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STOCK ANNEX FOR THE EUROPEAN EEL

Stock-specific documentation of the assessment procedures used by the International Council for Exploration of the Sea (ICES) for European Eel (*Anguilla anguilla*).

Stock	European Eel: *Anguilla anguilla*_SA
Working group	Joint EIFAAC/ICES/GFCM Working Group on Eels (WGEEL)
Last updated	September 2020
Revised by	WGEEL
Timeline of revisions	Version 1.0 – developed 2016, updated 2017 (v1.1); Version 2.0 – developed 2020.

Main modifications This Version 2.0 of a Stock Annex for Eel adds new sections on Data Handling, Analysis, alongside updates to all other sections plus restructuring some parts to reflect most recent priority work areas for the WGEEL.

Contents

1 A. General

1.1 Introduction

The reports of the joint EIFAAC/ICES/GFCM Working Group on Eels (WGEEL) document the ongoing process of describing the stock of the European eel, associated fisheries and other anthropogenic impacts, and developing a methodology for giving scientific advice on management to effect a recovery in the international, panmictic European eel stock. The archive of WGEEL reports is available from the ICES Publications section.

EIFAAC is the European Inland Fisheries and Aquaculture Advisory Commission.

GFCM is the General Fisheries Commission for the Mediterranean.

The Specific Grant Agreement (Administrative Agreement) between the European Union (EU) and ICES requires an assessment of the status of the eel stock every year. The annual ToRs are designed with this in mind but there are *ad hoc* requests too. Several metrics have been developed which act as the basis of the annual assessment – these are populated using recruitment and landings data that are collated by the WG via an annual Data Call. Since 2012, national and regional biomass and anthropogenic mortality stock indicators are reported every three years by EU Member States, in accordance with the Council Regulation (EC) No 1100/2007 (the so called 'Eel Regulation') (European Council, 2007). ICES is currently considering how these reported Indicators could be incorporated into a form of advice.

This document, the Stock Annex for the European Eel, describes the characteristics of the eel stock, the development of the ICES advice, the management frameworks and the analysis of the recruitment for provision of advice. Chapter A is intended to give an overview of the main features of the eel biology and factors limiting production in the wild: this text is not intended to be exhaustive. Additional source material should be consulted for the detail.

Annexes SA1 and SA2 of this document provide a list of Abbreviations and a Glossary of Terms used in this Stock Annex.

The United Nations Food and Agricultural Organization (FAO) makes the following distinction between fish *stock* and fish *population*;

"Fish stock or fish resource means the living resources in the community or population from which catches are taken in a fishery. Use of the term fish stock usually implies that the particular population is more or less isolated from other stocks of the same species and hence self-sustaining". The CFP definition of a stock is "a marine biological resource that occurs in a given management area" (European Council, 2013), albeit that European eel being catadromous does not only occupy marine waters.

The problem is that there can be multiple scales of 'management area' for the European eel, from the whole stock (oceanic and continental waters) on which the ICES Advice is made, to that of river basin districts, river basins or lagoons.

Thus, since the European eel is fished upon, the population is referred to by WGEEL as a stock. Furthermore, the eels within a national or regional area are referred to as the 'local stock' or 'stock in UK waters', for example.

1.2 WGEEL directly supports certain Advisory and/or Management Bodies

1.2.1 International Council for the Exploration of the Sea

ICES is an intergovernmental organization that develops science and advice to support the sustainable use of the oceans through the coordination of oceanic and coastal monitoring and research. ICES advises international commissions and governments on marine policy and management issues.The ICES area of competence extends into the North Atlantic Ocean, the Arctic, the Mediterranean Sea, the Black Sea, and the North Pacific Ocean with 20 Member Countries.

The content of ICES scientific advice is the responsibility of the ACOM and not subject to modification by any other ICES entity. ACOM has one member from each member country, under the direction of an independent chair appointed by the Council and works on the basis of scientific analysis prepared in the ICES expert Working Groups. The advisory process includes peer review of the analysis before it can be used as basis for the advice.

1.2.2 European Inland Fisheries and Aquaculture Advisory Commission

The role of EIFAAC is established under the provisions of Article XIV of the FAO Constitution to promote the long-term sustainable development, utilization, conservation, restoration and responsible management of European inland fisheries and aquaculture. This is based on the best available scientific advice, the application of an ecosystem approach, the precautionary approach, and the need to safeguard biodiversity. EIFAAC seeks to support sustainable economic, social, and recreational activities towards these goals through providing advice, information, and coordination, encouraging enhanced stakeholder participation and communication, and the delivery of effective research. The area of competence covers all of Europe, with the exception of parts of the Balkans, together with Turkey and Israel, and has membership from most of the countries including the EU.

1.2.3 General Fisheries Commission for the Mediterranean

The GFCM is a regional fisheries management organization (RFMO) established under the provisions of Article XIV of the FAO Constitution. The GFCM initially started its activities as a Council in 1952, when the Agreement for its establishment came into force, and became a Commission in 1997. The main objective of the GFCM is to promote the development, conservation, rational management, and best utilization of living marine resources as well as the sustainable development of aquaculture in the Mediterranean, the Black Sea and connecting waters. Membership consists of 23 countries and the EU.

1.3 Life cycle

European eel life history is complex and atypical among aquatic species, being a long-lived semelparous and widely dispersed stock (Figure 1). The whole stock is generally considered to be panmictic (Palm *et al*., 2009), however, there is no full and final evidence (e.g. Baltazar-Soares *et al.,* 2014). Data indicate the spawning area is in the southwestern part of the Sargasso Sea (McCleave *et al*., 1987; Tesch and Wegner, 1990; Westerberg *et al.,* 2018) with mating taking place across a longitudinal range of about 2000 km (Miller *et al*., 2019). The *leptocephalus* larvae drift with the ocean currents to the continental shelf of Europe and North Africa where they metamorphose into glass eels and enter continental waters. The growth stage, known as yellow eel, may take place in marine, transitional, or freshwaters. This stage may typically last from two to 25 years but could exceed 50 years. Thereafter, the eel undergoes a metamorphosis to the silver eel stage in readiness for the migration to the spawning area. Age-at-silvering varies according to temperature, ecosystem characteristics, and density-dependent processes. The period of the European eel life cycle is generally shorter for populations in the southern (warmer) part of their range compared to the (colder) north. Silver eels then migrate to the Sargasso Sea where they spawn and die, an act not yet witnessed in the wild (ICES, 2014).

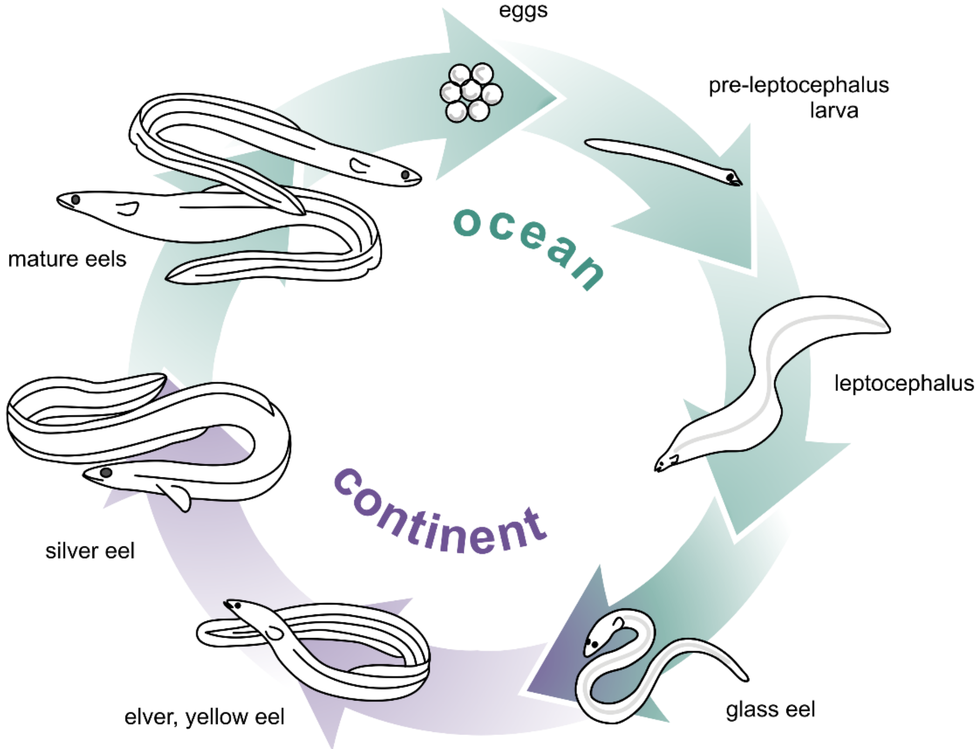


Figure 1. The life cycle of the European eel. The names of the major life stages are indicated; spawning and eggs have never been observed in the wild and are therefore only tentatively included. Source: Henkel *et al.*, 2012.

1.4 Natural Range

The continental phase of European eel is distributed across the majority of coastal countries in Europe and North Africa, with its southern limit in Morocco (30°N) and its northern limit situated in the Barents Sea (72°N) and spanning all of the Mediterranean basin (Figure 2, Table 1). Note that the Black Sea area has been made exempt from the Eel Regulation (European Council, 2007) on the basis that it does not constitute significant natural range today, but is included in Figure 2 below because of its historical context.

The spawning area in Sargasso Sea is thought to be situated quite narrowly between latitudes 23° and to 29.5°N but on a wider longitudinal range from 48° to 78°W (McCleave *et al*., 1987; Tesch and Wegner, 1990; Miller *et al.*, 2019).

At the continental scale, eels have a wide and scattered distribution and are found in virtually all types of waterbodies from rivers and lakes to estuaries and coastal waters.

In biology, the *range* of a species is the historical geographical area where the species may be found or has been found. The *distribution* is the geographical area where it is currently found (Colautti and MacIsaac, 2004).

Given the diversity in environmental characteristics and distance from continental areas to the Sargasso Sea, it has been suggested that some areas might make varying contributions to the spawning stock (Kettle *et al.*, 2011). However, in the absence of data to support this theory, it is assumed that all areas have the same reproductive potential.

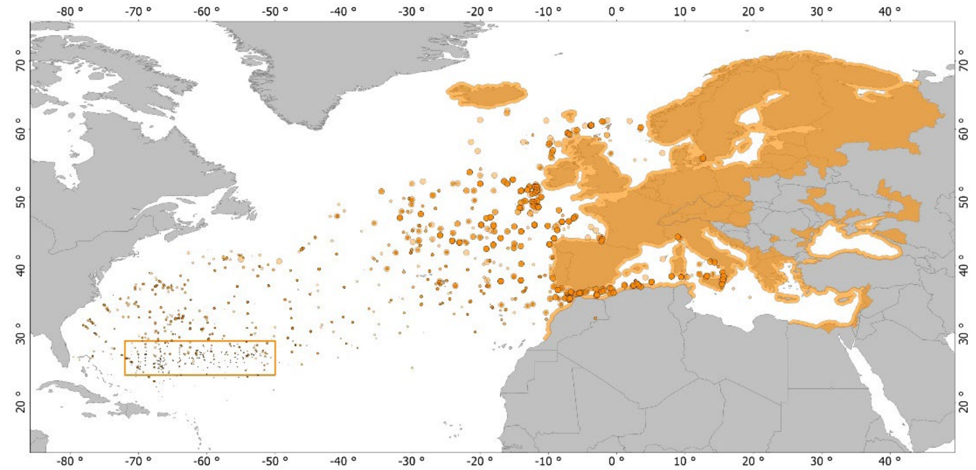


Figure 2. The distribution area of European eel. Points represent the occurrence of leptocephalus larvae caught during scientific surveys. The size of the points is proportional to the number of larvae (sources ICES database, www.Fishbase, C. Durif).

Table 1. Countries within the natural range of *Anguilla anguilla*.

Country	Code	EU/non-EU	EIFAAC[1]	ICES[2]	GFCM[3]
Albania	AL	non-EU	x		x
Algeria	DZ	non-EU			x
Austria	AT	EU	x		
Belarus	BY	non-EU			
Belgium	BE	EU	x	x	
Bosnia-Herzegovina	BA	non-EU	x		
Bulgaria	BG	EU	x		x
Croatia	HR	EU	x		x
Cyprus	CY	EU	x		x
Czechia	CZ	EU	x		
Denmark	DK	EU	x	x	
Egypt	EG	non-EU			x
Estonia	EE	EU	x	x	
Finland	FI	EU	x	x	
France	FR	EU	x	x	x
Georgia	GE	non-EU			
Germany	DE	EU	x	x	
Greece	GR	EU	x		x
Hungary	HU	EU	x		
Iceland	IS	non-EU	x	x	
Ireland	IE	EU	x	x	
Israel	IL	non-EU	x		x
Italy	IT	EU	x		x
Latvia	LV	EU	x	x	
Lebanon	LB	non-EU			x
Libya	LY	non-EU			x
Lithuania	LT	EU	x	x	
Luxembourg	LU	EU	x		
Malta	MT	EU			x
Moldova	MD	non-EU			
Monaco	MC	non-EU			x
Montenegro	ME	non-EU			x
Morocco	MA	non-EU			x
Netherlands	NL	EU	x	x	
North Macedonia	MK	Non-EU			

[1] The EU is also a member of EIFAAC.

[2] Canada and the USA are also members of ICES.

[3] The EU and Japan are also members of GFCM.

Country	Code	EU/non-EU	EIFAAC[1]	ICES[2]	GFCM[3]
Norway	NO	non-EU	x	x	
Poland	PL	EU	x	x	
Portugal	PT	EU	x	x	
Romania	RO	EU	x		x
Russia	RU	non-EU		x	
Serbia	RS	non-EU			
Slovakia	SK	EU	x		
Slovenia	SI	EU			x
Spain	ES	EU	x	x	x
Sweden	SE	EU	x	x	
Switzerland	CH	non-EU	x		
Syria	SY	non-EU			x
Tunisia	TN	non-EU			x
Turkey	TR	non-EU	x		x
Ukraine	UA	non-EU			
United Kingdom	GB	non-EU	x	x	
Vatican	VA	Non-EU			

1.5 Diversity in the stock

1.5.1 Size and age at silvering

Eels are a long-lived species with the yellow eel stage lasting 2–20+ years for males or 5–50+ years for females (Dekker, 2002). The age at which eels transform to the silver stage is hugely variable, and dependent on many factors. These include latitude, temperature, food availability, barriers to migration, growth rate and sex. Durif *et al.* (2009, 2020) examined datasets from across the species distribution in relation to age at silvering, which indicated a range of 2 to 15 years for males and 2 to 30 years for females.

Dekker *et al.* (1998) described the ranges of silver eel sizes as 21.2–44.4 cm for males and 26.4–101.0 cm for females. When compared to other fish, growth is slow and variable, with perhaps an average of 3–4 cm a year (Dekker, 2002) but as low as 1 cm a year or less in the northern areas (e.g. Poole *et al.*, 1992; 1996a,b; J. D. Godfrey, personal communication) and as high as 15 cm a year in the more southern areas (Dekker, 2002).

The mean length of the female silver eel increases with latitude while the same relationship for males is absent (Figure 3, left panel) and there is also an increase in age with latitude (Figure 3, right panel).

These differences in growth rates and ages-at-silvering mean that the spawning stock in any one year could consist of eels of a large range of ages (e.g. 5 to 50 years). It is not possible to determine the number of age groups that contribute successfully to the spawning effort (Daverat *et al.*, 2012).

