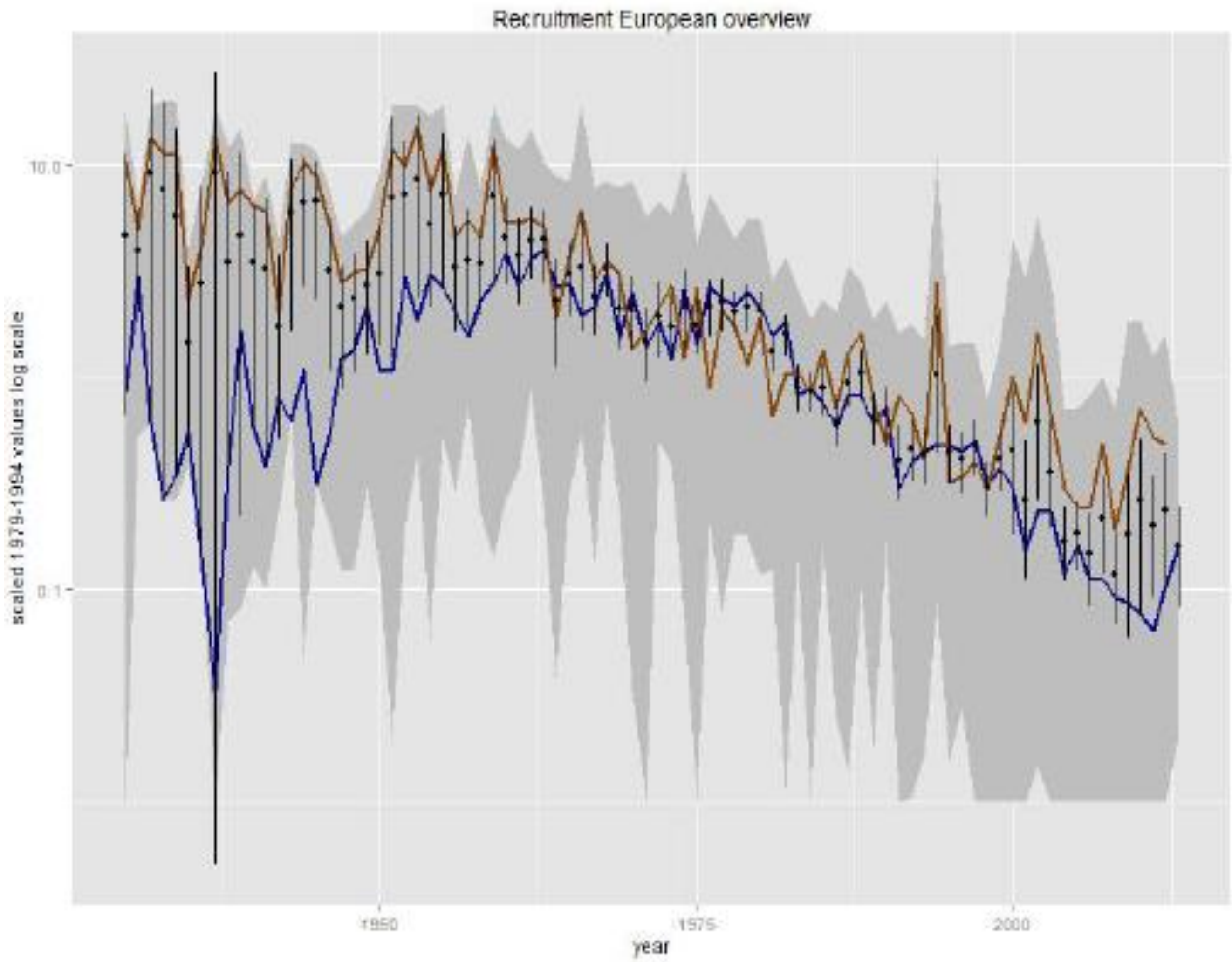

Figure 3. Time-series of glass eel and yellow eel recruitment in European rivers with data series >35 years (45 rivers), updated to 2013. Each series has been scaled to its 1979–1994 average. Note the logarithmic scale on the y-axis. The mean values of combined yellow and glass eel series and their bootstrap confidence interval (95%) are represented as black dots and bars. The brown line represents the mean value for yellow eel series, the blue line represents the mean value for glass eel series. The range of the series is indicated by a grey shade (from ICES 2013).

While the relationship between recruitment and continental populations is unclear, both have declined during the same period, though the latter less severely (ICES, 2013a). For certain data sets, changes in recruitment are not reflected in the population (ICES, 2013a) - it is possible that the less pronounced decline will be partially due to density dependant mortality (Svedäng, 1999). However, it needs to be taken into account that the age range of yellow eels is broad and that there may very well be a time lag in knock-on population effects. As such, the increase in recruitment described above would not be expected to be immediately mirrored in a rise in yellow eel numbers; indeed, it is possible that this life stage may continue to decline.

