European Eel Briefing Note for Sargasso Sea Alliance

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The Sargasso Sea Alliance is led by the Bermuda Government and aims to promote international awareness of the importance of the Sargasso Sea and to mobilise support from a wide variety of national and international organisations, governments, donors and users for protection measures for the Sargasso Sea.

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COVER PHOTO: European eel (James Prosek).

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Foreword

BETWEEN 2010 AND 2012 a large number of authors from seven different countries and 26 separate organisations developed a scientific case to establish the global importance of the Sargasso Sea. A summary of this international study was published in 2012 as the "Summary science and Supporting Evidence Case." Nine reasons why the Sargasso Sea is important are identified in the summary. Compiling the science and evidence for this case was a significant undertaking and during that process a number of reports were specially commissioned by the Sargasso Sea Alliance to summarise our knowledge of various aspects of the Sargasso Sea.

This report is one of these commissioned reports. These are now being made available in the Sargasso Sea Alliance Science Series to provide further details of the research and evidence used in the compilation of the summary case. A full list of the reports in this series can be found in the inside back cover of this report. All of them can be downloaded from **www.sargassoalliance.org.**

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European Eel Briefing Note for Sargasso Sea Alliance

In the past 30 years there has been growing concern in relation to the decline in recruitment 'outside its safe biological limits' of the European eel *(Anguilla anguilla)* across Europe (Dekker, 2003; ICES, 2006). *A. anguilla* is listed as 'Critically Endangered' on the IUCN Red List of Threatened Species and has received legislative attention in the past ten years from both the European Union (in the form of mandatory management plans from member states) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; Appendix II listing) to help address decline in this species. There are various suggestions as to the actual decline in both European eel recruitment and populations–which for the former could be as high as 99% in some catchments (Gollock et al., 2011)–however, due to the poor data collection across Europe, offering a catch-all figure for either metric would be difficult. It is generally, agreed, though, that the rate of decline of the European eel over the past 30 years is of huge concern.

There are a number of suggested causal factors that have been implicated in the decline, which will be discussed in detail later in this document, however, both the complex nature of the European eel's life cycle, and the aforementioned dearth of information relating to any phase of the cycle, are impediments to the management and conservation of the species. A great deal of attention has been paid to the importance of the Sargasso Sea to breeding of European eels and the early part of the migration of leptocephali in the report submitted by Miller and Hanel (2011). As such, this report will not re-visit this aspect of the eel's life history in any great detail, but the full life-cycle will be briefly discussed before how each phase is impacted by both natural and anthropogenic pressures is addressed. Prior to discussing the lifecycle it is essential to highlight the importance of panmixia to the life-history of European eels. Panmixia in eels effectively means that irrespective of where the adults have fed, grown and migrated from, the genetic pool is communal, i.e. all eels spawn in one place–most likely, the Sargasso Sea–and are not believed to select a mate based on geographic history (Als et al., 2011). This highlights the huge importance of the region to the survival of the European eel, as it is the seat of reproductive activity that larval recruits across the full species' distribution range originate from.

Life cycle

The life of a European eel can be split into three main phases: the first marine phase; the continental phase; and the second marine phase (**FIGURE 1**).

As eloquently described by Miller and Hanel (2011), the eel appears to starts its life in the Sargasso Sea (Kleckner and McCleave, 1988) where leptocephali develop from floating eggs. These passive migrators are carried by currents away from the spawning grounds towards the Europe (McCleave and Kleckner, 1987). There is discussion as to how long the migration to the