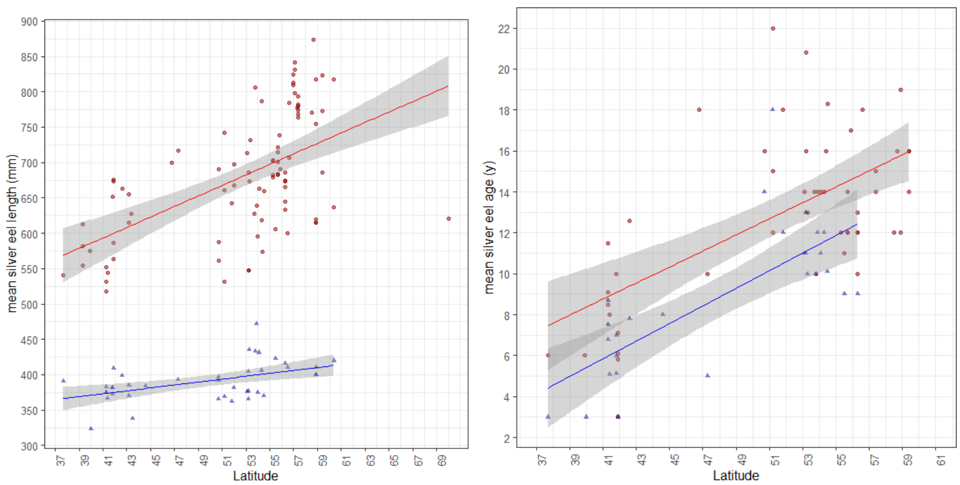


Figure 3. Left panel: Mean silver eel length according to latitude from twelve different countries (66 different locations), blue: male; red: female (ICES, 2010b): Right panel: Mean silver eel age according to latitude from twelve different countries, blue: male; red: female (ICES, 2010b).

1.5.2 Sex ratio

Catadromous eels enter continental habitats as sexually undifferentiated glass eels and develop into males and females before migrating back to sea as silver eels. Females develop ovaries directly from the ambiguous primordial gonad (Geffroy *et al.,* 2013) whereas males pass through a transitional intersexual stage before developing testes.

In the European eel, this sex differentiation (sex-specific gonad development) generally first occurs at 20–30 cm length during the yellow eel stage (Geffroy and Bardonnet, 2016). The male life span is approximately a third to a half compared to females, which implies that in the spawning area, the male:female ratio should be about 2–3:1 (Tesch, 2003; Geffroy and Bardonnet, 2016). This conforms with observations at several continental sites that long-living females are often substantially more abundant than less long-living males (Geffroy and Bardonnet, 2016).

Sex differentiation appears to be governed more by environmental factors than genetics. High eel densities tend to favour a larger proportion of males. This could be triggered by higher levels of the stress hormone cortisol at high densities (Geffroy and Bardonnet, 2016).

Density-dependent sex ratio has also been suggested to be an adaptive strategy to achieve maximum fitness. Males which exhibit a time-minimizing growth strategy by maturing as soon as possible would predominate at high densities; while at low density levels females, which postpone maturation with a size-maximizing growth strategy to attain higher fecundity, would be favoured (Helfman *et al*., 1987; Larsson *et al*., 1990; Vøllestad, 1992). High competition for food might make it difficult for a female to both produce enough eggs and to store enough energy to successfully migrate back to the Sargasso Sea.

Sex ratio in silver eel can vary to a great extent in eel stocks, in time as well as in space (e.g. Parsons *et al*., 1977; Rosell *et al*., 2005; Bark *et al.,* 2007; Poole *et al.,* 2018). Proportions of males in the silver eel migrations, of both American and European Eel (Helfman, 1988; Oliveira, 1999; Jessop, 2010; Vøllestad, 1992) tend to be lower in more northern latitudes and with increasing distance from the Sargasso Sea (Kettle *et al.,* 2011) and are higher in areas where eel density is high and food abundant, such as Mediterranean lagoons (De Leo and Gatto, 1996). There are also tendencies towards a higher male percentage in the lowest part of catchments (i.e. estuaries and lagoons) (Ibbotson *et al*., 2002).

During the period 1970–2017, the proportion of male silver eel has been falling in the Norwegian river Imsa, and in the Irish river, the Burrishoole (Poole *et al.,* 2018). Density-dependent changes in sex ratio were also evident in rivers in England and Wales (Bark *et al.,* 2007). In rivers where eel populations were stable, the populations were male biased, while rivers with declining populations were female biased.

One management implication from studies of sex ratios is that adding eels from dense, male-dominated conditions in aquaculture to the spawning stock may increase the number of reproductively redundant males at the spawning area (Geffroy and Bardonnet, 2016).

1.5.3 Natural mortality

There are hardly any empirical data on natural mortality (M) rates for eel. A value of $M=0.1386\ yr^{-1}$ is frequently applied, giving Dekker (2000a) as a reference. However, Dekker assumed that value to be an empirically sound level of mortality rate. Indeed, some studies report density-dependent natural mortality of post-settlement stages rather than a fixed value (e.g. Vøllestad and Jonsson, 1988; De Leo and Gatto, 1996; Lobón-Cerviá and Iglesias, 2008; Bevacqua *et al*., 2011).

Beaulaton and Briand (2007) reviewed pre-settlement rates for glass eels. Bevacqua *et al*. (2011) calibrated a general model for natural mortality for the post-settlement yellow eel stage, considering the effects of body mass, temperature, stock density and gender. Results showed eel mortality values appreciably lower than those of most fish, most likely due to the exceptionally low energy consuming metabolism of eel. These findings have been confirmed by Dekker (2012) who found that natural mortality on Swedish restocked eels has been much lower than the usual estimates (M=0.10 yr^{-1}) (ICES, 2012a).

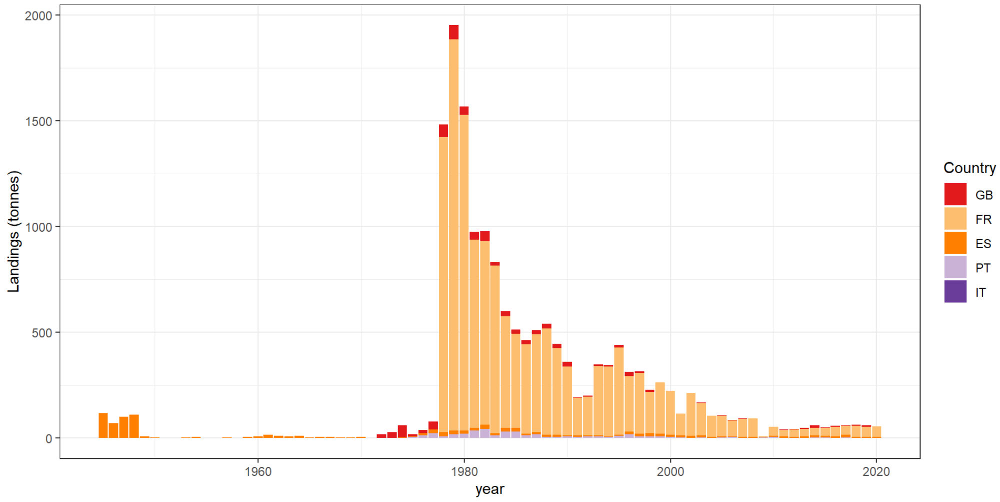
Many species are known to consume the European eel (ICES, 2016a). For instance, in the Baltic Sea, cormorants have been estimated to take eel at the same order of magnitude as the commercial fisheries in the coastal and marine zones (Hansson *et al.*, 2017). Cormorants also consume eels in inland waters (Thalinger *et al.*, 2016). Other birds may prey on eel, albeit probably to a less considerable extent (Salman, 2017). Fish prey on eels also, including for example Guilleraut *et al*. (2017). During the oceanic migration, cetaceans, and endothermic fish – e.g. tuna and some shark species – have been identified as preying upon eels (Wahlberg *et al.*, 2014; Righton *et al.*, 2016). Seals have been observed to eat eel in or near fishing gear (Karl Lundström, pers. comm.).

1.6 Factors affecting eel production and/or escapement

There are many natural or human-induced factors affecting eel production and/or escapement. In line with the Ecosystem Approach, these factors must be accounted for in analysis and management. This section summarises the most important of these factors. This section is closely associated with the stock indicator ΣA (anthropogenic mortality rate), which is the sum of all fisheries (ΣF) and non-fisheries (ΣH) anthropogenic mortalities. There have been varying degrees of progress in mitigating the effects of these factors, but for the sake of brevity, they have not been addressed here.

1.6.1 Fisheries

Fisheries have taken place over the whole continental range and on all continental life stages (i.e. glass, yellow and silver eels), and most often occur as scattered small-scale rural enterprises (Dekker, 2004). Eel are traded both locally and internationally. Total landings and effort data are incomplete. There is a great heterogeneity among the time-series of landings because of inconsistencies in reporting by, and between, countries, as well as incomplete reporting. Changes in management practices have also affected the reporting of non-commercial and recreational fisheries. This said, there have been concerted efforts to improve data reporting, collection, and analysis. For example, a more structured Data Call hosted by ICES, EIFAAC and GFCM and covering all natural Range States of the European eel was implemented in 2017. This was considered an effective mechanism to significantly improve the situation of data provision and use; refer to the most recent ICES WGEEL report for more information. Figure 5 presents the total landings for all life stages as reported by countries to the WGEEL.



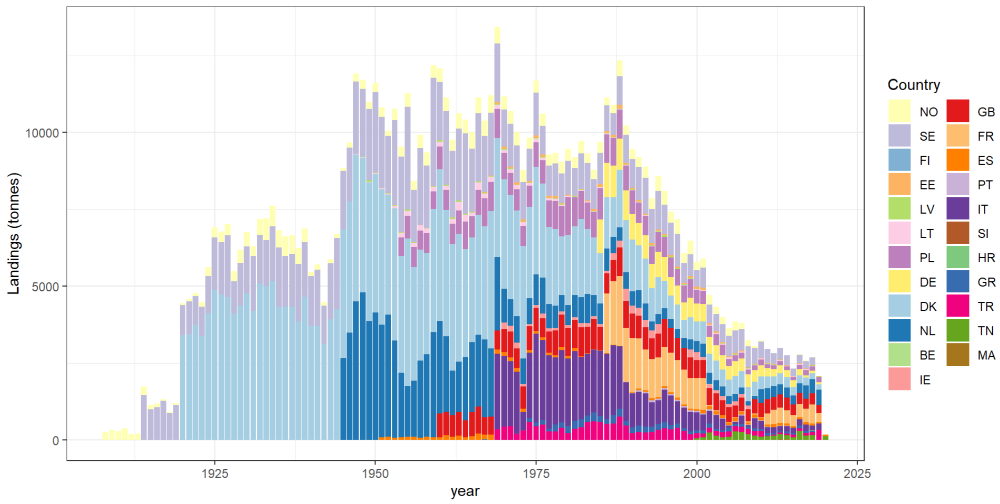


Figure 5. Time-series of total landings weight (tonnes) (upper = glass eels; lower = yellow and silver eels) from countries reporting to the WGEEL via the 2020 ICES Data Call on eel. See the chapter on Data for details relating to GLM analysis to account for missing datapoints.

1.6.1.1 Glass eel fisheries

The glass eel fisheries are mainly concentrated around SW England, the Bay of Biscay area and along the Mediterranean coasts of Spain and Italy and Morocco (ICES, 2019; 2020). Note that some countries have reduced or closed their fisheries in response to the Eel Regulation. Glass eels arrive – and as such, become susceptible to exploitation by local fisheries – in waters off Portugal and Spain in October–November and the UK, northern France, and Ireland from January onwards (ICES, 2020a). Recruits to the Baltic must travel through the North Sea. They are pigmented by arrival to the Baltic and migration may take several years after their cohort first arrived in Portugal (ICES, 2020a). The same general principal applies to other areas of the eels' distributional range (e.g. Northern Africa, Mediterranean): the arrival of glass eel occurs later with increasing distance from the spawning site (ICES, 2020a). This takes place in winter and early spring when they arrive on the European coast. The glass eel fishing gear consists of both active and passive gears – most are commercial fisheries but there are recreational fisheries in Spain and used to be in France. The active gear includes different hand-held or ship-borne nets while passive gear is composed of traps and fykenets kept fixed in a flow of water (Dekker, 2002). The glass eels caught are used for restocking, aquaculture or consumption (ICES, 2013b). The Eel Regulation (Article 7.1) states that '*…60% of the eels less than 12 cm in length caught annually should be reserved for* *restocking'*. Note too that illegal fishing and illegal trade occurs (see Section 1.6.1.4) and issues with traceability schemes for landings prevent a complete understanding of the ultimate destination of some landings.

1.6.1.2 Yellow eel / Silver eel fisheries

Yellow and silver eel fisheries – both commercial and recreational – have occurred across the distribution area of the species, from the Mediterranean basin to northern Scandinavia (Dekker, 2003), with some countries having reduced or closed their fisheries in response to the Eel Regulation. The largest landings have been reported from Denmark, France, Italy, Germany, the Netherlands, Poland, Sweden, Tunisia and the UK (Figure 5; ICES, 2020). Various types of gear are used in the yellow and/or silver eel fisheries, including different nets, traps, hooks, etc. in saltwater, brackish water, and freshwater (Dekker, 2003). The eel fisheries, located in the coastal and rural areas all over Europe are rather small-scale with large-scale fishing making up less than 5% (by weight) of the total European landings (Dekker, 2002). According to Moriarty and Dekker (1997) small-scale fisheries employed thousands of people across Europe in the 1990s but the number appears to have declined although the data on number of fishing licences are incomplete (ICES, 2019). In many of the European countries, yellow and silver eel landings were combined in the reported landings (ICES, 2014). Directed fisheries for silver eel in coastal waters are specific to the Baltic/Kattegat, where poundnets and fykenets are used (Dekker, 2003; Wickström *et al.*, 2019). Yellow and silver eel caught are mainly sold for consumption, either locally or after export to neighbouring countries (ICES, 2015a).

1.6.1.3 Recreational and non-commercial fisheries

The WGEEL considers the term Recreational and non-commercial fishing to mean the capture or attempted capture of living aquatic resources mainly for leisure and/or personal consumption. Recreational and non-commercial fishery covers active fishing methods including rod, line, spear, and hand-gathering and passive fishing methods including nets, traps, pots, and setlines. In many countries, the recreational fishery contributes significantly to the total catch of yellow eel. Usually a licence or permit is required to be able to fish recreationally, however there are countries where the access to the fishery is free or based on private ownership (Dekker, 2005). Data on recreational fisheries are collected but the inconsistencies in reporting make assessment unreliable (ICES, 2014). Note that in some countries the possession and killing of eel caught by recreational fisheries is not permitted. However, the nature of some fishing gears used by recreational fisheries means it is not possible to 'ban' the capture of eel (e.g. one cannot command an eel to not take a bait) and therefore it is the possession and killing that is controlled rather than the capture – thus, catch may occur but not landings (WGEEL uses the term Landings to mean fish that are brought ashore whereas the term Catches means fish that are caught but not necessarily landed). Post-release mortality may be substantial and merits further investigation (ICES, 2016a; Weltersbach *et al.*, 2016, 2018).

1.6.1.4 Illegal, Unreported and Unrecorded (IUU) fishing and trade

Illegal, unreported, and unregulated fishing (IUU) is by its nature very difficult to quantify, and misreporting may therefore be substantial (CITES, 2018). Most countries do not report any IUU in their Country Reports. Organised illegal glass eel trade is supplied by both legally caught, and IUU-caught eel, and lack of traceability of the former is problematic (CITES, 2018). This trade is considered high priority by the

Europol (the EU's law enforcement agency) among environmental crimes, due to its economic significance, the poor status of the eel stock, and the large number of organisms affected (UNODC, 2020).

In addition, illegal eel trade from Range States is an issue of concern for the Convention on International Trade in Endangered Species (CITES, 2018). To summarize, while IUU fisheries certainly exist for glass, yellow and silver eel, there are insufficient data available to quantify their effect on the total stock size or status at any level of certainty.

1.6.2 Hydropower installations

Hydropower has been recognized as one of several factors contributing to the decline in the eel population (ICES, 2002), and anguillids tend to have considerably greater mortality rates from downstream passage at hydropower stations than other fish species (Hadderingh and Bakker, 1998). Mortality and injury due to hydropower stations can occur at inadequate deflection screens, in turbines and in the tail races. Note that impacts due to barriers to migration are dealt with later in this document. The rate of injury depends on the position of the turbine in the river bed (eels migrate in the main current), the working regime (switching off the turbine during the main migration period reduces the damage), the efficacy of the protection screen, the turbine type, the water flow rate, the head height, characteristics of the turbine, the presence and location of spillways, and the characteristics (e.g. length distribution) of the migrating eel population itself.