Silver eel decline was not as pronounced as yellow eel populations or recruitment; ICES (2013a) indicated that data from five rivers 'show reductions of about 50% from the 1970s to the years since 2000'. Again, this disparity may be due to density dependent mortality at previous life stages, but it cannot be ruled out that a decline in silver eel escapement may continue despite increases in glass eels and/or yellow eels due to the long generation time.

2.3. Habitat

As a leptocephalus, the European eel is found in both the epi- and meso-pelagic zones, up to 300m (Castonguay and McCleave, 1987). During its continental phase *Anguilla anguilla* is found in a wide range of habitats from small streams to large rivers and lakes, and in estuaries, lagoons and coastal waters. Under natural conditions, it only occurs in water bodies that are connected to the sea; it is stocked elsewhere. Its distribution indicates that it can live in a wide range of temperatures, from the borders of both the sub-tropical region and the Arctic circle. Further, it is extremely tolerant to low oxygen environments and poor water quality generally. Similar to the leptocephali, once adult silvering has taken place they transiently inhabit the epi- and meso-pelagic zones, though to greater depths of up to 1000m (Aarestrup et al., 2009).

2.4 Migrations

Due to the catadromous life cycle of anguillids there are several migratory behaviours exhibited by the European eel, both during the oceanic and continental phase. *Anguilla* spp. are believed to have originated from a marine ancestor – indeed all other species from the order Anguilliformes are marine species (Inoue et al., 2010) – and it has been suggested that the marine breeding habits of *Anguilla* species are a conservative trait (Arai and Chino, 2012). The migrations in the European eel's life cycle are the longest and most oceanographically complex of the anguillid species (Tsukamoto et al., 2002).

The oceanic migration of leptocephali to the continental shelf has been proposed to take anywhere from less than a year to over three years, but is estimated to take an average of two years (Bonhommeau et al., 2010; Zenimoto et al., 2011). However, beyond identifying the Gulf Stream and North Atlantic Drift as being involved, the mechanisms by which leptocephali reach the European and N. African coasts are also not well understood. Early stage leptocephali (<5 mm) of both *A. rostrata* and *A. anguilla* caught in the Sargasso sea were distributed between 50 m and 300 m both day and night, however, above this length diel vertical migration patterns appeared to develop (Castonguay and McCleave, 1987). Leptocephali measuring 5.0 - 19.9 mm were mainly found between 100 - 150 m during daylight hours and between 50 - 100 m in darkness, those >20 mm were found deeper, between 125 - 275 m during the day, and between 30 - 70 m by night (Castonguay and McLeave, 1987). Similar behaviour has also been noted in Japanese eel leptocephali (Otake et al., 1998). How long this diel migration is exhibited has yet to be established.

It is believed that European eel populations typically contain a mix of freshwater residents, saline water residents, and inter-habitat migrants (Daverat et al., 2006; ICES, 2009; Tabouret et al., 2010). The inter-habitat migrants have recently begun to be studied in more detail through the analysis of otolith microchemistry, and this is not a behaviour solely exhibited by the European eel (Arai and Chino, 2012). However, the subtleties of the movements between freshwater and saline waters, at the time of writing, remain poorly understood. It is believed that eels will make smaller migrations within their chosen habitat, and has been observed in rivers (Moriarty, 1986).

Once yellow eels have silvered and this maturing form has begun its oceanic migration towards the Sargasso Sea it exhibits a diel vertical migration. This manifests itself as the fish inhabiting deeper, cooler waters during daylight hours, and shallower, warmer waters at night (Aarestrup et al., 2009; Figure 4). The reasons for this migration are at present unknown, however, a number of hypotheses have been put forward including thermoregulation, predator avoidance and potentially as a means of stimulating the continuing maturation process. While the oceanic migrations of this species are not well understood, they are fundamental to the survival of the species.