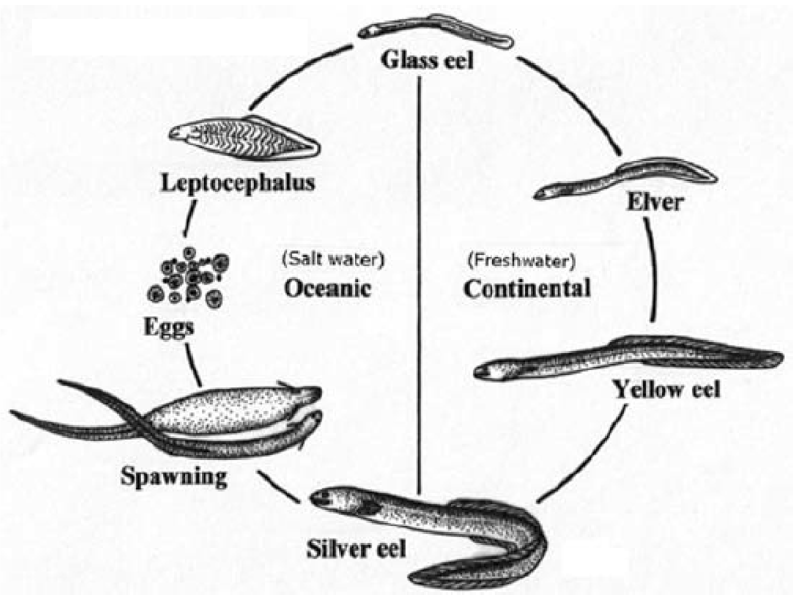

FIGURE 1. The life cycle of the European eel *(Anguilla anguilla)*– from ICES (2010).

rivers of Europe and North Africa where eels feed and grow takes, but it is suggested to be anywhere between 7-24 months (ICES 2010). Eels are believed to inhabit a European rivers draining to Mediterranean, North and Baltic Seas, in the Atlantic, south to the Canary Islands and parts of Mediterranean, Northern Africa and Asia (Kettle et al., 2010). As they reach the continental shelf and estuaries of rivers, they become elongate and develop into glass eels, which are washed into rivers tidally before they develop into pigmented elvers (Tesch, 1977). It is important to highlight that it is believed that there are potentially significant populations of eels that never enter freshwater, and grow in estuaries and coastal waters before migrating as adults (ICES, 2009), however, the monitoring and management of them is logistically very difficult and thus we will discuss freshwater populations only. As the elvers grow they move into freshwater and become yellow eels—this is vague term but usually implies an eel above 10-15cm in length. The growth and maturation of the European eel in freshwater may take anywhere between 5 and 50 years—dependent on environmental conditions, food availability and the sex of the individual—during which time they are able to inhabit a wide range of freshwater habitats, will feed on a broad range of prey, and equally, are able to survive extended periods of fasting (reviewed in van Ginneken and Maes 2005). It is during this period the eels build up fat stores that will ultimately be used to fuel the migration to the Sargasso, and in the case of the larger and longer-lived 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, and leave freshwater (Tesch, 1977). 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,* 2010).

Threats

There is a broad suite of proposed causal factors for the population decrease that can affect every life stage—elvers and glass eels migrating upstream; freshwater yellow eels; and silver eels migrating downstream (ICES, 2008). These include; exploitation (Feunteun, 2002; Dekker, 2003; ICES, 2006); changes in oceanic currents and/or climatic conditions (e.g. Castonguay et al., 1994; Bonhommeau et al., 2008a;b); barriers to migration (including hydro-power stations which damage and/or kill eels) (e.g. Winter et al., 2006; Chadwick *et al,* 2007); loss of freshwater habitat (e.g. Feunteun, 2002); pollution (particularly lipophillic substances such as PCBs and substances that affect lipid storage) (e.g. Robinet and Feunteun, 2002; Pierron et al., 2007); the effects of the swimbladder parasite *Anguillicoloides crassus* (e.g. Gollock et al., 2005); and poor condition of escaping silver eels (particularly in relation to insufficient lipid stores) (e.g. Svedäng and Wickström, 1997). While the weight of evidence for some of these factors is greater than others, it is unlikely that there will be one single cause, and due to the oceanic nature of eel emigration, it is difficult to monitor the effects of these in the field. Further, the research carried out and data available in relation to some of these issues is very limited, and why our understanding is so poor and consequently our efforts to conserve the European eel are hampered.

Below these threats are discussed in more detail:

Fisheries

As with many other species, exploitation has undoubtedly been a factor in the decline of the European eel, however, it is by no means the sole reason, as is often the case with commercial fish. 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). Fisheries primarily focus on the glass eels, with the majority being caught in France—landings for UK, France and Spain for the 2009–2010 seasons, are estimated to be 1.3 t, 41 t and 6.4 t respectively (ICES 2010). However, as part of the EU eel regulation (Council Regulation (EC) No 1100/2007) developed in 2007, an annually increasing % of the catch has to be made available for restocking purposes. Thus, there is an argument that the glass eel fishery, when carried out using low mortality methods such as hand nets and slow speed trawling, may help to protect the stock by removing natural, density dependent mortality in the wild, when they are grown on in culture facilities to the yellow eel stage. There is a strong feeling that silver eel fisheries should be halted to ensure adult eels that are escaping are given the greatest opportunity to migrate and spawn. Irrespective, fishing activities have been limited by legislation over the past ten years, 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.