Overall mortality rates (i.e. the proportion of eel killed) when passing a hydropower station also depend on 1) the proportion of eel moving into the power station intake, 2) the mortality rate of those moving into the power station (turbine mortality, impingement on the trash rack, etc.), and 3) the mortality rate of those using alternative routes (bypass channels, old river bed, etc.). Estimates of the mortality rates on downstream migrating eels caused by hydropower facilities are given in Table 2. The table summarizes field studies from several eel species (*A. anguilla*, *A. rostrata*, *A. dieffenbachii* and *A. australis*). It should be noted that in many rivers there are multiple hydropower installations and consequently there are cumulative mortalities summing up to considerable mortality rates in such rivers.

The most comprehensive estimation comes from a study (Gomes and Larinier, 2008) that developed predictive equations of mortality rates based on eel body length, turbine diameter, nominal discharge and blade velocity for Kaplan turbines. According to this model, based on 71 field studies, damage rate increases with fish length and is generally higher on small turbines with high rotation speeds than on slow, large diameter turbines. Damage is also lower at full opening compared to reduced opening (Gomes and Larinier, 2008).

Passing through a hydropower turbine, an eel can be injured in a variety of ways including collision with pump structures such as blades, barotrauma as a result of changes in pressure, and physical damage from turbulence and shear stresses (Čada, 2001; Deng *et al*., 2005; Pracheil *et al*., 2016). Mortalities from such impacts are not instantaneous and may be delayed for hours or even days (Stanford, 2017; Winter *et al*., 2012).

In the absence of direct turbine blade strikes, and the resulting obvious external damage, barotrauma impacts produce significant internal damage, which leaves few external signs of a moribund eel (Abernethy *et al*., 2001; Stanford, 2017). Whilst the immediate lethal impact of hydro/pumping installations is known and quantified, (Winter *et al*., 2012) less is known of the sub-lethal effects or the moribund status of silver eels as a direct consequence of such internal damage in the days following passage. The University of Veterinary Medicine, Hannover investigated 77 silver eels from the river Weser and found by X-ray that 45% of the externally undamaged eels and in total 53% of all investigated eels showed damage to the spinal column (Jung-Schroers, 2019). The limited data existing on barotrauma and other delayed mortality effectively mean that direct mortality assessments should only be considered as a minimum. The above impacts can also apply in relation to both pumping stations and cooling water intakes (see below). See also ICES (2019) for a review of the impacts of hydropower, pumping stations and cooling water intakes.

Table 2. Mortality estimates of eel at hydropower generating plants according to type of turbine and presence/absence of a mitigation system (bypass, fish-friendly turbine). The number of studies used to calculate the average mortality rates is given in brackets (from ICES, 2011a). Note, there is no direct correspondence between the two columns.

	TURBINE MORTALITY %	TOTAL MORTALITY %
Average (all turbines)	28 (29)	36 (10)
Average francis	32 (7)	52 (3)
Average kaplan	38 (9)	28 (6)
Average other turbines (mix, propeller, unknown)	21 (11)	40 (1)
Average no bypass or unknown	32 (24)	44 (6)
Average with bypass	9 (5)	26 (4)

1.6.3 Pumping stations

Pumping stations can cause damage and direct or delayed mortality in fish when they pass through a pump. In addition, a pumping station functions as a barrier for both upstream and downstream migration of diadromous fish like eel. The risk of being captured by commercial or recreational fishermen is higher in the vicinity of pumping stations when migratory fish aggregate while searching for an opportunity to pass. Furthermore, fish that are damaged and/or disorientated after passing through pumps will make easier prey for piscivorous fish or birds.

Various factors, such as pump and propeller type, head of water, capacity, and timing of operation, are known to influence the level of impact on eel (ICES, 2011a) and some impact estimates are summarised in Table 3. Buysse *et al*. (2014) demonstrated that propeller pump and Archimedes screw pumps cause eel mortality in lowland canal situations and therefore may significantly threaten escapement targets set in Eel Management Plans (EMPs). Buysse *et al*. (2015) assessed maximum mortality rates ranging from 19 ± 4% for the large de Wit Archimedes screw pump, to 14 ± 8% for the small de Wit Archimedes screw pump, based on the condition of the fish and injuries sustained over a 12–month period (2012–2013).

Table 3. Mortality estimates of eel passing through pumping stations of various types. The number of studies used to calculate the average mortality rates is given in brackets (summarised from ICES, 2011a). Some additional mortality consequent on undetected internal injury may have occurred in a few studies. Note, there is no direct correspondence between the two columns.

	Damaged %	Mortality %
Average (all pumps)	30 (18)	26 (27)
Average Water wheel	0 (1)	0 (1)
Average Archimedes	12 (4)	5 (7)
Average Centrifugal	1 (3)	13 (4)
Average Turbine-Archinmedes	0 (1)	0 (1)
Average Propeller-Centrifugal	-	11 (2)
Average Propeller	60 (8)	60 (9)
Average Propeller (closed)	-	35 (2)
Average Hidrostalpump	<3 (1)	0 (1)

1.6.4 Cooling waters

Intakes used for water supply represent another anthropogenic threat to aquatic ecosystems and fish stocks. When water is abstracted from surface waterbodies, there is a risk that fish and other organisms will be drawn in. This may prevent fish from migrating effectively and lead to death or injury to fish at screens, turbines and pump mechanisms (Environment Agency, 2011). Eels can get caught up in intake flows and screens at any stage of their life. However, they are most at risk during their upstream and downstream migrations within freshwaters (Environment Agency, 2011). The degree of risk or damage is highly site-specific, and depends largely on the actual conditions at each location (e.g. type of power plant or technical facility in general, capacity of water intake, configuration and design of mitigation measures including screens and behavioural deterrent systems, biological characteristics of the potentially impacted species). It should also be noted that outfall sources can also divert and delay eel migrations leading to additional mortality.

1.6.4.1 Intakes

Adult silver eels are particularly vulnerable when they actively follow currents downstream ('positive rheotaxis').

Glass eel and elvers are also at risk when they must pass areas with intakes, which sometimes have enormous capacities for water intake.

1.6.4.2 Outfalls

Juveniles (glass eels, elvers or smaller yellow eels) are more at risk during active migration upstream ('negative rheotaxis').

1.6.5 Parasites and diseases

Infestation of the introduced swimbladder nematode *Anguillicola crassus* (Kuwahara *et al.*, 1974), now widespread across Europe, may affect the capacity of European eels to complete their spawning migration. The impacts include a negative effect on silver stage physiology (Fazio *et al.*, 2012); swimbladder damage which impairs swimming performance (Palstra *et al.*, 2007); and a reduced ability to cope with high pressure during their reproductive migration (Vettier *et al.*, 2003, Sjöberg *et al.*, 2009). Prevalence of the parasite has been found to be higher in smaller eels, potentially due to their preference for invertebrate prey, which can act as intermediate hosts for *A. crassus* (Barry *et al.*, 2017, Hafir-Mansouri *et al.*, 2018).

Various diseases are known to affect eel, but the most important are probably the viruses, Anguilla herpesvirus 1 (AngHV-1), Eel Virus European (EVE) and other aquabirna viruses (IPNV) and Eel Virus European X (EVEX) (ICES, 2015c).

1.6.6 Contaminants

A variety of contaminants have been found to affect the eel and impacts were reported on several levels of biological organization from subcellular, organ, individual up to even population level (Belpaire *et al.*, 2019). The toxic effects can occur at different periods in the eel's life cycle: during growing, silvering, migration, the development of reproductive cells, and larval stage (Geeraerts and Belpaire, 2010). Contamination (e.g. by PCBs) might impair fertility (Palstra *et al*., 2006) and affect lipid metabolism resulting in insufficient energy reserves to power successful migration and reproduction (Belpaire *et al*., 2009). Evidence was found that persistent organic pollutants such as PBDEs, their brominated and chlorinated substitutes (Sühring *et al.*, 2015) as well as PCBs (Freese *et al.*, 2017) are redistributed from muscle tissue to gonads and eggs. Freese *et al*. (2015) found habitat-dependent and life-history stage-related accumulation of several PCBs, leading to the conclusion that the contamination status of water systems is fundamental for eel performance and should be considered in stock management and restocking programmes.

Brinkmann *et al*. (2015) developed a physiologically-based toxicokinetic model to predict the uptake and distribution of water-borne organic chemicals in the whole eel and in different tissues at any time during exposure. The authors conclude that this model has the potential to help identify suitable habitats for restocking under EMPs.

Most reports deal with the yellow eel stage and a wide range of effects have been demonstrated. However, in this phase, the effects are apparently less harmful, because contaminants are stored in lipid tissue while growing. It is assumed that most toxic effects start during the silvering phase, when morphological and physiological changes take place initiated by hormonal changes. Meanwhile, fat is being metabolized, resulting in a remobilization of the lifetime accumulated contaminants. Eels are more vulnerable to pollution than many other fish as they accumulate contaminants to a much higher degree (Belpaire and Goemans, 2008). However, many knowledge gaps remain, especially concerning the impacts (dose-effect relationships) of contaminants and diseases on both migration and reproductive success of the European eel.

1.6.7 Climate Change

Climate change is resulting in increased air (Figure 6) and ocean temperatures, drought, melting ice and snow, rising sea levels, increased rainfall, flooding, and other effects. Recent reports also suggest that the intensity and frequency of extreme rainfall and storm events are expected to increase in response to increases in atmospheric heat and moisture (Andersson *et al.*, 2020; Kelly *et al.*, 2020). The "State of the Climate" Annual Reports issued by the American Meteorological Society (BAMS: Blunden & Arndt, 2020) provide global and regional annual updates (https://www.ametsoc.org/index.cfm/ams/publications/bulletin-of-the-american-meteorological-society-bams/).

Besides anthropogenic factors acting during the continental life stages of eel, climatic and oceanic factors influence the variability and population dynamics of the eel stock at both the stock and local level. Key variables that affect eel include temperature, salinity, river productivity and in the ocean, sea temperature, and direction and strength of currents. Climate change can be expected to influence all these factors. The following sections are not intended to provide an exhaustive review but to point to important factors that may influence the eel stocks, stock assessments and future management under a changing climate.

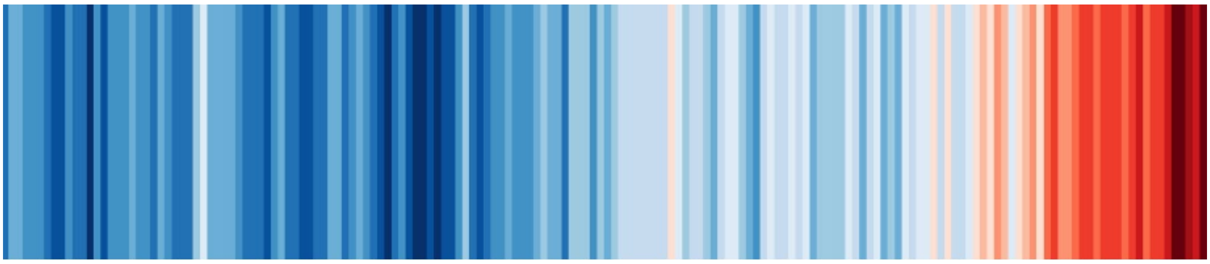


Figure 6. Warming stripe developed by Ed Hawkins (Reading University, UK). Each vertical line shows the global average temperature of a whole year, starting at 1850 on the far left and ending with 2019 on the far right. The underlying data are from the HadCRUT4.6 dataset of the UK Met Office Hadley Centre (taken from: Blunden and Arndt, 2020).

1.6.7.1 Continental Waters

Climate change is considered to be one of the principal threats to biodiversity and to the structure and functioning of ecosystems (see Review: Graham and Harrod, 2009), placing a further stress on fish that are already subject to a series of natural and anthropogenic stressors: species introductions, pathogens and disease, predation; poor catchment management, prey availability in both freshwater and marine environments, intensive aquaculture, overfishing, river obstacles such as dams and weirs, pollution, drought and water extraction. Often, these factors work in concert to affect a fish population and accelerating climate change will likely further compound adverse anthropogenic effects on fish populations.

Warming of inland waters has been ongoing since at least the mid–1990s, with a mean warming trend of lake surface waters from 1995 to 2019 of 0.21 ± 0.02°C per decade, broadly consistent with previous analyses (Carrea *et al.*, 2020) and in Europe, 127 monitored lakes have shown a rising trend in the annual surface water temperature anomaly since 1995, with 2018 being the warmest. However, while the annual trends are positive, the rate of increase differs between lakes and between seasons, with some lakes warming at a significantly faster rate in the winter months (Woolway *et al.*, 2019).

Rising water temperatures, alone and in combination with changes in river flow, may have an impact on eel dynamics such as growth, survival and silver eel run timing. Determining those impacts will be complex as the response of eel will be a combination of energetics, physiology and food and habitat availability. Daverat *et al.* (2012) showed a positive effect on eel growth at temperatures greater than 13°C over the past century, although as temperatures continue to rise, negative impacts due to extreme seasonal temperatures may be anticipated. High water temperatures and low oxygen levels, as repeatedly observed during unusually warm summers in recent years, may stress eels and/or favour some bacterial and viral diseases (ICES, 2015c). Sweden reported on frequent findings of diseased and dead eels from several lakes (Axén, SVA, pers. comm.) and Estonia also experienced eel mortalities in connection to high water temperatures, and several incidences of unexplained eel mortalities were reported in the UK (ICES, 2018b). Eels infected with *A. crassus* exposed to hypoxia exhibited a more pronounced stress response (Gollock *et al.*, 2005). Timing of silver eel escapement appears to be getting earlier in some rivers with the migration moving by ~0.8 days/year in one river and annual silver eel output being positively influenced by warm summers (Sandlund *et al.*, 2017, Poole *et al.*, 2018).

According to the European Environment Agency (EEA) data available in 2008, 14 million hectares of Southern, Central and Eastern Europe, showed "very high" and "high" sensitivity to desertification (ECA, 2018). The affected part increases to more than 40 million hectares if moderate sensitivities are also considered. The situation is most serious in Southern Portugal, a large part of Spain, Sicily, south-eastern Greece, Cyprus, and the areas bordering the Black Sea in Bulgaria and Romania (noting that Black Sea area is exempt for European eel in the Eel Regulation but may have held eel prior to this). This is having a profound impact on the availability of water in some catchments, with whole river basins drying up in areas of Spain. This reduces the amount of habitat available for eel production, potentially reducing the ability of the eel stock to ever reach historical production levels (B_0), at least in some EMUs.

1.6.7.2 Oceanic waters

Climatic and oceanic factors are considered to influence population variability of eels by affecting the oceanic life phases between silver eel escapement, reproduction, and glass eel recruitment to continental waters (ICES, 2008). Investigations in the Sargasso Sea suggest that recruitment is already reduced at early larval stages (Hanel *et al.*, 2014; Westerberg *et al.*, 2018).

Long-term time-series of glass eel recruitment and natural climatic oscillation over the North Atlantic reflect the same periodicity (Durif *et al.*, 2010). However, the steep decline in recruitment between 1980 and 1983 and the failure for this to recover in the following years cannot be easily explained by oceanic factors alone and is out of phase with the North Atlantic Oscillation (NAO). Continual climate and ocean warming in the most recent decades has probably overridden the effect of the NAO (ICES, 2008). Reduced food availability for larvae in the spawning area caused by altered temperature regimes and changes in larval transport, and/or silver eel migration, caused by changes of oceanic currents are potential impacts on spawning success, larval survival and abundance (Knights, 2003; Friedland *et al.*, 2007; Bonhommeau *et al.*, 2008; Durif *et al.*, 2010; Munk *et al.*, 2010; Riemann *et al.*, 2010).