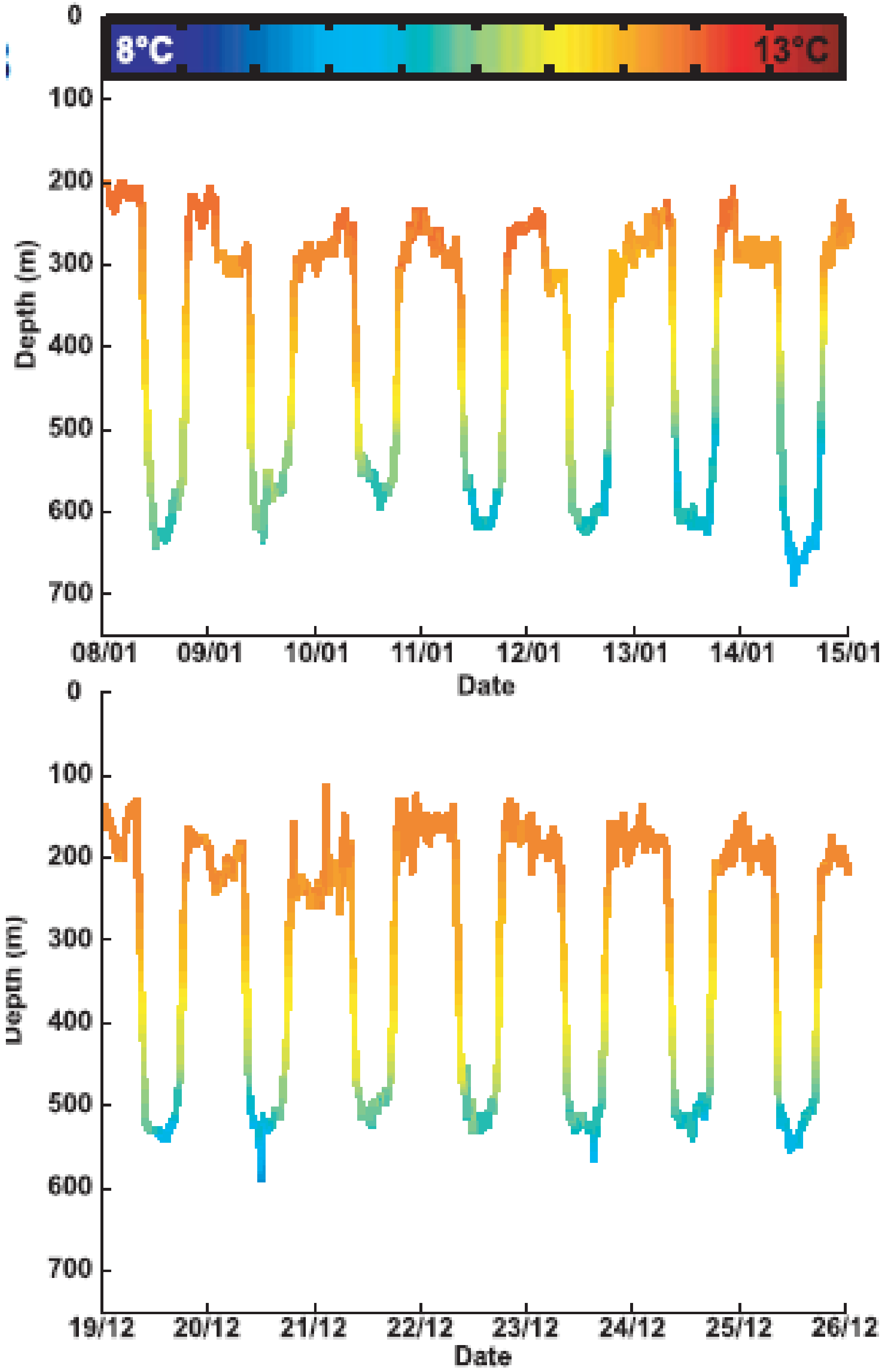

Figure 4. Depth and temperature data from two satellite tagged European eels exhibiting diel vertical migration (from Aarestrup et al., 2009).

3. Threat data

The causes of the declining recruitment, population and escapement are still not fully understood (Dekker, 2007), and while there are many hypotheses, the significance of any single threat, or the synergy it may have with other threats is not well understood. There is a broad suite of proposed causal factors for these declines, which can affect every life stage – the oceanic transport of leptochepalus; elvers and glass eels migrating upstream; freshwater yellow eels; and silver eels migrating downstream (ICES, 2008) - and these will be discussed below. However, there is a significant body of information and a great deal of contradiction in peer-reviewed and grey literature, and expert opinion relating to these threats and the short review below is far from comprehensive.

3.1 Direct threat to the population

As with many other species, exploitation has undoubtedly been a factor in the decline of the European eel. Across its distribution all continental life history stages of the European eel are currently exploited although data from different regions varies in quality and longevity. However, fisheries are by no means the primary reason for the decline, as can often be the case with commercially exploited fish species. Indeed in the same report that stated that "that the stock is outside safe biological limits and that current fisheries are not sustainable", it was also stated that "However, restrictions on fisheries alone will be insufficient, and management measures aimed at other anthropogenic impacts on habitat quality, quantity and accessibility will also be required" (ICES, 2006).