Ocean currents and conditions

As Miller and Hanel (2011) described, the passive migration of European eel leptocephali is not well understood, but it is believed that the majority are carried on the Gulf Stream-North Atlantic Drift (McCleave and

Kleckner 1987; Bonhommeau et al., 2009), but changes as a result of both natural fluctuations and anthropogenic activities may affect this migration. The North Atlantic Oscillation, an atmospheric phenomenon that has both physical and biological effects on the ocean in the North Atlantic region, and is believed to have historically affected freshwater recruitment of European eels (Knights, 2003) indicating that it affects ocean currents. Most relevant to the Alliance, Bonhommeau et al., (2008a,b) have suggested that an increase in sea surface temperature in the Sargasso Sea from 1979 onwards correlates with a decline in primary productivity, and it turn recruitment in European rivers—likely due to reduced feeding success, which may in turn be affected by changes in vertical mixing in the region (Friedland et al., 2007). The increase in sea surface temperature, and the associated knock on effects, is very likely linked to rising sea temperatures due to climate change. Another effect of temperature change in the region could be that the spawning location is shifted northwards from where it was traditionally believed to take place, which in turn, may affect transport by ocean currents. It should be noted that it has been suggested that the effects of the Sargasso Sea temperature change may have over-ridden the effects of the NAO that have been observed (Miller et al., 2009).

Again, echoing the sentiment of Miller and Hanel (2011) the European eel's migration is the longest of the anguillid species and thus oceanic changes are likely to have a far more profound effect on them.

Barriers to migration and loss of freshwater habitat

These two issues are intrinsically linked, as the creation of barriers to migration, be it for navigation, water abstraction, hydro power or tidal control to name a few, the result is often the same—a reduction in available freshwater habitat due to either direct physical obstruction, or due to changing the hydrology of the an area such that wetted areas decrease. While this mainly applies to glass eels and elvers that are making the initial migration into freshwater, it also applies to yellow eels, as they have been shown to make migrations within freshwater once they have become established (Moriarty, 1986). This reduction in freshwater habitat may result in increased competition and density dependent mortality in juvenile eels, and potentially reduced resources which could result in poor condition of escaping silver eels. Further, hydro-power stations are particularly damaging for silver eels due to their elongate morphology and can result in mortality or significant sub-lethal injury if they pass through the turbines (Winter et al., 2006). Eel passage, habitat restoration and hydro-power station screening are key elements of many of the EU eel management plans.

Pollutants

Eels by their nature—due to their need to store lipids for the marine migration, during which they do not feed—are susceptible to a number of the well known aquatic pollutants as they are lipophilic, and/or they can affect lipidogenesis (Robinet and Feunteun, 2002). Consequently it is possible that there will not be enough fat stored as a result of the physiological disruption and/or the fat that is stored will be 'toxic', and when it is mobilised during the oceanic migration, the xenobiotics may have delayed physiological effects.

The range of problems related to exposure to pollutants is summarised in **FIGURE 2.**

Anguillicola crassus

Possibly the most successful invasive fish parasite to be introduced into a new locale is the nematode *A. crassus* (**FIGURE 3**) (Kennedy, 1994). The parasite was originally known to exist in the swimbladder of the Japanese eel, *Anguilla japonica* in S.E. Asia without causing severe pathological effects (Kuwahara et al., 1974). However, when *A. japonica* was imported to Europe for re-stocking and aquacultural purposes, the nematode quickly spread from fish farms to infect wild populations of the European eel, *A. anguilla* (De Charleroy et al, 1990). Since its initial identification in Germany in 1982, *A. crassus* has now been found to be present with a high infection prevalence (% of whole population infected) and higher worm loads per fish than *A. japonica,* across most of Europe, North Africa and also in the American eel *A. rostrata* (Moravec, 1992; Fries et al., 1996; Baruš et al., 1999; Evans et al., 2001). There is limited evidence as to the effects of *A. crassus* on the migration of *A. anguilla* but the migration of the parasite's larvae through the swimbladder has been shown to cause damage to the organ (Würtz and Taraschewski, 2000). As the ocean migration occurs at depth (Aarestrup et al., 2009), and thus it can be assumed the swimbladder is required, the damage, along with the blood-feeding nature of the parasite, may make it more metabolically expensive to migrate. Again relating to condition of migrating adults, as lipids are believed to be the main source of energy for the migration of silver eels (van Ginneken and van den Thillart, 2000) if these are used up more quickly in infected eels, it is possible that females will have less available for egg production, should they reach the Sargasso.