A causal link between climate and recruitment strength has not been identified, nor has where and/or when ocean environmental factors affect the eel. If the causal factors of oceanic influence are unknown, it is not safe to assume that the decline is explained by climate alone, especially while other, more direct, anthropogenic influences are better understood and more tractable. Furthermore, the fact that oceanic variables may contribute to recruitment variation is not grounds for abstaining from continental measures to increase silver eel escapement and boost spawning–stock biomass.

1.6.8 Habitat loss

To be updated with next version of this stock annex.

1.6.9 Stock Transfers

There is some variation in the way that different stakeholders name stock transfers; the WGEEL broadly categorises them as 'releases'. Below we describe terminology and actions that fall within this term. Restocking is referred to as '*the process of capture, and translocation to new locations in the wild'* while assisted migration refers to when '*eels are caught and immediately released in the same Eel Management Unit (EMU)* (ICES , 2019) and can be directed either upstream or downstream, as described below.

Upstream assisted migration: this involves transporting young recruits across a barrier within a river system to make habitats available to the eel and maintain a natural eel population in those habitats (ICES, 2016b). Whether or not access to these habitats will increase the net production of silver eel escapement, will need to be proven in each individual case.

Downstream assisted migration: otherwise called 'trap and transport' (T&T) is the diversion of silver eels around hazards such as hydropower stations and pumping stations, and is recognised as being a practical, if short-term solution, to reduce mortality when effective diversion of silver eels to bypass channels is not possible (ICES, 2019). The efficacy of T&T depends on a variety of factors e.g. effects of handling and transporting, river discharge, fishing effort, timing, duration of migration events and total number of silver eels available (ICES, 2019).

Although the definition of restocking is clear, the process is complex with a varied and broad sequence of steps and even life stages. Data have been reported on restocking comprising eels released at the glass eel phase, either directly, or after a quarantine, after a period of some months of growth in aquaculture, at the yellow eel or silver eel stage or mixed life stages (ICES, 2019). There is also a spatial element that complicates matters, ranging from the capture and movement of eel <1km within the same waterbody to bypass an obstacle, generally agreed to be assisted migration, to eel being moved several 100 km from one country or ecoregion to another.

1.6.9.1 Restocking

In several European countries, restocking of eels has long been practised in eel fishery management (Dekker and Beaulaton, 2016). Until recently, restocking has been used primarily as a tool to enhance fisheries, with little focus on spawner escapement. Restocking of eel increased again after the implementation of management plans in EU Member States in 2009, because of the inclusion of this as a potential conservation measure in the Eel Regulation (European Council, 2007).

Several essential preconditions have been proposed, first that demonstrable surplus should exist in some local (donor) glass eel stocks and that anthropogenic mortality in the recipient areas is minimized (ICES, 2016b). The potential risks involved have been discussed (ICES, 2011a, 2016b), noting these apply only to eels and not the impact of restocking on the broader ecology of the donor and recipient sites.

Some of the issues were:

- Restocking being used as an alternative to reduction of mortality, i.e. generating no net benefit;
- Mortality of recruits used in restocking e.g. at the initial capture, transport and quarantine stages;
- The risk of reducing fitness of the stock;
- The risk of altering genetic aspects of eel stocks;
- The risk of spreading of disease and parasites;
- Potential effects on sex ratio in recipient waters;
- Potential problems in homing ability of eels translocated to distant waterbodies

There is evidence that translocated and restocked eel will grow to yellow and silver stages, and will attempt to migrate (ICES, 2016b).

When restocking to increase silver eel escapement and thus aid stock recovery, an estimation of the prospective net benefit should be made prior to any action. Net benefit of restocking, taking into account the risks outlined above, was defined as "where the (re)stocking results in a higher silver eel escapement biomass than would have occurred if the glass eel seed had not been removed from its natural (donor) habitat in the first place" (ICES, 2016b). ICES (2011a) examined the potential net benefit of translocating glass eels using the TRANSLOCEEL model. Four scenarios were calculated, and the only situation which resulted in an increase in numbers of glass eel produced in the long term, was when the glass eels are left *in situ*, and the corresponding mortality is reduced. All other situations led, at best, to a stabilization of the population. It was concluded that a net benefit of restocking for the whole stock will be difficult to achieve. Restocking should not be seen as a substitute for reducing mortality caused by human factors, but as an additional measure.

An ICES convened workshop on restocking in 2016 (ICES, 2016b), while providing the most up to date information, concluded that studies were found to lack controls and/or a simultaneous assessment of the life history of those glass eels left *in situ*. This in effect means that, whilst a local benefit may be apparent, an assessment of net benefit to the wider eel stock is not currently quantifiable. For the (lifetime) natural mortality, there is little information available, and no reporting obligations. The contribution of silver eel derived from restocking to the spawning stock is still not quantifiable and is limited by the lack of knowledge on the breeding of *any* eel.

Data on the amount of restocked eel are provided and updated annually in the WGEEL reports. Note that various countries use different size and weight classes of eels for restocking purposes, as well as different methodologies. Figures 7 and 8 provide an overview of quantities restocked.

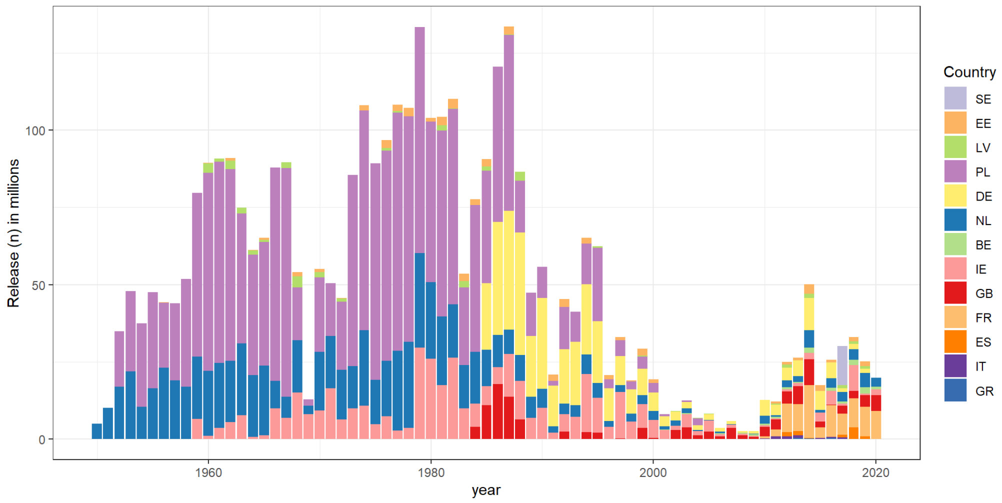


Figure 7. Reported releases of glass eel (in millions) per country: Sweden (SE), Estonia (ES), Latvia (LV), Poland (PL), Germany (DE), The Netherlands (NL), Belgium (BE), Ireland (IE), United Kingdom (UK), France (FR), Spain (ES), Italy (IT) and Greece (GR) (1945–2020).

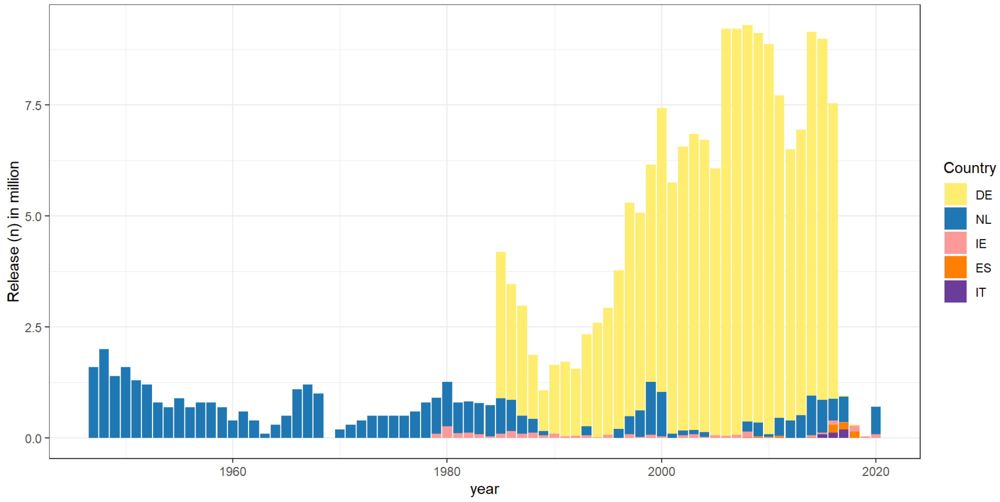


Figure 8. Reported releases of yellow eel (in millions) per country: Germany (DE), The Netherlands (NL), Ireland (IE), Spain (ES) and Italy (IT) (1945–2020).

2 Advice on eel management within the ICES framework for advice

2.1 History of the Working Group

The Working Party on Eel/Working Group on Eels (WGEEL) has been to the forefront of many research and development activities on eel since the 1960s, with main publications produced under various fora including the FAO Occasional Papers, Working Party Reports and ICES Reports. Noting the decline in landings and stock, and the alarming deterioration in recruitment, from the mid–1990s the WGEEL played a leading role in raising awareness of the seriousness of the situation, in developing the framework on which the Eel Regulation (European Council, 2007) was built, in providing encouragement and support at the international level and in support and development for the monitoring, assessment and reporting for the recovery of the eel stock. The following provides a chronology of the WGEEL activities.

In 1968, the European Inland Fisheries and Aquaculture Commission (EIFAC, more recently EIFAAC) held a plenary session in Rome following considerable international interest in eels, with a decline in the landings noted and restocking being proposed as a mitigation measure. In 1970, EIFAC organized a first meeting on the development of eel fishing gear (Hamburg). In 1974, a second EIFAC meeting was held in Dublin, and then in 1976, a joint ICES/EIFAC working group and a symposium series were convened, which led to working group meetings to examine available data such as landings and recruitment.

By 1981, it was realized that the data were inconsistent and incomplete, and the Working Groups lost impetus. EIFAC continued the interest in eel by undertaking biennial working parties which included some collation of annual data, such as recruitment time-series. These continued until 1996, when EIFAC and ICES joined their forces on eel again. During this time (1985) it was noted that there was a widespread decline in recruitment since 1980 and by 1993 that the recruitment decline had lasted for an eel generation, and thus was affecting spawner production. This prompted renewed concerns and, following the establishment of the joint ICES/EIFAC Working Group, ICES issued advice that the eel stock needed protection and that fishing pressure should be reduced.

A Working Group meeting in 1999 initiated renewed data collection and examined the trends in recruitment, landings, restocking, etc. Causes for the decline could not be identified although fisheries, habitat loss, hydropower and ocean change were likely involved. The contents for a possible recovery plan were proposed.

From 2001, the joint EIFAC/ICES Working Group met annually with advice provided within the EU–ICES MoU framework, which had been amended to specifically include eel. The collation of data was improved with the introduction of Country Reporting following the 2002 meeting. Intense activity during the period 2003 to 2007 supported the EU in the establishment of an Eel Regulation for Stock Recovery with the EU issuing the first draft plan in 2003 and the Official version in 2006, ratified in 2007 (European Council, 2007).

From 2006, the WGEEL has focused on: continuing the collation of time-series data in support of provision of the ICES Advisory process; providing support for local stock assessments and the determination of the local stock indicators (biomass, mortality); developing an international framework for post-evaluation of the Eel Regulation, and stock assessment for the development of Biological Reference Indicators.

In 2014, in response to the need for a stock-wide recovery and to fill non-EU gaps in the data for the international stock assessment, the GFCM entered into a Memorandum of Understanding (MoU) with EIFAAC and ICES for a joint EIFAAC/ICES/GFCM Working Group on Eels (WGEEL).

In addition to the annually recurring WGEEL, developments in various aspects of the work have been made through a series of Workshops and other Working Groups, some proposed by the WGEEL itself while others have been formed to respond to ad hoc requests for advice from the EC or others, as listed in Table 4.

Table 4. List of working groups, workshops and advice associated to WGEEL activities, with embedded hyperlinks to online publications.

Year	Group	Abbreviation	ICES Advice
2009	Age Reading of European and American Eel	WKAREA	N/A
2009	Study Group on Anguillid Eels in Saline Waters	SGAESAW	N/A
2010	Review Service: Evaluation of Eel Management Plans	RS-EMP	N/A
2010	Report of the Workshop on Baltic Eel	WKBALTEEL	N/A
2010	Study Group on International Post-Evaluation on Eels	SGIPEE-10	N/A
2011	Study Group on International Post-Evaluation on Eels	SGIPEE-11	N/A
2011	Age Reading of European and American Eel (II)	WKAREA	N/A
2012	Workshop on Eel and Salmon DCF Data	WKESDCF	N/A
2013	Workshop on Evaluation Progress Eel Management Plans	WKEPEMP	Advice
2015	Workshop on Eel and CITES	WKEELCITES	Advice
2016	Workshop on Eel Stocking	WKSTOCKEEL	N/A
2016	Workshop of the working group on eel and working group on biological effects of contaminants	WKBECEEL	N/A
2016	Review of the Trans-border management plan for European eel, *Anguilla anguilla*, in the Polish-Russian zone of the Pregola River basin and Vistula Lagoon	RGTEMPP	Advice
2017	Workshop on Fisheries Related Anthropogenic Impacts on Silver Eels	RGMAREEL	Advice

YEAR	GROUP	ABBREVIATION	ICES ADVICE
2017	Workshop on Designing an Eel Data Call	WKEELDATA	N/A
2018	Workshop on Tools for Eel	WKTEEL	N/A
2018	Workshop for the Review of Eel Management Plan Progress reports	WKEMP	Advice
2019	Second Workshop on Designing an Eel Data Call 2	WKEELDATA2	N/A
2019	Age Reading of European and American Eel (III)	WKAREA	N/A
2020	Workshop on the temporal migration patterns of European eel	WKEELMIGRATION	Advice
2021	The workshop on the Future of Eel Advice	WKFEA	future

2.2 The ICES framework for advice

The process of advice is illustrated in this schematic below (Figure 9). The Advice request is made by the EC to ICES as part of the Recurrent Advice package set out in the Administrative Agreement. The WGEEL is the Expert Group, drawing on expertise from across the ICES, EIFAAC and GFCM scientific communities. The report of the WGEEL is published at or around the same time as the ACOM–approved Advice.

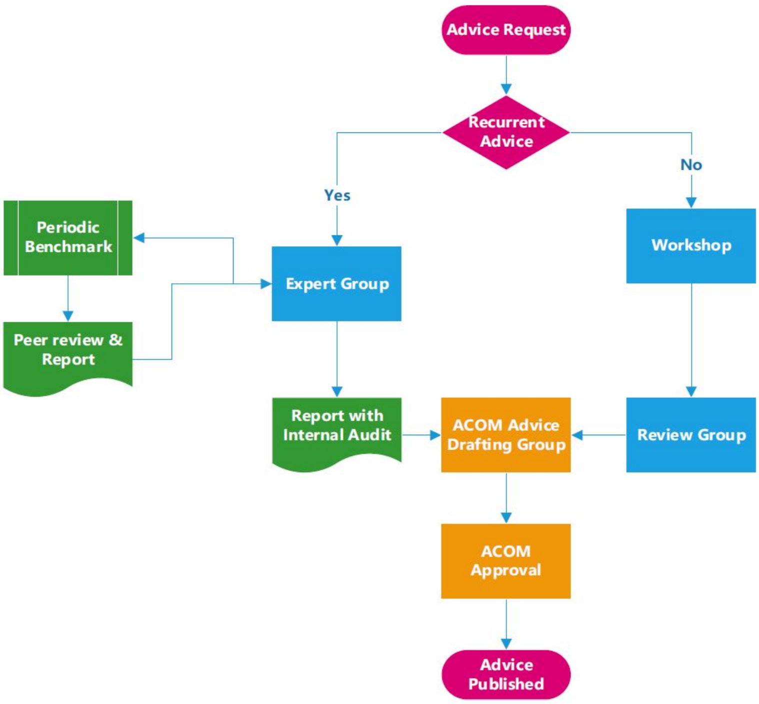


Figure 9. Schematic of the steps in the ICES Advisory process.