Fishing of various life stages of the European eel from glass eel to silver eel, continues in a number range States, though management measures such as bans and quotas have been imposed nationally. Fisheries of glass eels are by far the most economically lucrative as these are used for seed stock for farms, and in some cases restocking programmes. The currents that carry the leptocephali, most specifically the North Atlantic Drift, mean that the majority of glass eels arrive in the Bay of Biscay and this is reflected in the focus of the fishery being in France followed by Spain and the UK. Most recent glass eel data relating to 2013 indicates that France caught 30.5t – it is important to highlight that this was the quota and not limited by effort quota – Spain caught 8.7t and the UK caught 8.6t (ICES, 2013a). Both Spain and the UK's catches increased compared to 2012.

Fishing activities have been limited since the establishment of the eel regulation in 2007 with a number of member states ceasing fisheries, and exports of any eel products outside of the EU—mainly to South-East Asia where the demand was greatest—being banned in 2010 (see section 4.2). This closure had ramifications on other species of anguillids – particularly the American eel and species found in the Philippines - which were heavily exploited to meet the continued demand (Crook and Nakamura, 2013). Further, under-reporting, poaching and illegal trade are believed to occur throughout the range of the European eel fisheries. These activities endanger the species and make assessment of the impact of this fishery difficult, and it's associated management problematic.

In relation to threats from predators, until recently the little available data related to the continental populations of eels, primarily predation by cormorants, and it appears their impact is regionally variable (Carpentier et al., 2009; DEFRA, 2010) - however, two studies have indicated that adult eels are also predated upon during migration (see section 3.4).

3.2 Habitat destruction

One of the major threats to European eel populations, like many anguillid species, is barriers for flood control, water-level management and the abstraction of surface and ground water for both domestic and commercial (e.g. agricultural) use. Barriers can inhibit both upstream and downstream migration and hydropower turbines and their associated screens and water management systems can cause mortality or sub-lethal injury of silver eels – see section 3.4. These barriers result in a reduction in available freshwater habitat due to either direct physical obstruction, or due to changing the hydrology of the region such that the wetted area decreases.

Factors such as habitat modification, water abstraction and/or gravel extraction are problematic across the species range, but have been raised as of specific concern in North Africa, as has the effects of drought on available eel habitat (Azeroual, 2010).

3.3 Indirect threat

The reduction in freshwater habitat associated with impassable barriers may have knock on effects such as increased competition, predation and density dependent mortality. The subsequent reduced resource and food availability could result in poor condition of escaping silver eels which may affect the success of migration and/or spawning due this species' reliance - particularly the female's - on fat stores for reproductive success. Boëtius and Boëtius (1980) proposed that escaping silver eels required >20% lipid stores to allow them to complete the oceanic migration, however, more recent studies indicated that eels can escape with 'insufficient' fat stores, (Svedäng and Wickström, 1997). This suggests that silvering and escapement may occur independently of lipid storage. Lab studies using swim tunnels have assessed whether eels can complete the migration to the Sargasso Sea (van Ginneken and van den Thillart, 2000; van Ginneken et al. 2005) however, these experiments were limited in that they were not carried out under pressure to mimic the depth of the migration, used yellow rather than silver eels, and/or were extrapolated from short swims. Interestingly, poor condition, related to changing food sources and oceanic temperatures - two factors linked with the decline of the European eel - have been proposed in Atlantic salmon (Todd et al. 2008).

The parasite nematode *(Anguillicola crassus*) exists in the swimbladder of anguillid eels. It had been show to live in the Japanese eel, *Anguilla japonica* in S.E. Asia without causing severe pathological effects. However, when *A. jap*onica was imported to Europe for farming purposes in the 1980s, the nematode found its way into natural watercourses and infected wild populations of the European eel (De Charleroy et al., 1990). The parasite spread with alarming speed and is now present across the entire range of the European eel, which, as a naïve host, has exhibited a high infection prevalence (i.e. the percentage of the whole population that is infected) and higher worm loads per fish than *A. japonica,* (Moravec, 1992; Baruš et al., 1999; Evans et al., 2001) as well as negative physiological effects due to its presence (Gollock et al., 2005).

Due to the poor understanding of the oceanic migration of the European eel, it is extremely difficult to assess the effects of the parasite on this behaviour, both in the wild and in the lab. However, there have been studies that indicate that its presence may have negative effects on migration. Fazio et al., (2012) showed that the presence of the parasite had a disruptive influence on silvering; Palstra et al., (2007) showed impaired swimming performance in infected eels; and Würtz and Taraschewski (2000) showed that migration of the parasite's larvae through the swimbladder can cause damage and associated fibrosis to the organ. As we now know that the migration involves a diel vertical migration (Aarestrup et al., 2009) , the damage and potential loss of function of the swim bladder, which may play an important role in these movements, along with the blood-feeding nature of the parasite, may make it more metabolically expensive to migrate. This would very much depend on the worm load, and size and condition of the fish, but it is difficult to imagine that a heavy work burden would not have at least some effect on both horizontal and vertical migrations.