Poor condition of escaping adults

The previous sections on reduced freshwater habitat, pollutants and *A. crassus* have referenced poor condition of escaping silver eels, which highlights the synergistic nature of many of these problems. Boëtius and Boëtius (1980) suggested that lipid stores should be greater than 20% in escaping silver eels to allow them to complete the oceanic migration, however, there are studies that have indicated that eels will escape with 'insufficient' fat stores, which indicates that silvering and escapement may occur independently of lipid storage (Svedäng and Wickström, 1997). There are recent studies that have suggested that eels do have sufficient fat stores to make the migration to the Sargasso, and that they are very efficient at swimming (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 eels, and/or extrapolated from short swims. It is essential that a greater understanding of the energetic needs of migrating silver eels is gained. Interestingly, the concept of poor condition—related to food sources and changing oceanic temperatures, two factors linked with the decline of the European eel—has been observed in Atlantic salmon (Todd et al., 2008).

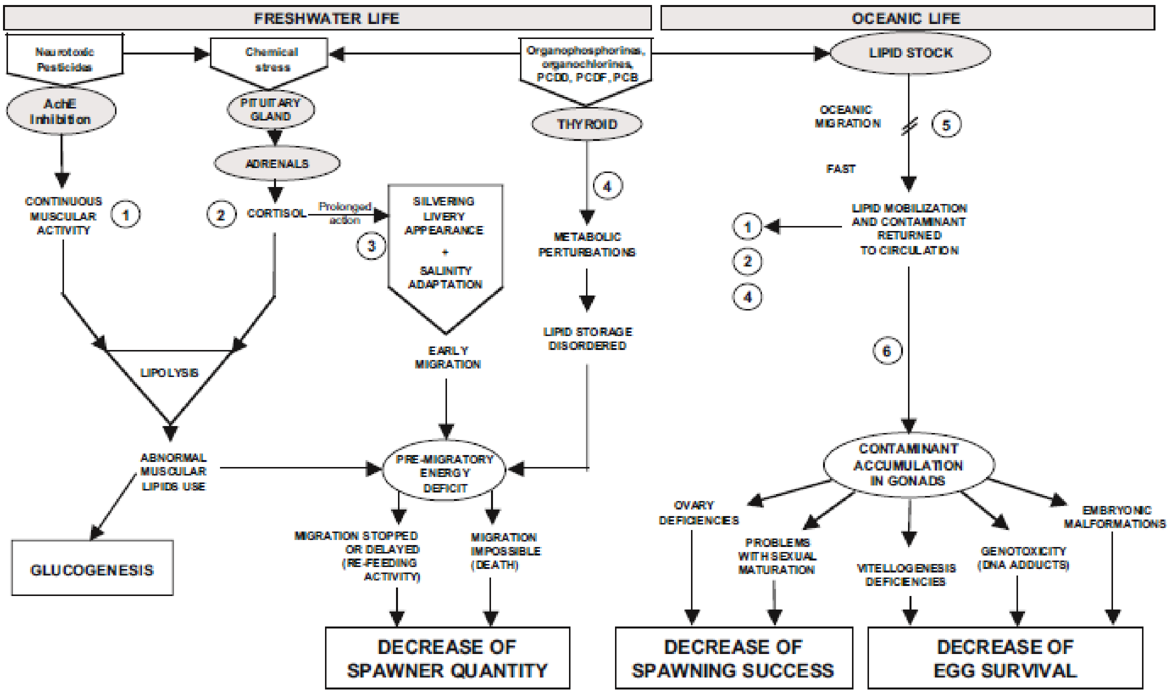

FIGURE 2. **The potential effects of pollutants on the European eel (from Robinet and Feunteun, 2002). (1) Continuous muscle activity results in use of lipid stores. (2) Cortisol release stimulates release of muscle lipid stores. (3) Cortisol triggers early migration in poor condition (4) Thyroid balance is affected and lipid storage is disrupted. (5) Stored toxins are released. (6) Toxins affect gonad function.**

FIGURE 3. **The *A. crassus* wormload from an *Anguilla anguilla* swimbladder. There were >50 parasites in this eel which is 5-10 times greater than would be expected in *A. japonica*. The dark colour of the worm is due to the blood feeding activity of the worm.**