For long-lived stocks with estimates of population size, ICES bases its advice on attaining an anthropogenic mortality rate at or below the mortality that corresponds to long-term biomass targets. However, $B_{MSY-trigger}$ is a biomass level triggering a more cautious response. Below $B_{MSY-trigger}$, the anthropogenic mortality advised is reduced, to reinforce the tendency for stocks to rebuild. Below $B_{MSY-trigger}$, ICES suggests to use a proportional reduction in mortality reference values (i.e. a linear relation between the mortality rate advised and biomass).

For general fish stocks, the normal tendency to recover may break down at very low spawning stock levels. In these cases, the advised fishing mortality rate is likely to be so low that fishing may cease anyway. When stock size is so low that recruitment failure is a concern (e.g. at or below B_{lim}), additional conservation measures may be recommended for the stock to prevent a further decline.

For eel, however, current stock and recruitment are historically low, and indications are that the conventionally assumed mechanisms e.g. a compensatory stock–recruitment relationship, might not hold. While the decline of the stock may have forced some fishers to cease their exploitation, the side effects of other anthropogenic activities (such as hydropower generation) will not have reacted to low stock abundance, and rising prices for scarce products has kept other eel fisheries viable.

2.2.1 Recovery/Management Plan

ICES has defined procedures to evaluate the conformity of management strategies with the precautionary approach (ICES, 2012b).

A recovery plan (or an initial recovery phase within a long-term management plan) cannot be judged using the same criteria for precautionarity than as a management plan. It is more logical to judge a recovery plan according to its ability to deliver spawning biomass recovery within a certain time frame that is appropriate for that stock (e.g. for a stock with around 5–10 cohorts in the fishery five years from the start of the plan). In that case, the requirement for considering the recovery plan as precautionary would be that the probability of spawning biomass to be above B_{lim} in a pre-specified year is 95%.

In the case of the eel recovery and long-term management plan, the following applies:

- The status of stock-wide spawning biomass is not known;
- The time frame to recovery was not defined. (STECF recommended three generations; the Regulation states “in the long term”);
- The probability of achieving the target is undefined.

Therefore, evaluation of the individual, and combined, impact, of the EMPs is unlikely to indicate conformity with the precautionary approach. It is also unlikely that a comprehensive database for the analysis of stock-wide recovery time frames and likelihoods can be compiled successfully within a reasonable time frame.

While ICES welcomed the adoption of the Eel Regulation as a significant step toward the recovery of the eel population and supported the approach taken therein (European Council, 2007) to develop management plans based on Eel River Basin Districts (ICES, 2007a; Water Framework Directive 2000/60/EC), a system of post-evaluation and feedback to Member States and EMP managers has not been established in support of its implementation. ICES noted the seriousness of the state of the stock and urged that the measures to achieve significant reductions in mortality should be implemented as soon as possible. Any delay in reducing mortality may lead to an extremely long time-scale for recovery or a collapse of the stock if that hasn't already occurred.

Member States are required under the Eel Regulation (European Council, 2007) to report updates on the implementation of the EMPs. ICES undertook technical evaluation of the 2012 and 2018 (ICES, 2013a; 2018a). A mechanism needs to found between the EU and the ICES rules to facilitate advisory feedback on the status of the implementation of the EMPs.

2.2.2 Whole stock Advice

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

The advice rule applied by ICES in developing the advice on fishing possibilities depends on management strategies agreed by relevant management bodies and the information and knowledge available for the concerned stocks.

If an agreed management plan or strategy is in place and has been evaluated by ICES to be consistent with the precautionary approach, ICES will provide advice in accordance with the plan/strategy.

If no management plan/strategy has been agreed by all relevant management parties, or the agreed plan/strategy has been evaluated by ICES not to be consistent with the precautionary approach, ICES will provide advice applying the ICES MSY advice rule or the precautionary approach. ICES MSY advice rule requires a relative high level of data and knowledge on the dynamics of the stocks concerned. If the data and knowledge requirements are not fulfilled ICES cannot provide advice consistent with MSY; instead ICES applies an advice rule that is only based on precautionary considerations.

For the purposes of identifying the advice rule to be applied, ICES classifies the stocks into six main categories on the basis of available knowledge.

Given a quantitative assessment for the whole stock is not possible, eel falls under Category 3 rules (stocks for which survey-based assessments indicate trends) and particularly in category 3.1.4; for extremely low biomass, a recovery plan and possibly zero catch is advised (ICES, 2012b, p. 16).

Given that eel has an average generation time across the whole stock in the order of ten years or more, and given the low recruitment level (1–10% of the historical level), it is probable that the indicator for eel (i.e. recruitment time-series) will be slow to react to management measures conserving glass or yellow eel life stages. Therefore, the usefulness of providing annual advice at this level is questionable, although monitoring of recruitment and landings should of course be continued and improved.

The annual ICES Advice includes a compendium of advice since 1998 (see ICES, 2019b).

2.3 Forward Focus on Advice for Eel

Over the past decade, a framework of reference points and post-evaluation procedures has been developed by WGEEL, along the lines of the ICES framework for advice, that is adapted to the peculiarities of the eel (Dekker, 2010, 2016; ICES, 2010b). This framework has been used for the reporting by EU Member States to the European

Commission and the international post-evaluation in 2012 and 2018 (ICES, 2013a,b; 2018a). Most non-EU areas have only recently been involved in this joint process, and further development, of reference points, assessment procedures, and feedback mechanisms, might be required, to cope with unforeseen complications and/or to familiarise local experts, and involve them in future standardisation processes. Additionally, reference points, assessment procedures and feedback mechanisms will need to be agreed upon for the whole distribution area; this is the topic of an ICES workshop (WKFEA) to be held in early 2021.

3 Management frameworks for Eel

3.1 EU Regulation 1100/2007

The Eel Regulation (European Council, 2007) sets a long-term general objective ("the protection and sustainable use of the stock of European eel"), for Member States to implement local management and protective measures, the monitoring, and the local post-evaluation (European Council, 2007). The long-term objective is set for the biomass of silver eel escaping from each management area "at 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". Eel management plans (EMPs) were submitted by Member States to the European Commission, reviewed by the ICES Technical Services for the EC in 2009/2010 (ICES, 2010c), adopted by the EC (in some cases after requested revisions), and implemented by Member States.

The Eel Regulation (European Council, 2007) sets a limit for the escapement of (maturing) silver eels at 40% of the natural escapement (in the absence of any anthropogenic impacts and at historic levels of recruitment). Because current recruitment is generally far below the historical level and assumed to be so due to anthropogenic impacts, a return to this limit level is not expected within at least decades, even if all anthropogenic impacts are removed (FAO, EIFAAC and ICES, 2006; ICES, 2007c; Åström and Dekker, 2007).

Note that the Eel Regulation (European Council, 2007) sets a limit, but refers to it as a target. This is a mixing of terms. Management of any natural resources ideally requires knowledge of both the abundance and diversity of the stock and measures (e.g. biological reference points: BRPs) against which these can be assessed. These BRPs will generally be targets or limits (Caddy and Mahon, 1995; FAO, 1995; Garcia, 1996; Potter *et al.*, 2002). A target is a point to aim at, and a target reference point therefore represents a desirable state, and may, for example, provide the basis for setting a quota. A limit, on the other hand, defines a lower threshold which, ideally, the stock should not go below. Limit reference points are therefore used to demarcate undesirable stock levels or levels of fishing activity, and the ultimate objective when managing stocks and regulating fisheries is to ensure that there is a high probability that the stock remains or exists above the undesirable levels. Thus, while the Eel Regulation (European Council, 2007) describes '40% biomass' as a target, it should in fact be treated as a limit.

Under the Eel Regulation (European Council, 2007), each Member State shall report to the Commission initially every third year until 2018 and subsequently every six years; although the "Joint Declaration on strengthening the recovery for European eel (Commission and Member States)" (December 2017) agreed to continue the triennial reporting "until there is strong scientific evidence of recovery signs for the eel population across Europe".

Progress reports have been prepared in 2012, 2015, 2018 and the next series is anticipated in 2021. The 2012 and 2018 series of reports were reviewed by ICES (ICES, 2013a, 2018a).

The European Commission published a report in 2014 "On the outcome of the implementation of the Eel Management Plans, including an evaluation of the measures concerning restocking and of the evolution of market prices for eels less than 12 cm in length".

In 2019, the European Commission carried out an Evaluation of the Eel regulation and found that:

- The eel regulation remains an important instrument in helping the European eel stock to recover. It ensures the management of eel in all its life stages and addresses both fisheries and non-fisheries related human impact.
- Despite noteworthy progress in reducing fishing efforts and a concerted attempt to develop a pan-EU management framework, the status of the European eel remains critical.
- The silver eel escapement is still well below the target of 40% biomass that would have existed if no human influence had impacted the stock.
- Whilst restocking occurs in some Member States, not all have achieved their restocking targets.
- Member States' annual reporting on glass eel prices is incomplete. Many countries fund glass eel restocking through the European Maritime and Fisheries Fund (EMFF).
- Non-fisheries related mortality has not declined significantly over the last decade. This has received insufficient focus in the EMPs and related actions.
- Although the eel regulation offers the necessary framework to help restore the stock, its recovery is still far from certain. It is widely recognised that the recovery of the European eel will take many decades, given the long lifespan of the species.

3.1.1 Reference Limits associated with the Eel Regulation

"The objective of each EMP shall be to reduce anthropogenic mortalities so as to permit, with high probability, the escapement to the sea of at least 40% of the silver eel biomass relative to the best estimate of escapement that would have existed if no anthropogenic influences had impacted the stock" (European Council, 2007). It is noted that neither an explicit time frame nor a short-term mortality limit were set in the Eel Regulation.

ICES (2002) discussed a potential reference value for spawning–stock biomass: "a precautionary reference point for eel must be stricter than universal provisional reference targets. Exploitation, which provides 30% of the virgin (F = 0) spawning–stock biomass is generally considered to be such a reasonable provisional reference target. However, for eel a preliminary value could be 50%." That is: ICES advised to set a spawning–stock biomass limit above the universal value of 30%, at a value of 50% of B_0. In the Eel Regulation however, a limit is set at an escapement ($B_{current}$) of 40% of B_0, in-between the universal level and the more precautious level advised. ICES (2007) added: "an intermediate rebuilding target could be the pre–1970s average SSB level which has generated normal recruitments in the past."

Because current recruitment is generally far below the historical level, a return to this is not to be expected within a short period, even if all anthropogenic impacts are removed (Åström and Dekker, 2007). The Eel Regulation (European Council, 2007) indeed expects its objective to be achieved "in the long term", but it does not specify a duration. Noting the general objective to protect and recover the European eel stock, we conclude that a further deterioration of the status of the stock should be avoided, which implicitly sets an upper limit – in the order of magnitude of $\Sigma A = 0.92$, see below – on anthropogenic mortality.

The 40% biomass limit of the Eel Regulation (European Council, 2007) applies to all management units, without differentiation between the units. Whether or not that implies that the corresponding mortality limit ($\Sigma A = 0.92$) also applies to all units or not, is unclear. However, since it is unknown whether all areas contribute to successful spawning, a uniform mortality limit for all areas will constitute a risk-averse approach (Dekker, 2010).

3.1.2 Stock Indicators to achieve reporting requirements of the Eel Regulation

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

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

- Silver eel production (biomass)

  B_0 The amount of silver eel biomass that would have existed if no anthropogenic influences had impacted the stock;

  $B_{current}$ The amount of silver eel biomass that currently escapes to the sea to spawn;

  B_{best} The amount of silver eel biomass that would have existed if no anthropogenic influences had impacted the current stock, included restocking practices, hence only natural mortality operating on stock.

- Anthropogenic mortality (impacts)

  ΣF The fishing mortality rate, summed over the age-groups in the stock;

  ΣH The anthropogenic mortality rate outside the fishery, summed over the age-groups in the stock;

  ΣA The sum of anthropogenic mortalities, i.e. $\Sigma A = \Sigma F + \Sigma H$. It refers to mortalities summed over the age-groups in the stock.

- Restocking requirements

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

Guidance for the national Progress Reports was published by the European Commission in 2015. Updated guidance was published by the European Commission in 2018; click on the pdf icon for the covering letter to Member States in 2018.

Letter to Member States 2018 report.p

Comparing the terms B_0 and pristine in eel terms

A management framework had been proposed (ICES/EIFAC WGEEL 2001 onwards, as reported in ICES, WGEEL 2005), based on reducing fishing and other anthropogenic mortality, with the following reference points: A provisional limit reference point of 30% spawners per recruit (SPR) (Rosell and Potter, 2001); and a second, more precautionary reference point of 50% SPR considering the many uncertainties in eel biology and management. The 40% reference point of the Eel Regulation was a compromise between these two (Dekker and Rosell, pers. comm.).

ICES (WGEEL, 2005) explained further that "it is important to note that these SPR reference points do not mean an actual ratio of spawner to recruit, but rather a notional point on an SSB to R relationship. These %SPR reference points are conventionally applied with harvest rate models, in which the unexploited state can be estimated, irrespective of absolute levels of recruitment. In the case of eel, knowledge was/is insufficient to allow this approach, predominantly since anthropogenic impacts other than fisheries have an impact on the stock. Therefore, the reference points proposed for eel related to a percentage of spawner production in a notional "pristine" or "virgin" state. No explicit definition was given of what this pristine state might be for eels. At one extreme it can be defined as a stock level that would exist if the eel inhabited an environment, both continental and oceanic, free from all anthropogenic impacts. This notional pristine state can only be set on a regional, preferably catchment, basis and may in the most data rich cases refer to known historical data. On the other hand, for data-poor catchments this level may only be derivable theoretically or by modelling. This theoretical approach requires that decisions be made as to what point in history is selected as the reference point. An SPR level referenced back to a pre-industrial era will be extremely difficult to attain, given the large loss of freshwater habitats. However, a more pragmatic historical level may not be a sustainable level.

Article 2.4 of the Eel Regulation (European Council, 2007) sets the Limit Point at "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" which can be read as the pristine condition, but then Article 2.5 suggests three ways to estimate B_0 including one referring to the pre-1980s:

Article 2.5: The target level of escapement shall be determined, taking into account the data available for each eel river basin, in one or more of the following three ways: (a) use of data collected in the most appropriate period prior to 1980, provided these are available in sufficient quantity and quality; (b) habitat-based assessment of potential eel production, in the absence of anthropogenic mortality factors; (c) with reference to the ecology and hydrography of similar river systems.

Therein lies the ambiguity of trying to fix B_0 to a time and/or a state of the natural environment. The 30% SPR was intended to be measured against "a notional "pristine" or "virgin" state", but the Eel Regulation (European Council, 2007) allows them to be measured against the pre-1980s state. In fact, an alternative reference point of 100% pre-1980s was considered that would be more in keeping with the overall concept, but this was not adopted in the Eel Regulation (Dekker, pers. comm.) This ambiguity has resulted in differences in approach between EU Member States, and raising some concerns about the validity of 'simply' summing the B_0 estimates for all management units. The WGEEL is redesigning the Data Call for 2021 (and beyond) to seek to clarify this ambiguity.

3.2 Other EC Legislation and Initiatives

Note that much of the following section is taken or adapted by the EC's Evaluation of the Eel Regulation (European Commission, 2020).

3.2.1 Measures on European eel fisheries

Since 2018, a 3-month closure for eel commercial fishing has been in place at the EU level for eels above 12 cm in Union waters of ICES area, including in the Baltic Sea (European Council, 2018). This closure has been extended in 2019 to cover commercial and recreational fisheries for all eel life stages in EU marine and brackish waters in the North East Atlantic and the Mediterranean Sea (European Council, 2019a,b). Such measures have been rolled over to 2020 (European Council, 2020).

3.2.2 Control Regulation for eel fisheries

The Control Regulation (EC) No 1224/2009 (European Council, 2009), applies primarily to activities covered by the CFP carried out on the territory of MSs or in Union waters or by Union fishing vessels, the latter being defined by the CFP Regulation as any vessel equipped for commercial exploitation of marine biological resources. The Control Regulation defines several rules that apply to fisheries targeting diadromous species during their marine phase, and to freshwater fisheries, aquaculture, processing and marketing. In some cases, the Control Regulation covers specific fishery measures outlined in the Eel Regulation.