It has been well documented that the release of xenobiotic chemicals into the aquatic realm can have hugely detrimental effects on both vertebrates and invertebrates. Anguillid eels are particularly vulnerable to the effects of lipophilic toxins due to reliance on accumulating lipid stores to fuel both the spawning migration and gonadogenesis - particularly in relation to females. Indeed, in some cases they accumulate specific toxins to levels that are problematic to human health when consumed and as a result some fisheries have been closed (Geeraerts and Belpaire, 2010; ICES, 2013a). In relation to the eel's migration, exposure to these chemicals and their subsequent storage and release when fat stores are broken down during migration has been proposed to have a wide range of effects on eels, both in freshwater and during oceanic migration and spawning. These disruptive effects can affect osmoregulation; stress response; silvering; lipid accumulation, mobilisation and utilisation; sexual development; gonadogensis; and embryo and larval development (Robinet and Feunteun, 2002; Palstra et al., 2006; Geeraerts and Belpaire, 2010). All of these could potentially have significant effects on the eels' ability to migrate and/or spawn.

3.4 Threat connected especially with migrations

Climate change has been proposed to influence larval transport and glass eel recruitment through its impact on the oceanography of the Sargasso Sea and oceanic currents that drive recruitment to near shore and freshwater environments. However, there is a great deal of contradictory evidence in the published literature. For example, the North Atlantic Oscillation (NAO) has been studied as a driver of recruitment in both the European and American eel, with literature arguing for and against this hypothesis. Durif et al., (2011) posited there was a negative correlation between periods of high NAO and recruitment due to larvae being driven into colder water and slowing the process of metamorphosis considerably. Further, changing ocean climate might potentially be responsible for fluctuations in productivity and thus food availability for leptocephali (Miller et al., 2009). However, using predictive models, Pacariz et al., (2014) found that the overall success of larvae from the spawning ground to the East Atlantic was not affected by changes in climate between 1958-2008, suggesting that trends in recruitment are attributable to factors other than changing currents, a theory also supported by Henderson et al., (2012).

Other suggested effects that occur in the oceanic phase of the eel's life cycle are that a climate change-induced increase in sea surface temperature in the Sargasso Sea from 1979 onwards correlates with a decline in primary productivity, and as a consequence, recruitment in European rivers (Bonhommeau et al., 2008a,b). It is suggested that this decline may be due to reduced food availability and feeding success, which may in turn be affected by changes in vertical mixing in the region (Friedland et al., 2007; Bonhommeau et al., 2008b). Temperature change in the region may also be shifting the spawning location of the species northwards which could, in turn, affect transport of leptocephali by ocean currents (Miller et al., 2009).

Until recently, little was known about predation of eels in their oceanic phase, however, research now indicates that predation by cetaceans occurs during the migration (Wahlberg et al., 2014), and adult American eels have been predated on by oceanic sharks (Béguer-Pon et al., 2012). It is also generally assumed that leptocephali are predated upon during their oceanic migration.

In freshwater, the impact of dams, hydropower stations and water abstraction can have a significant effect on both the upstream and downstream migration of eels (Piper et al., 2013). Across Europe, there are a total of 24,350 hydropower plants and this figure is set to rise in the near future (van der Meer, 2012). Indeed, in the Netherlands alone there are a total of 4,671 water pumping stations which inhibit the spawning migrations of adult silver eels downstream and the upstream migration of glass eels. Due to their size, and their migration being upstream, barriers can significantly impede the upstream migration of glass eels and elvers that enter freshwater. Moreover, they can also affect yellow eels, as they have been shown to make migrations within freshwater once established (Moriarty, 1986). Upstream fish passage solutions that can be retro-fitted to barriers are available – primarily for glass eels and elvers – though depending on the scale of the barrier, the cost can be prohibitively high.