Conclusion

While this report has focussed on the eel life cycle as whole and the threats that may be reducing their numbers, rather than the Sargasso Sea specifically, it is important to highlight the circumstances of the European eel in a holistic manner, and how numerous pressures are impacting the species. There is a general feeling amongst those that study and work to conserve the eel that the marine environment is a part of the eel's life-cycle that will be difficult to incorporate into management and conservation plans, and that efforts should be focussed on the freshwater environment. The creation of a marine protected area in the Sargasso Sea would add to the growing suite of initiatives that are working towards the protection of the European eel. With changing oceanic currents affecting leptocephalus migration, and the available freshwater environment being reduced in both area and quality, it is essential that the adults that manage to escape, spawn, and thus maximise larval production. Protecting the spawning grounds, is the most obvious way of ensuring that the environment for larval production is at its healthiest and that it remains so. Further, the eel is just one part of this ecosystem and the eggs, larvae and carcasses of spent adults are all part of the unique vertical food chain that exists in the Sargasso.

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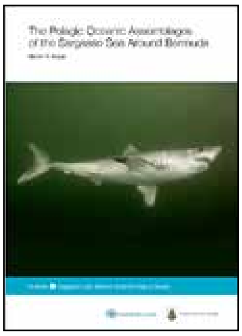

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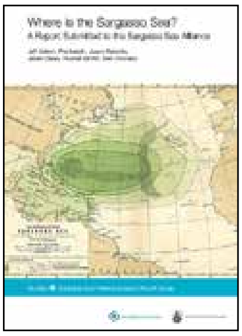

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3

Gollock, M. 2011. *European eel briefing note for Sargasso Sea Alliance.* Sargasso Sea Alliance Science Report Series, No 3, 11 pp.

4

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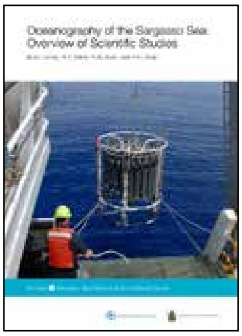

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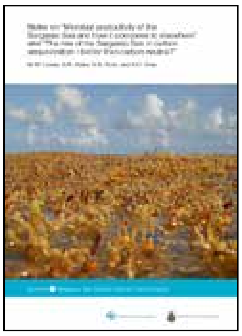

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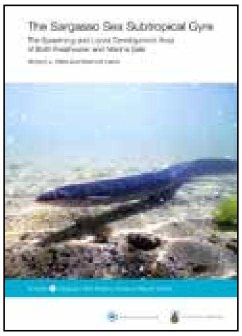

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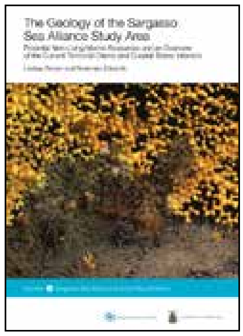

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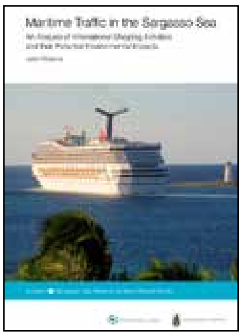

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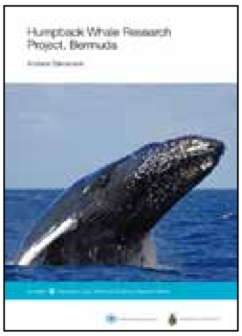

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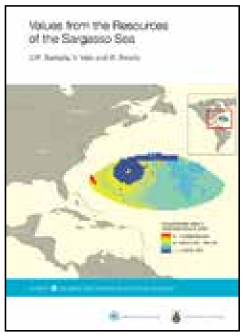

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SARGASSO SEA ALLIANCE

Since the initial meetings the partnership around the Sargasso Sea Alliance has expanded. Led by the Government of Bermuda, the Alliance now includes the following organisations.

PARTNER	TYPE OF ORGANISATION
Department of Environmental Protection	Government of Bermuda
Department of Conservation Services	Government of Bermuda
Mission Blue / Sylvia Earle Alliance	Non-Governmental Organisation
International Union for the Conservation of Nature (IUCN) and its World Commission on Protected Areas	Multi-lateral Conservation Organisation
Marine Conservation Institute	Non-Governmental Organisation
Woods Hole Oceanographic Institution	Academic
Bermuda Institute for Ocean Sciences	Academic
Bermuda Underwater Exploration Institute	Non-Governmental Organisation
World Wildlife Fund International	Non-Governmental Organisation
Atlantic Conservation Partnership	Non-Governmental Organisation