The Control Regulation also applies to marketing of fisheries and aquaculture products, from first sale to retail, including transport. Eels caught by professional fishermen are subject to submission of sales notes by registered buyers, mandatory weighing, and take-over declarations if the products are intended for sale at later stages, which may be the case of restocked eels. The traceability systems set up by MSs under the Control Regulation concern eel caught in marine waters. However, eels caught or farmed in freshwater are not excluded from the scope of the Control Regulation.

Until 2018, eel fisheries were not included in the scope of the Specific Control and Inspection Programmes (SCIPs). As of 2019, Commission Implementing Decision (EU) 2018/1986 (European Commission, 2018) included fisheries exploiting eels in Union waters of the Mediterranean, of the Baltic Sea, of the North Sea and ICES Division IIa, and of Western Waters (ICES areas VI, VII, VIII and IX). SCIPs trigger cooperation and pooling of inspection resources between MSs with the European Fisheries Control Agency (EFCA) assuring operational coordination of joint inspection activities in this frame.

3.2.3 Common Fisheries Policy

The scope of the Common Fisheries Policy (CFP) includes the conservation of marine biological resources and the management of fisheries targeting them. In addition, it includes, in relation to market measures and financial measures in support of its objectives, fresh water biological resources and aquaculture activities, as well as the processing and marketing of fishery and aquaculture products, where such activities take place on the territory of MS or in Union waters. A key objective of the CFP reform in 2013 is to restore or maintain fish stocks at levels that support maximum sustainable yield (MSY) by 2020 at the latest. Therefore, the CFP and its MSY objective is applicable to the European eel at certain stages in its life cycle. There are however considerable difficulties in applying the MSY approach to catadromous species such as the European eel and the Eel Regulation 40% escapement biomass target is considered a proxy for MSY (European Commission, 2020).

3.2.4 Data Collection Framework

Regulation (EU) 2017/1004 of the European Parliament and of the Council establishes an EU framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the CFP. This data collection framework (DCF) is applicable to eels and covers marine and inland waters, specifically establishing a programme for the collection of biological data on all stocks caught or by-caught in EU commercial and, where appropriate, recreational fisheries in and outside EU waters, including eels. Data on eels from the EU DCF may be useful for stock assessment purposes but does not cover non-fisheries related eel mortality.

EU Member States must report their DCF Annual Workplan to the EC every October in the year before implementation, and then report on delivery of that plan in May the year after implementation. These Workplans and Annual Reports are published by the EC and are available here.

3.2.5 Water Framework Directive

The Water Framework Directive (WFD) introduced the spatial management model of River Basin Districts (RBD); these often define EMUs. This alignment of spatial EMUs and RBDs provides opportunity for clear interlinkages between the management measures required to improve eel stocks and ecological status within waterbodies. The WFD serves to ensure the 'good status' of aquatic habitat in coastal, transitional, and inland surface waters across a range of ecological and chemical quality indicators. WFD is also important in improving river connectivity, which should benefit eel migration. However, significant effort is required to meet good ecological and chemical status across European surface waters as only 40% of surface waterbodies are in good ecological status, and 38% of surface waters are in good chemical status. Moreover, 40% of surface waterbodies are affected by hydromorphological pressure (EEA, 2018). The authorities responsible for the EMP are not necessarily involved in the implementation of the River Basin Management Plans (RBMPs) under the WFD. Thus, there is scope to improve linkages between RBMPs and EMPs, and the authorities tasked with their delivery. The Fitness Check of the EU Water Policy, including the WFD, report stated "*The WFD contributes to the protection and preservation of the EU eel stock through its requirement to ensure continuity along rivers. Nonetheless, insufficient links have been made between RBMPs and the eel management plans established by EU Member States under the Eel Regulation and there is a lack of coordination among the competent authorities.*"

3.2.6 Marine Strategy Framework Directive

The Marine Strategy Framework Directive (MSFD) came into force in 2008 and is focussed on the environmental status of marine waters through the adoption of an ecosystem-based approach. Based on the good environmental status descriptors, MSs have developed relevant definitions and targets. In relation to eels, good environmental status of the marine environment may have a positive effect on the reproductive potential of silver eel (ICES, 2018b).

3.2.7 Others

The following lists other relevant legislation and initiatives. More detail will be provided for these in a future iteration of this document.

- EMFF Regulation (EU) 508/2014 provides for financial support for implementation of the CFP. Evaluation of the Eel Regulation found that EMFF supported measures related to eel restocking, habitat recovery, data collection, studies and temporary cessation of fishing activities;
- Habitats Directive as important for the protection of the eel-related habitats;
- Wildlife Trade Regulations;
- EU Action Plan against Wildlife Trafficking;
- EU Biodiversity Strategy for 2020;
- EU Biodiversity Strategy for 2030 as key element of the European Green Deal.

3.3 GFCM

The Eel Regulation (European Council, 2007) only applies to EU Member States plus areas of transboundary plans, but the eel distribution extends much further than this. A whole-stock (international) assessment requires data and information from both EU and non-EU countries producing eels. Some non-EU countries provide such data to the WGEEL and more countries are being supported to achieve this through efforts of the GFCM. In the GFCM region, that includes the Black Sea area, eel is included as one of the priority fisheries shared by all countries. The GFCM has recently been integrated into the WGEEL with the goal of facilitating knowledge transfer and a full international stock assessment. The GFCM is currently undertaking a series of case studies to develop regional multiannual management plans for shared stocks. Coordinated measures, however, must necessarily be adaptable to data-poor situations given the wide variation in data availability across countries.

The GFCM adopted, in Recommendation GFCM/42/2018/1, the following measure for Contracting Parties (CPCs): "… establish an annual fishing closure of three consecutive months where landing European eel shall be prohibited. To decrease fishing mortality effectively, the closure period shall be defined by the CPCs in their national management plan, together with its fisheries and the gear targeting European eel. The fishing closure period shall be consistent… …with national management plans in place and with the temporal migration patterns of European eel in the CPC concerned". This came in to force as of 01/01/19.

3.4 Other countries or regions with national management frameworks

Norway

Norway has incorporated EU environmental legislation into its own laws, even if it is not an EU Member State. Its first EMP was adopted in 2008. In 2010, eel fishing was banned, one year after the ban of recreational fishing for eels. Glass eel fishing has always been prohibited. A monitoring program in the form of a scientific fishery was started in 2016, organized by the Institute of Marine Research. Fishers are allowed to land and sell up to 700 kg of eels (yellow and/or silvers) per year, and must report on the number of eels, their weight and number of fykenets used. The total allowable landings is 21 tons.

The electricity production of the country is highly dependent on hydropower, which severely constrains eel habitat. Construction of passages for eel and other fish is ongoing while remaining a challenge.

The United Kingdom

The United Kingdom left the EU at the beginning of February 2020. Having previously been an EU Member State, its EMPs are still in effect at the time of writing (October 2020).

Belarus

Belarus includes parts of the natural range of the European eel. However, hydropower plants and other barriers nowadays prevent natural recruitment. Restocking with seed from the EU is prohibited due to the zero import/export quota for European eel. Belarus has an official target to allow 40% silver eel escapement. A recent scientific report (Anon) claims that Belarus is prepared to develop an Eel Resource Management Plan in case it will be allowed to import glass eel from the European Union.

Russia

Russia has naturally recruited eels in the Kaliningrad region bordering the Baltic Sea. Russia finalised its first EMP in 2010 and has been working on removing barriers in the region. More recently, Poland and Russia submitted a joint cross-border EMP to the European Commission that was reviewed by ICES (ICES, 2016) but has not been approved by the European Commission.

3.5 Other International agreements and initiatives

3.5.1 Convention on International Trade in Endangered Species of Wild Fauna and Flora

The European eel was listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 2007, although this did not come into force until March 2009. This is transposed into the EU law through Council Regulation (EC) N°338/97 Wildlife Trade Regulation. Since listing, any international trade in this species needs to be accompanied by an export permit[4]. All trade in to, and

[4] Article IV.2 of the CITES Convention requires that, amongst other things: The export of any specimen of a species included in Appendix II shall require the prior grant and presentation of an export permit. An export permit shall only be granted when the

out of, the European Union ceased in December 2010 as the EU Scientific Review Group (SRG) stated that it was not possible to produce a non-detriment finding (NDF). Trade from non-EU Range States to non-EU countries (Range States and Non-Range States) is still permitted provided the former have developed their own NDF. Note that such NDF should be made available to the CITES Secretariat if there are concerns regarding the status of a species, and several North African countries are undergoing this 'Review of Significant Trade' (RST) at the time of writing.

In 2015, the EC requested ICES to provide advice on criteria for defining a non-detriment finding. The ICES advice was published (ICES, 2015b), following a Workshop on Eel and CITES (WKEELCITES) (ICES, 2015a).

3.5.2 Convention on the Conservation of Migratory Species of Wild Animals

The European eel was added to Appendix II of the Convention on the Conservation of Migratory Species of Wild Animals (CMS) in 2014, whereby Parties, covering almost the entire distribution of European eel, to the Convention call for cooperative conservation actions to be developed among Range States.

There have been three Range State meetings relating to the European eel, 2016, 2018 and 2019, and it was agreed at the third meeting that an Action Plan be proposed to the 13th Conference of the Parties (CoP). This was approved and is presently being developed by the Secretariat.

3.5.3 Convention for the Protection of the Marine Environment of the Northeast Atlantic

The Convention for the Protection of the Marine Environment of the Northeast Atlantic (the "OSPAR Convention") was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. It has been ratified by Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Sweden, Switzerland, and the United Kingdom and approved by the European Community and Spain.

The European eel was included on the OSPAR List of threatened and/or declining species and habitats in 2008 (OSPAR Agreement 2008–6). In 2010, OSPAR issued a background document which provides a compilation of the reviews and assessments that have been prepared concerning this species since the agreement to include it in the OSPAR List. The original evaluation used to justify the inclusion of *A. anguilla* in the OSPAR List is followed by an assessment of the most recent information on its status (distribution, population, condition) and key threats prepared during 2009–2010. ICES (2007b) provided fast-track advice into this process in 2007.

In 2014, OSPAR issued a recommendation (OSPAR Recommendation 2014/15) to strengthen the protection of the European eel at all life stages in order to recover its population and to ensure that the population is effectively conserved in Regions I, II, III and IV of the OSPAR maritime area. This includes recommending that Contracting Parties implement eel management plans, control measures and monitoring of all life stages of eel. Contracting Parties should report by 31 December 2016 and then by 31 December 2019 on the implementation of this Recommendation to the appropriate

following condition has been met: a Scientific Authority of the State of export has advised that such export will not be detrimental to the survival of that species.

OSPAR subsidiary body. After 2019 Contracting Parties should report every six years on the implementation of this Recommendation. (A future version will attempt to list these reports or provide links).

3.5.4 United Nations Convention on the Law of the Sea

The United Nations (UN) Convention on the Law of the Sea (UNCLOS, 1982), Article 67 relates to catadromous species, including European eel, with the following rules applicable to UN Member States, including the EU:

- *Coastal states/countries are responsible for management, but also states through the territory of which the species migrate are responsible for binding agreements concerning management measures;*
- *Management must include provisions for secured immigration and emigration of the species.*

3.5.5 HELCOM

The Baltic Marine Environment Protection Commission, also known as the Helsinki Commission (HELCOM), is an intergovernmental organization (IGO) and a regional sea convention in the Baltic Sea area, consisting of ten Contracting Parties. HELCOM is the governing body of the "Convention on the Protection of the Marine Environment of the Baltic Sea Area," also known as the Helsinki Convention.

The eel stock in the Baltic constitutes an important part of the total European stock. For eel, the Baltic Sea area is essentially a single biological management unit and HELCOM aims at integration of the existing national protection efforts. In 2010, a first Baltic Eel workshop was jointly organized by HELCOM and ICES (ICES, 2010a). This workshop compiled an overview of available information on the eel stock in the Baltic. Another coordination workshop was held in 2017, gathering representatives from management bodies, scientific experts and stakeholders.

The HELCOM Baltic Sea Action Plan (BSAP) was adopted by the coastal states of the Baltic Sea in 2007. Its overall objective is to reach good environmental status of the Baltic Sea by 2021. As this target will most likely not be reached, the BSAP is currently being revised. The existing plan already contains several targets for European eel, but additional conservation measures are being discussed as part of this revision.

4 WGEEL stock state assessments

4.1 Introduction

As noted above, given a quantitative assessment for the whole stock is not possible, eel falls under Category 3 rules (stocks for which survey-based assessments indicate trends). The following section details the data and analyses used in developing the trend-based recruitment indices. Other data sources based on silver eel time-series estimates of escapement biomass and human-induced mortality rates are discussed thereafter.

4.2 Recruitment assessment

Recruitment time-series have been collated by the WGEEL since the early 1980s and these, along with the much less complete fisheries landings, have formed the basis for the provision of ICES advice on the status of the eel stock since that time. The trend in recruitment for the European eel is derived from long-term time-series collected in estuaries scattered over all of Europe. These recruitment-series are the best indicator of the status of the stock over this wide spatial scale and decadal time-scale, as there is no pan-European evaluation of the silver eel stock output.

This chapter provides the background and methods used by the WGEEL in the analysis of the recruitment data. It has been updated to use the 2020 data and results as a demonstration of the process.

4.2.1 Introduction

The recruitment time-series data are derived from fishery-dependent (i.e. commercial landings records) and fishery-independent surveys (i.e. similar gears to fisheries plus others, with survey design based on scientific data collection) across much of the geographic range of European eel (Figure 10). The life stages of recruits are categorized as glass eel (G – having arrived from the ocean in year 0, including pigmented 0+ eel), yellow eel (Y – at least one year older than glass eels), and samples of recruits comprising both G and young Y but generally dominated by G (G+Y). The WGEEL Glass Eel Recruitment Index series is based on the glass eel-only (G) or a mixture of glass eel and young yellow eels (G+Y). The WGEEL Yellow Eel Recruitment Index uses Time-series data that mostly come from trapping ladders. These eels are aged 1+ and older, with the age range varying between series (and possibly within years within series), for example, yellow eel from the Baltic series might be several years old.

The WGEEL usually meets in September, therefore setting a deadline for data reporting in August of that year, to give time to collate, check and analyse the data. That means that some recruitment sites are still collecting that year's data beyond the deadline. In some years these most recent data have been reported as Provisional but then Finalised the next year. Earlier deadlines for data reporting in 2018/2019 exacerbated this issue and therefore the WGEEL in 2019 adopted the following treatments:

- Move the WGEEL meeting as late in September as possible to maximize the number of Final data to be included.
- Consider whether to declare the most recent assessment as Provisional. Update the previous year's data to final versions and declare an analysis based on these as Final.