Also of concern is that due to the elongate morphology of the species – particularly the larger females - escaping silver eels are significantly more prone to mortality or sub-lethal injury from passing through hydropower turbines (Figure 5). Damage and/or mortality can occur as a result of direct contact with the turbine, but also from being pinned against protections screens and trash racks, rapid changes in hydrostatic pressure and/or salinity, and disorientation after passage through turbines increasing the risk of predation (ICES, 2002; 2007). A number of studies have been carried out to date to assess the severity of this threat and results indicate that there is a large variation in the percentage of eel mortality, dependent on flow regime and the type of turbine that is used, ranging from 0-100% (ICES, 2002; Winter et al., 2006; Jansen et al., 2007; Calles et al., 2010; Pedersen et al. 2012; Piper et al., 2013; Buysse et al., 2014). This indicates that there are options that could be considered more 'eel-friendly' and with appropriate screening and bypass, mortality could be kept extremely low. This, however, does not take into account the effects of sub-lethal mortality from screens, turbines and pressure change; these include skin and/or fin damage, 'pop-eyes', internal haemorrhage, ruptured swimbladder and/or internal organs, crushing injuries, and spinal fractures (ICES, 2002; 2007). Clearly some or all of these effects could a significant impact on the ability of silver eels to complete their spawning migration. Further, many rivers have multiple, sequential hydropower units, and as such cumulative damage and mortality, need to be accounted for in management of this threat. For example, it was hypothesised in the 2007 ICES/EIFAC eel working group report that 'if 20% is a typical average mortality rate, the total mortality rate of downstream migrating silver eel after the passage of five hydroelectric power stations reaches approximately 70%". As a consequence hydropower mortality is an issue that has been included in a number of EU Eel Management Plans (EMPs) – see section 4.2.

Figure 5. Mortality of European eels passing through hydropower turbines (© Sustainable Eel Group)

3.5 National and international utilization

All life stages of *Anguilla anguilla,* except for leptocephali – i.e. glass eel to silver eel - are harvested in a number of European eel range States and traded live for consumption, on-growing in farms or for restocking of rivers/estuaries. Prior to 2011, the demand for European eels was primarily driven by East Asian countries, in particular Japan and mainland China. Farming of anguillid eels is responsible for over 90% of all production of these species globally and is believed to have averaged 280,000 tonnes per annum since 2007, (FAO, 2013). Unlike the farming of many other species in captivity, artificial breeding of the European eel has never been achieved - it has for the Japanese eel, but this is not yet commercially viable - and as such is reliant on wild-caught juvenile eels or glass eels for seed stock. Historically, eel farms in East Asia used species of local provenance, however, towards the end of the 1990s, a decline in stocks of Japanese eels, led to many to change to the European eel for their culture material (Ringuet et al., 2002). In 2010 a ban on export outside the EU was imposed due to concern over the decline in recruitment and stocks of the European eel meaning there was no further legal trade to East Asia.

Due to the fact that Customs data is not species-specific i.e. referred to simply as *Anguilla*, and that trade can include fresh, frozen and smoked/prepared eels for consumption, the actual quantities of European eel traded are relatively unknown. East Asian Customs imports of live juvenile *Anguilla* eels (defined as “live eel fry”) from European eel range States to mainland China, Taiwan, Korea, Japan and Hong Kong fluctuated between ~9 and 70 tonnes from 2003 and 2010. In 2011 and 2012 imports were ~7 and ~5 tonnes respectively - these lower numbers are as a result of the EU ban in place since late 2010 (V. Crook, *in litt.*).

Since the listing of the European eel on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 2009 (see section 4.2), species-specific trade data for European eel has been reported. From 2009-2011, exports of over 360 tonnes of live eels (including 20 tonnes of juvenile eels for farming) were reported from a number of European eel range States. During these three years, nearly 30,000 tonnes of *A. anguilla* meat and bodies were also reportedly exported (mostly from farms in mainland China), in addition to ~11,000 leather products and ~13,000 skins (mostly from Mexico, but originating in Korea) (UNEP-WCMC, 2013). Since December 2010, illegal trade in European eel has been a concern – authorities have seized several European glass eel shipments destined for East Asian eel farms (Traffic, 2012).

As part of a number of EU member state’s national EMPs (see section 4.2) stocking water bodies with glass eels, elvers or small yellow eels in order to increase escapement of silver eels is a key activity. Indeed, the associated EU Regulation 1100/2007 requires that any glass eels/elver (<12 cm total length) fishery retains a proportion of the catch for restocking[1]. There is evidence that stocked eels survive and escape as silver eels, and researchers are currently working to determine whether stocked individuals can successfully migrate to the Sargasso Sea to spawn. A recent tagging study indicated that eels from a stocked watershed migrate in a similar way to wild populations in Sweden (Westerberg et al., 2014). However, there is still a great deal of uncertainty as to the effectiveness of this practice. Recent reviews (ICES, 2010; Pawson, 2012) on the contribution of stocking to the recovery of the European eel unambiguously state that there are major knowledge gaps relating to growth and condition,

[1] In the year EMPs were introduced (2010), 35% was expected to be made available for restocking within the EU and this figure was to increase to at least 60% by 31st July 2013.

sex ratio, behaviour and migration of stocked eels to be addressed before firm conclusions either way can be drawn (ICES, 2013a).