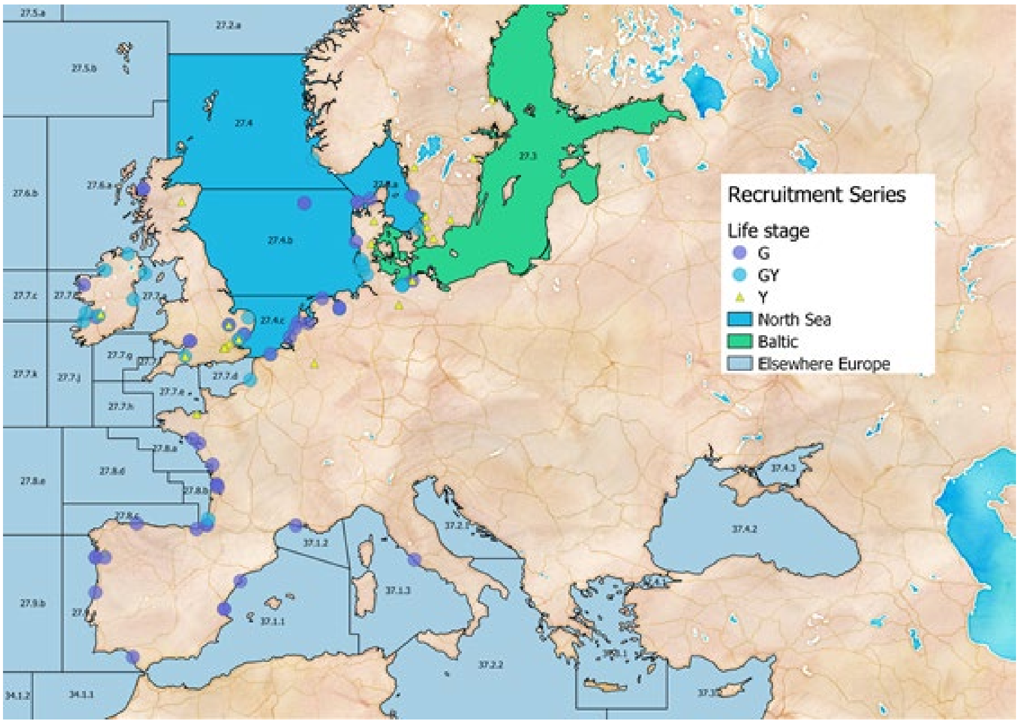


Figure 10. The distribution of recruitment series by type (G, GY and Y) collated by WGEEL. Not all sites contribute to the analysis (see Table 5).

4.2.2 Site data

At the time of writing (October 2020) the WGEEL had collated information on recruitment from 95 time-series. Some of the time-series date back to the beginning of the 20th century (yellow eel, Gőta Älv, Sweden) or 1920 (glass eel, Loire, France). The 'glass eel' series are grouped into those in the North Sea area versus all others (Elsewhere (in) Europe), on the basis of different Time-series trends (in the 1980s) (ICES, 2010b). For the series presently included in the recruitment analysis, the series code, name, comments about the data collection method, whether they are part of the North Sea or Elsewhere in Europe series, the country, river, location, sampling type, data units, life stages sampled, and first and last year of data currently held, are all fully described in Table 5. The raw data for each location may be available upon request to the WGEEL Chair. For the most recent list of series included and excluded from the analysis see the Recruitment chapter of the latest WGEEL report.

Table 5. Collated metadata descriptions for the glass and yellow eel recruitment series available to the WGEEL (as of 2020).

CODE	NAME	RIVER/SITE	COUNTRY	North Sea/ Europe Elsewhere	STAGE (Glass or Yellow)	DATA RANGE	METHOD	Data Units
ImsaGY	Imsa Sandnes trapping all	Imsa	NO	NS	G + Y	1975–2020	Freshwater elver trap	Number
DalaY	Dalälven trapping all	Dalä	SE	NS	Y	1951–2019	Trapping all	Kg
MorrY	Mőrrumsån trapping all	Mőrrumsån	SE	NS	Y	1960–2018	Trapping all	Kg
MotaY	Motala Strőm trapping all	Motala	SE	NS	Y	1942–2019	Trapping all	Kg
RingG[1]	Ringhals scientific survey	Ringhals	SE	NS	G	1981–2020	Scientific estimate modified midwater trawl at power plant water intake	Index
YFS2G	IYFS2 scientific estimate	Skagerrak-Kattegat	SE	NS	G	1991–2020	Scientific estimate midwater trawl	Index
KavlY	Kävlingeân trapping all	Kävlingeån	SE	NS	Y	1992–present	Trapping all	Kg
LagaY	Lagan trapping all	Lagan	SE	NS	Y	1925–2019	Trapping all	Kg
RonnY	Rőnne å trapping all	Rőnne	SE	NS	Y	1946–2018	Trapping all	Kg
GotaY[2]	Gőta ålv trapping all	Gőta älv	SE	NS	Y	1900–2017	Trapping all	Kg
ViskGY	Viskan Sluices trapping all	Viskan	SE	NS	G+Y	1972–2019	Trapping at overflow dam	Kg
YFS1G	IYFS scientific estimate	Skagerrak-Kattegat	SE	NS	G	1975–1989	Scientific estimate	Index
EmsG	Ems Herbrum commercial catch	Ems	DE	NS	G	1946–2001	Commercial catch	Kg
SleG	Slette A	Slette Å	DK	NS	G	2008–2020	Electrofishing	Eels/m^2
KlitG	Klitmoeller A	Klitmoeller Å	DK	NS	G	2008–2020	Electrofishing	Eels/m^2
NorsG	Nors A	Nors Å	DK	NS	G	2008–2020	Electrofishing	Eels/m^2
HartY[3]	Harte trapping all	Harte	DK	NS	Y	1967–2020	Trapping at HPS	Kg
GudeY	Guden À Tange trapping all	Guden Å	DK	NS	Y	1980–2020	Trapping all	Kg
VidaG	Vidaa Højer sluice commercial catch	Vidaa	DK	NS	G	1971–1990	Commercial catch	Kg
RhDOG	Rhine DenOever scientific estimate	Rhine	NL	NS	G	1938–2020	Scientific estimate, net	Index
RhIjG	Rhine IJmuiden scientific estimate	Rhine	NL	NS	G	1969–2020	Scientific estimate, net	Index
KatwG	Katwijk scientific estimate	Katwijk	NL	NS	G	1977–2020	Scientific estimate	Index

CODE	NAME	RIVER/SITE	COUNTRY	North Sea/ Europe Elsewhere	STAGE (Glass or Yellow)	DATA RANGE	METHOD	Data Units
LauwG	Lauwersoog scientific estimate	Lauwersoog	NL	NS	G	1976–2020	Scientific estimate, net	No/h
StelG	Stellendam scientific estimate	Stellendam	NL	NS	G	1971–2020	Scientific estimate	Index
YserG[4]	Ijzer Nieuwpoort scientific estimate	Ijzer	BE	NS	G	1964–2020	Scientific estimate dipnets	Kg
ShaAGY	Shannon Ardnacrusha trapping all	Shannon	IE	EE	G+Y	1977–2020	Trapping all	Kg
FealGY[6]	River Feale	Feale	IE	EE	G+Y	1985–2018	Trapping all	Kg
ShaPY[7]	Shannon Parteen trapping partial	Shannon	IE	EE	Y	1985–2020	Trapping partial	Kg
MaigG[8]	River Maigue	Maigue	IE	EE	G	1994–2020	Trapping all	Kg
InagGY[9]	River Inagh	Inagh	IE	EE	G+Y	1996–2018	Trapping all	Kg
ErneGY[10]	Erne Ballyshannon trapping all	Erne	IE	EE	G+Y	1959–2020	Trapping all from 1980	Kg
SeEAG[11]	England & Wales, commercial catch	Severn+	GB	EE	G	1979–2020	Commercial catch	T
BannGY	Bann Coleraine trapping partial	Bann	GB	EE	G+Y	1960–2020	Partial trapping	Kg
VilG	Vilaine Arzal trapping all	Vilaine	FR	NS	G	1971–2015	Trapping all: fishery corrected data	t
FreY	Frémur	Frémur	FR	NS	Y	1997–2019	Trapping all	number
AdCPG	Adour Estuary (cpue) commercial cpue	Adour	FR	EE	G	1928–2008	Commercial CPUR	cpue
AdTCG	Adour Estuary (catch) commercial catch	Adour	FR	EE	G	1986–2008	Commercial catch	t
GiCPG	Gironde Estuary commercial (cpue)	Gironde	FR	EE	G	1961–2008	Commerical cpue	cpue
GiTCG	Gironde Estuary (catch) commercial catch	Gironde	FR	EE	G	1923–2008	Commerical catch	t
GiSCG	Gironde scientific estimate	Gironde	FR	EE		1992–2020	Scientific estimate	Index
LoiG	Loire Estuary commercial catch	Loire	FR	EE	G	1924–2008	Commercial catch	Kg
SevNG	Sèvres Niortaise Estuary commercial cpue	Sèvres	FR	EE	G	1962–2008	Commerical cpue	cpue
BresGY[12]	Bresle	Bresle	FR	EE	G+Y	1994–2020	Trapping all	number
NaloG[13]	Nalon Estuary commercial catch	Nalon	ES	EE	G	1953–2020	Commericial catch: San Juan de la Arena fishmarket sales	Kg
EbroG	Ebro delta lagoons	Ebro	ES	EE	G	1966–2020	Commercial catch: fishmarket	Kg

CODE	NAME	RIVER/SITE	COUNTRY	North Sea/ Europe Elsewhere	STAGE (Glass or Yellow)	DATA RANGE	METHOD	Data Units
AlbuG[14]	Albufera de Valencia commercial catch	Albufera	ES	EE	G	1949–2020	Commercial catch	Kg
AlCPG[15]	Albufera de Valencia commercial cpue	Albufera	ES	EE	G	1982–2020	Commercial cpue	cpue
MiSpG	Minho Spanish part, commercial	Miño	ES	EE	G	1975–2020	Commercial catch	Kg
MiPoG	Minho Portugese part, commercial catch	Miño	PT	EE	G	1975–2020	Commercial catch	Kg
TibeG	Tiber Fiumara Grande commercial catch	Tiber	IT	EE	G	1975–2006	Commercial catch	t
BeeG	Beeleigh_Glass_<80mm	Beeleigh	GB	NS	G	2006–2020	Trapping partial	nr
BroG	Brownshill_glass_<80mm	Brownshill/Great Ouse	GB	NS	G	2011–2020	Trapping partial	nr
BroY	Brownshill_Yellow _>120mm	Brownshill/Great Ouse	GB	NS	Y	2011–2020	Trapping partial	nr
BurrG	Burrishoole	Burrishoole	IE	EE	G	1897–2020	Trapping partial	Kg
DoElY	Dove Elbe eel ladder	Dove Elbe	DE	NS	Y	2003–2019	Trapping partial	nr
FlaG	Flatford glass eel < 80mm	Flatford/Stour	GB	NS	G	2007–2020	Trapping partial	nr
GirnY	Girnock Burn trap scientific estimate	Girnock/Dee	GB	NS	Y	2008–2020	Trapping partial	nr
GreyGY	Greylakes_Elvers (<120mm)	Parrett	GB	EE	G+Y	2009–2020	Trapping partial	nr
GuadG	Guadalquivir scientific monitoring	Guadalquivir	ES	EE	G	1998–2007	Scientific estimate	index
HellGY	Hellebaekken	Hellebaekken	DK	NS	G+Y	2010–2020	Scientific estimate	nr
MolY	Thames–Molesey weir	Thames	GB	NS	Y	2005–2020	Trapping partial	nr
NmiGY	New Mills Elvers/Yellow (>120mm)	Wensum	GB	NS	Y	2009–2020	Trapping partial	nr
OriaG	Oria scientific monitoring	Oria	ES	EE	G	2005–2019	Scientific estimate	nr/m^3
RodY	Thames – Roding	Thames	GB	NS	Y	2005–2019	Trapping partial	nr
VacG	Vaccarés	Étang de Vaccarés	FR	EE	G	2004–2020	Trapping partial	nr
VerlGY	Verlath Pumping Station	Vida	DE	NS	G+Y	2010–2020	Trapping partial	nr
WiFG	Frische Grube	Mühlenbach/Grube	DE	NS	G+Y	2006–2019	Trapping partial	nr

CODE	NAME	RIVER/SITE	COUNTRY	North Sea/ Europe Elsewhere	STAGE (Glass or Yellow)	DATA RANGE	METHOD	Data Units
WisWGY	Wallensteingraben	Wallensteingraben	DE	NS	G+Y	2004–2019	Trapping partial	nr

Changes in data collection regimes and major data anomalies are described below:

[1]Ring. Sampling dependent on cooling water intake, Intake sampling has been moved from the old reactors 1 and 2 to the newer reactors 3 and 4. Data seem compatible.

[2]Gota. Fish pass rebuilt 2010/2011.

[3]Hart. Affecting data from 1991 onwards, a bypass allowing eels to avoid the facility was completed in 1990 and the number of eel traps was reduced from two to one. From spring 2008 to present, there has been a 60% reduction in water flow at power station, directly affecting catch. Both changes likely lead to decrease in catch.

[4]Yser. Variable fished effort noted, low in 2006, high in 2012 and 2013: accompanying effort data available from 2002 onwards.

[5]Meus. New Fish pass built in 2008, perhaps affecting catch from 2008 onwards.

[6]Feal. Operation of fish trap switched from commercial fisherman to scientific staff (IFI) in 2009.

[7]ShaP. Trap improved prior to the run in 2015.

[8]Maig. Operation of fish trap switched from commercial fisherman to scientific staff (IFI) in 2009. Trap improved prior to the run in 2011. 2014 catch is certainly an underestimate, as it was derived from partial trapping effort only.

[9]Inag. Operation of fish trap switched from commercial fisherman to scientific staff (IFI) in 2009. Trap improved prior to the run in 2011. Significant flood in 2012 leading to underestimate (floods not recorded prior to 2009).

[10]Erne. The trap was significantly upgraded between the 2014 and 2015 seasons.

[11]SeEA. The related series SeHM was dropped since the 2015 recruitment assessment as it contains the same information as this series, and so is not independent.

[12]Bres. Change in trapping ladder affecting catch (increase in trapping efficiency) in 2003. Second change in trapping ladder affecting catch from 2013 onwards.

[13]Nalo. In the 1970s (no more specific date available) fishermen started to use boats to catch eels in addition to the land-based methods.

[14]Albu. In 2001 there was a change in data compilation methods, but the series integrity has been preserved.

[15]AlCP. In 2001 there was a change in data compilation methods, but the series integrity has been preserved.

4.2.3 Time-series description

The number of reported recruitment series varies through time as old series become discontinued and new series are started (Figure 11). Series may be discontinued because of lack of recruits in the case of the fishery-based surveys (Ems in Germany, stopped in 2001; Vidaa in Denmark, stopped in 1990), a lack of financial support (the Tiber in Italy, 2006) or the introduction of quota from 2008 to 2011 that has disrupted the five fishery-based French time-series.

Not all series contribute to the WGEEL Recruitment Indices. For example, in 2020 WGEEL held data for 95 recruitment sites, but only 68 contributed to the indices. Three rules have been used for this selection procedure.

1) If there are two or more series from the same location, they cannot be regarded as independent and only one series is retained. For instance, the longer series has been kept for the Severn (Severn EA) while the other series (Severn HMRC) has been dropped from the list, as it was considered a duplicate being based on the same fishery.
2) Series with less than ten years' duration are excluded from the analysis. The series are nevertheless updated in the database until they are long enough to be included.
3) Finally, it was decided to discard recruitment series that were obviously biased by restocking (e.g. Farpener Bach in Germany).

Series with changes in data collection methods which could potentially influence recruitment estimates are indicated in Table 5.

The number of glass eel and glass eel + young yellow eel time-series available declined from a peak of 42 available in 2015 to 34 in 2020 (Figure 10).

Before 1960, the number of glass eel or glass eel + yellow eel series available was quite small, with six series before 1959 (Figure 11). Those are Den Oever (scientific survey), the Loire (total catch), the Ems (mixture of catch and trap and transport), the Gironde (total catch), the Albufera de Valencia in the Mediterranean, and the Adour, which dates as far back as 1928, and is based on CPUE. For the latter however, only the years 1928 to 1931 are available and the series only resumes in 1966.

The maximum number of yellow eel time-series increased to 15 in 2019 (but only six were already available for 2020 (Figure 11).

For details of the series included/excluded in the most up to date analysis see the Recruitment chapter in the most recent WGEEL report.