4. Protection status and needs

Presently, the European eel is listed as 'Critically Endangered' on the IUCN Red List indicating that the population is in a very poor state. To qualify for this category, the assessment posits that there has been an >80% decline in mature adults over the period of three generations. This is particularly challenging to determine in a species with a life cycle as complex as the European eel which also exhibits geographical and sexually dimorphic variation in life history. However, the severity of the listing is in line with the language used by recent ICES WGEEL reports which suggest the stock is 'outside its safe biological limits' (ICES, 2006). In addition to the global IUCN listing, *Anguilla anguilla* has been included as part as a number of regional and national Red List assessments in Europe over the past 10 years. The European eel has been assessed as Critically Endangered across Europe as a whole (Freyhof and Brooks, 2011) as well as in Sweden (Gärdenfors, 2005), Denmark (NERI, 2009), France (UICN, 2010) Norway (Kålås et al. 2010) and Ireland (King et al., 2011) and in regional assessments for the Baltic Sea area (HELCOM, 2013) and north Belgium, (Verreycken et al., 2013). Indeed the European eel showed the largest negative population trend of any of the freshwater fishes (-75%) in the Belgian report (Verreycken et al., 2013). A regional Red List assessment in North Africa categorised *A. anguilla* as Endangered, indicating a 50-80% decline in mature adults over three generations (Azeroual, 2010).

4.1 National protection status

Country level EMPs have been developed as a result of EU legislation, and as such they are discussed below in section 4.2. Research would indicate that the development of this legislation replaced existing national level legislation (OSPAR, 2010), however, this is not always true - Latvia's system of fishing regulation and catch recording has been adapted from the respective legislation of the former USSR (ICES, 2013a). In some cases, revised legislation was implemented to support the EMPs. In 2009, the UK developed national legislation, a statutory instrument, entitled 'The Eels (England and Wales) Regulations 2009'. This was implemented on 15^{th} January 2010 and related to a number of activities that relate to eels, including: catch and trade records, restocking, eel fishing licences, barriers and associated passage, and water abstraction and associated screening. The European eel is also one of 32 species of conservation importance selected with regards to designation of Marine Conservation Zones (MCZs) under the UK Marine and Coastal Access Act. Three of the 27 MCZs included in the first tranche for designation - Blackwater, Crouch, Roach and Colne Estuaries; Beachy Head West; and Pagham Harbour – included the European eel as a focal species, amongst focal habitats and other species. To date the associated management of MCZs has yet to be declared.

4.2 International protection status

During 2008 and 2009 EMPs were developed and implemented in EU Member States as a requirement of the EC Regulation 1100/2007 to "offer protection, promote recovery of silver eel escapement and enhance the sustainable management of this species". The objective of each EMP is to "reduce anthropogenic mortalities so as to permit, with high probability, the escapement to the sea of at least 40% of the silver eel biomass relative to the best estimate of escapement that would have existed if no anthropogenic influences had impacted the stock". Member States are responsible for implementing measures to achieve their targets, and these measures can include, but are not limited to; reducing commercial and recreational fisheries; restocking; improving habitats and making rivers passable; transportation of silver eels to the sea 'trap and transport'; reducing predation; and amending hydro-electric power turbine schedules to reduce mortality. In 2013, ICES convened an independent workshop at request of the EU DG MARE, to assess the progress made against EMP targets - 'Workshop on Evaluation Progress Eel Management Plans' (WKEPEMP). The assessment indicated that a large proportion of management actions across the species' range relate to commercial and recreational fisheries, with other actions relating to obstacles (including hydropower / pumping stations) habitat availability, restocking and predator control (ICES, 2013b). It was stated that "in most Eel Management Units[2] and depending on local conditions, progress has been made in implementing eel specific management measures for commercial and recreational fisheries, hydropower, pumping stations and obstacles, restocking measures on habitat and a few cases predator control" Ultimately, it was determined that currently, more than 50% of the 81 EMP progress reports across Europe are failing to meet their target silver eel biomass escapement of 40% in accordance with EC Regulation 1100/2007, however, of those that were not meeting their target 50% were trending towards achieving target in the future (ICES, 2013b).

In addition to the above European legislation the species was listed on Appendix II of CITES in 2007 due to concerns over the impact international trade was having on European eel stocks. This was in an attempt to ensure that all trade in the species was sustainable. Listing on Appendix II of CITES does not ban trade, however, it must be shown that '*export will not be detrimental to the survival of that species*'; this is referred to as a Non-Detriment Finding. The listing came into effect in March 2009, after which point all Parties to the Convention were obligated to issue permits for exports of the species. In December 2010, however, the European Union banned all imports and exports of live and processed European eel to and from the EU, as it was not felt they could assure that trade would not be detrimental to the species (Crook, 2011). This species can however, still be traded outside the EU from non-EU range states, for example countries in North Africa.

Finally, in relation to international policy, in 2008, *A. anguilla* was added to the OSPAR List of Threatened and/or Declining Species in the Northeast Atlantic (OSPAR 2010).

4.3 Additional protection needs

The international assessment of the eel stock collated in the 2013 ICES WGEEL report confirms "the critical state of the stock; the promising increase in recruitment observed in the last two years is set in historical perspective; but no prediction can be generated, and no evaluation of the implemented stock protection measures achieved". There is still a critical need for improvement in the quality and consistency of data reporting to improve "stock assessment (at local, national and international levels), identification and quantification of impacts (natural and anthropogenic), and the development and implementation of locally and internationally effective management measures" (ICES, 2013a). National level EMPs are an excellent first step towards protecting eels stocks, however, there is variation between range states as to how the plans were developed and associated metrics are assessed. For a species with such a wide range, that often includes trans-boundary watercourses, this has proven

[2] Dependent on the range state EMPs were developed for the entire country and/or for regions/river basins within the country. As such each EMP is linked to an "eel management unit" the scale of which varies.

problematic. Further, there are a number of range states, primarily outside of Europe, with no eel management at all.

Below is a list of areas of research and management that have been highlighted in the report and the associated references that require improvement to ensure the species is better protected and managed. This list is by no means exhaustive.

- Fisheries enforcement and management
- Freshwater habitat restoration, improvement and protection – including water quality
- Trans-boundary protection
- Monitoring programmes – particularly in North Africa and the Mediterranean
- Stock assessments
- Area protection for key locations e.g. Sargasso Sea
- Easement of barriers such as dams and hydropower units to improve both upstream and downstream freshwater passage – including trap and transport programmes
- Threat assessment at the local, national and international level
- Water abstraction management e.g. screening of intakes and reduction of hydropower turbine activity during silver eel escapement
- Understanding of the benefits and limitations of restocking programmes

With regard to the proposed listing on CMS, this would be especially beneficial in relation to a number of these needs. As stated in section 4.2, >50% of the 81 EMPs are failing to meet the target silver eel escapement in accordance with EC Regulation 1100/2007 indicating that current mitigation and management efforts require further refinement. Despite this, a number of European eel range states have yet to develop any management plans for the species and this could potentially be facilitated and encouraged through the listing on Appendix II. North African populations are poorly understood in comparison to other range states and the development of monitoring and management programmes in line with those in other range states.

More fundamentally, due to the life history of the species, there is a great need for trans-boundary collaborations both in relation to both the marine and freshwater habitats; at present there is little co-ordination and developing these would be hugely beneficial for the species. As indicated in section 3.4, barriers to migration have the potential to reduce available habitat for eels, and, in the case of hydropower, reduce escapement due to mortality and sub-lethal injury. Development of collaborations in relation to trans-boundary waterways could hugely benefit the management of both upstream and downstream migration.

4.4 Proposed co-operative actions for discussion

- 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.

- 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.

- 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.

5. Range States

Country	CMS Party
Albania	Yes
Algeria	Yes
Austria	Yes
Belarus	Yes
Belgium	Yes
Bosnia and Herzegovina	No
Bulgaria	Yes
Croatia	Yes
Cyprus	Yes
Czech Republic	Yes
Denmark	Yes
Egypt	Yes
Estonia	Yes
Finland	Yes
France	Yes
Georgia	Yes
Germany	Yes
Greece	Yes
Iceland	No
Ireland	Yes
Israel	Yes
Italy	Yes
Latvia	Yes
Lebanon	No
Libya	Yes
Lithuania	Yes
Luxembourg	Yes
Malta	Yes
Mauritania	Yes
Monaco	Yes

Country	CMS Party
Montenegro	Yes
Morocco	Yes
Netherlands	Yes
Norway	Yes
Poland	Yes
Portugal	Yes
Republic of Moldova	Yes
Romania	Yes
Russian Federation	No
Serbia	Yes
Slovakia	Yes
Slovenia	Yes
Spain	Yes
Sweden	Yes
Switzerland	Yes
Syrian Arab Republic	Yes
The former Yugoslav Republic of Macedonia	Yes
Tunisia	Yes
Turkey	No
Ukraine	Yes
United Kingdom (incl. Gibraltar, Guernsey, Isle of Man and Jersey	Yes

FAO areas

27. Atlantic – northeast
31. Atlantic - western central
34. Atlantic - eastern central
37. Mediterranean and Black Sea

6. Comments from Range States

TBD

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