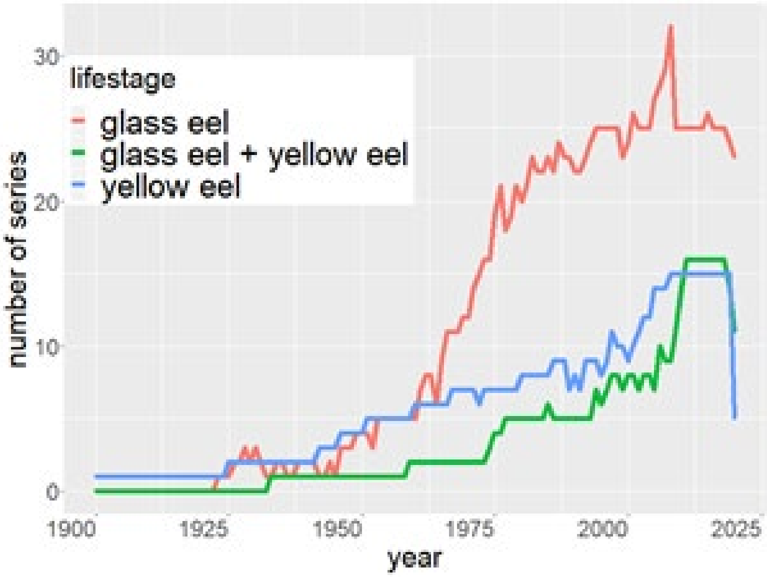


Figure 11. Trends in number of glass eel (red), glass+young yellow eel (green) and older yellow eel (blue) time-series reported in any specific year.

4.3 Analysis of the WGEEL Recruitment Indices

For the development of the Stock Annex, we have used the analysis outputs by the WGEEL 2020 and as presented in the Eel Advice for 2020 to demonstrate the assessment methodology.

4.3.1 Setting Reference Periods

The original analysis of trends in recruitment data (Dekker, 2000b; 2002) used a scaling to a period which encapsulated the highest number of dataseries, i.e. 1979–1994. In the interests of consistency over time, the WGEEL has kept this "historical analysis" reference.

Recruitment was first separated into glass eel and young yellow eel in 2006 (FAO, EIFAAC and ICES, 2006). Yellow eel are by definition at least one year class older than 0+ glass eel recruits. This age differential varies with location and the young yellow eel could include up to ten or more year-classes. The age structure of individual series are currently not known.

The scaling for yellow eel was done on the same time period as the glass eel series: WGEEL chose to be consistent between the two time-trends, though it could have spanned a longer period as more than four reliable series were available after 1946. The yellow eel series comprise data where the age is expected to be different and also probably integrate more bias due to local factors affecting the survival of young eels in the rivers (e.g. Meuse, Frémur, Shannon) or in the marine environment (e.g. Baltic series). Note also that these factors may vary between years and sites.

A new analysis of recruitment was introduced by WGEEL in 2015: The General Linear Model (GLM) – reconstructed WGEEL 'Recruitment Index' for which the reference period was set to pre-1980. There were initially 12 yellow eel and 39 glass eel series (see Figure 11 and the Recruitment chapter in the latest WGEEL report for present contributing series). 1960 was set as the start of the reference period (1960–1979) in order to exclude data from four series where a significant change in effort had occurred in three of them because they were based on total landings of commercial glass eel which were known to have been affected by changes in fishing practices, and the progressive shift from hand nets to push net fisheries from 1940 to 1960 (Briand *et al*., 2008: see paragraph 24.1.1 therein).

4.3.2 Simple Geometric Means of Raw Data

The latest iteration of the historical WGEEL analysis based on a simple geometric analysis of the raw recruitment data can be found in the Recruitment chapter of the latest WGEEL report. Although this was the principal WGEEL recruitment index until 2015 (ICES, 2015d), it is not considered further here, having been superseded by the GLM analysis.

4.4 GLM based trend

The 'WGEEL recruitment index' (ICES, 2008) is a statistical analysis using a simple GLM. A difference in spatial pattern of recruitment was observed at most stations in the North Sea, where the decline was sharper than elsewhere (ICES, 2010b). From that time onwards, therefore, the WGEEL has reported on two Glass Eel Recruitment Indices, for the North Sea and for Elsewhere.

The GLM (Generalised Linear Model): *glass eel ~ year: area + site*, where:

glass eel is individual glass eel series,

site is the site monitored for recruitment and,

area is either the North Sea or Elsewhere Europe.

The GLM uses a gamma distribution and a log link. The dataseries comprising only glass eel (G), or a mixture of glass eel and a portion of young yellow eel which could not be separated from the rest of the sample (G+Y), are grouped and later labelled as glass eel series.

In the case of yellow eel series, only one estimate is provided: *yellow eel ~ year + site*.

```
For Glass Eel
model_ge_area=glm(data_std~year_f:area+nam,data=glass_eel_yoy,family=Gamma(link=log),
    ⇨               subset=glass_eel_yoy$data>0 & glass_eel_yoy$year>1959 ,maxit=300)

    and this for Yellow Eel
model_older=glm(data_std~year_f+as.factor(nam),data=older,family=Gamma(link=log),subset=older$data>0 & older$year>1949 ,maxit=300)
```

The trends are constructed using the predictions from 1960. The number of individual series used change each year as more series are integrated: the number is reported in the Recruitment chapter each year. This analysis rebuilds all the series by extrapolating the missing values. Note that rebuilding annual values for the geometric means of predicted values is not different from looking at the coefficients for year in the model. The series are then averaged. Zero values are excluded from the GLM analysis: 17 for the glass eel model and 20 for the yellow eel model. This treatment is parsimonious, and tests showed that it has no effect on the trend (ICES, 2017). The GLM predicted vales (in 2020) for glass and yellow eel are shown in Tables 6 and 7.

The reference period for pre-1980 recruitment level is 1960–1979 and the data from 1950 to 1960 for four series were excluded. After 1960, the number of available series increases rapidly (Figure 11). Although no such biases are known for the yellow series recruitment series, the same reference period has been chosen to provide consistent results.

Following the high levels in the late 1970s, there has been a rapid decrease in the glass eel recruitment trends (Figures 12 and 13).

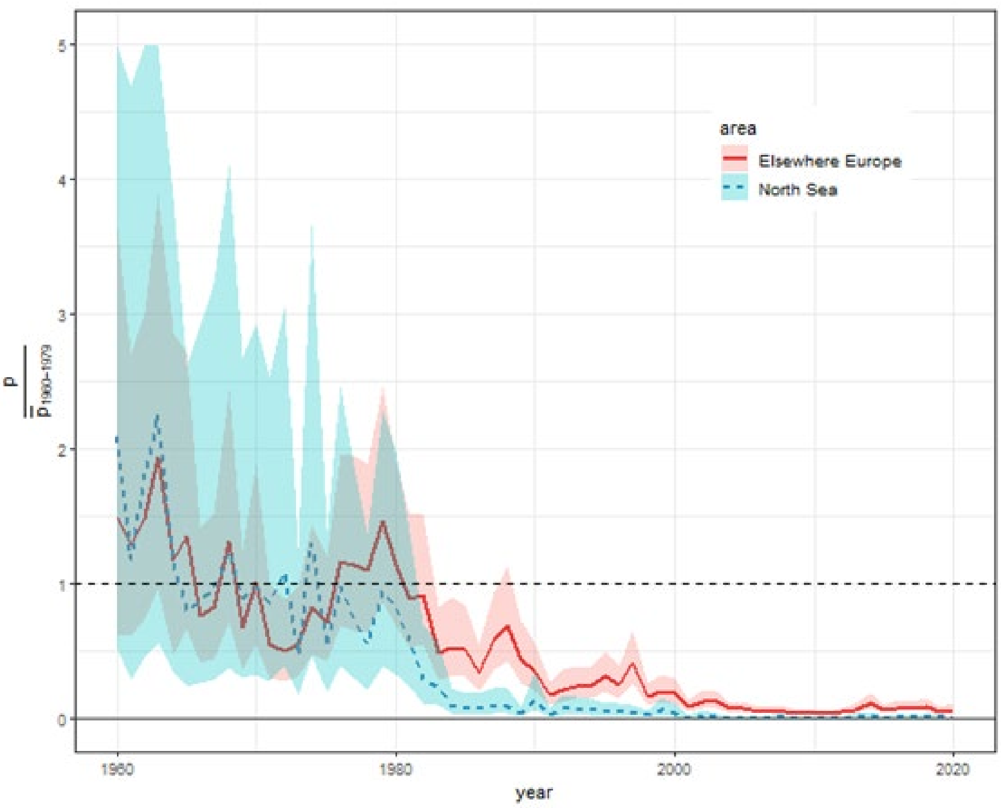


Figure 12. WGEEL recruitment index: estimated (GLM) glass eel recruitment for the continental North Sea and Elsewhere Europe series with 95 % confidence intervals updated to 2020. The GLM (glass eel ~ area:year + site) was fitted on 53 time-series comprising either pure glass eel or a mixture of glass eels and yellow eels. The predictions are scaled to the 1960–1979 average. In the Baltic area, recruitment occurs in the yellow eel stage only. Note: exemplar figure only: for the definitive version, please see the Recruitment chapter in the latest WGEEL report.

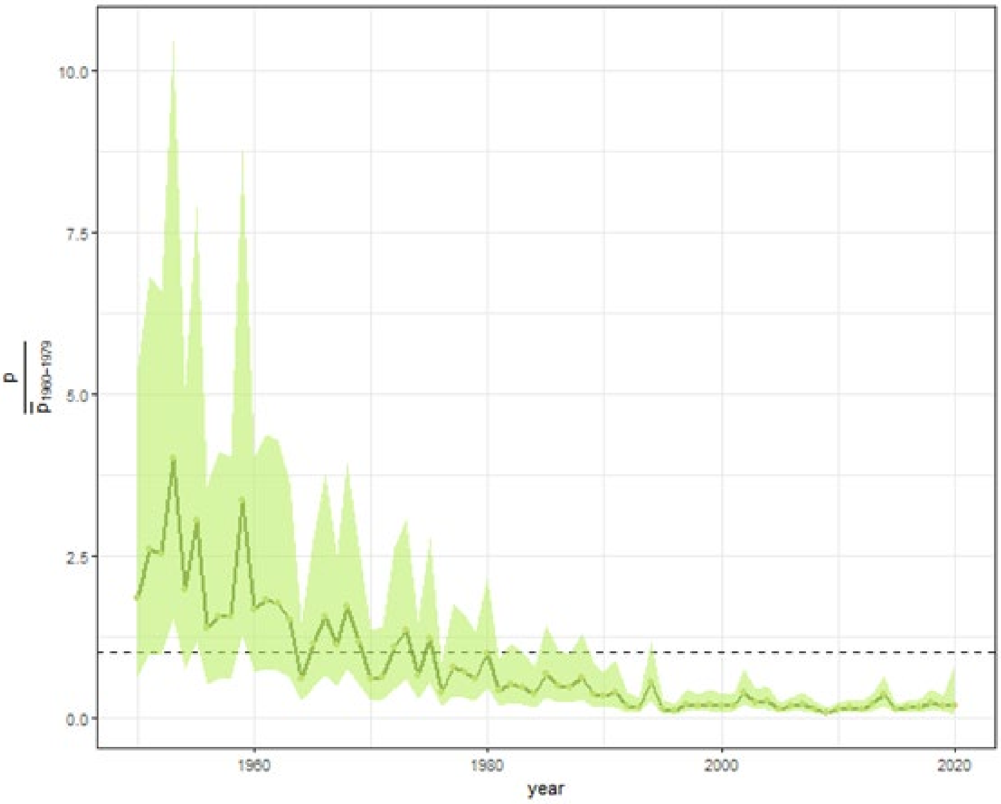


Figure 13. Geometric mean of estimated (GLM) yellow eel recruitment for Europe updated to 2020. The GLM (yellow eel ~ year + site) was fitted to 15 yellow eel time-series and scaled to the 1960–1979 average. In the Baltic area, recruitment occurs in the yellow eel stage only. Note: exemplar figure only: for the definitive version please see the Recruitment chapter in the latest WGEEL report.

Table 6. GLM glass eel ~ year: area + site geometric means of predicted values for 53 glass eel series, values given in percentage of the 1960–1979 period. Note these data provided as an illustration – they will be updated again at the next revision of the Stock Annex. Meanwhile up-to-date figures are published in the Recruitment chapter of the latest WGEEL report.

Year	1960s		1970s		1980s		1990s		2000s		2010s		2020s	
	EE	NS	EE	NS	EE	NS	EE	NS	EE	NS	EE	NS	EE	NS
0	150	208	102	98	114	81	35	15	19.4	4.7	4.4	0.7	6.6	0.5
1	128	118	56	85	89	58	17	3	8.7	1.0	3.6	0.5		
2	149	180	50	109	91	29	22	8	13.4	2.6	5.1	0.6		
3	194	225	56	47	49	24	24	7	12.9	1.9	7.2	1.9		
4	118	117	83	131	53	10	24	7	7.3	0.7	12.1	2.6		
5	135	79	72	54	52	8	32	5	8.0	1.1	6.7	0.9		
6	76	88	117	98	34	8	25	5	6.0	0.5	8.5	1.9		
7	82	97	113	75	59	9	41	4	6.4	1.3	8.1	1.1		
8	132	124	110	55	69	9	17	3	5.5	1.2	8.6	1.8		
9	68	89	147	95	45	4	21	7	4.1	0.8	5.4	1.4		

Table 7. GLM yellow eel ~ year + site geometric means of predicted values for 15 yellow eel series, values given in percentage of the 1960–1979 period. Note these data provided as an illustration, they will be updated again at the next revision of the Stock Annex. Meanwhile up-to-date figures are published in the Recruitment chapter of the latest WGEEL report.

year	1950s	1960s	1970s	1980s	1990s	2000s	2010s	2020s
0	184	167	59	99	32	18	12	18
1	261	181	62	41	38	18	14	
2	252	178	108	52	18	38	14	
3	401	151	135	47	14	23	20	
4	197	61	65	35	55	26	35	
5	304	114	122	66	13	13	11	
6	137	156	38	49	10	17	14	
7	157	111	78	47	22	20	15	
8	155	173	70	62	18	14	22	
9	335	116	59	37	22	8	18	

4.5 Determining a change in trend

An upward trend in recruitment is expected as a sign of a recovering stock. SGIPEE (ICES, 2011b), WGEEL (ICES, 2014, 2019a) have elaborated and refined methods to test signals of recovering recruitment. In 2014, a Bayesian Eel Recruitment Trend (BERT) model was proposed that accounts for the autocorrelation within recruitment series to give confidence in identifying a trend shift (ICES, 2014). The criterion can thus be defined based on this test. If the test gives a high credibility (95% for example) to a trend shift in the positive direction (i.e. an increase in recruitment), this can be considered as a good sign that the stock is at least moving towards recovery. Most recently (ICES, 2019a) updated the SGIPEE (ICES, 2011b) approach such that the model is now based on individual series as source data, not only the predictions. In addition, the model differs from that used by WGEEL for the GLM (above) as year is here treated as a continuous value, as opposed to a factor in the GLM for recruitment, and the years are restricted to decreasing part of the recruitment (after 1980).

$$\text{glass eel} \sim \alpha_{site}\text{site} + \beta_{area}Y_{>=1980} + \gamma_{area}Y_{>2011} + \varepsilon,$$

where

- glass eel are the data from glass eel and glass eel + yellow eel series, either for the 'Elsewhere Europe' or the 'North Sea' time-series,
- Y>=1980 is a continuous value corresponding to year after 1980,
- Y>2011 is also a continuous value,
- αsite, βarea and γarea are the estimated parameters, and
- • ε is a random error with mean 0 and standard deviation sigma.

This approach confirmed a change in recruitment slope in 2011. To examine if the slope of βarea + γarea, i.e. the slope of recruitment since 2011, is significantly positive, the NULL hypothesis H0: b <= 0 is tested. In 2020 the results showed a positive value for the trend after 2011, which is statistically significant for both the 'North Sea' and 'Elsewhere Europe' areas.

Although this criterion indicates a statistically significant positive trend in recruitment in recent years, it nevertheless describes recruitment at very low levels. Furthermore, it has no predictive power, and so cannot be used to infer the sustainability of a positive trend, nor the length of time before such a trend might be considered to reflect a recovered stock.

5 Data handling in the WGEEL

5.1 Data Call to collect the data

5.1.1 Introduction

Data from all countries within the geographic range of the European eel are requested from WGEEL in the form of a Data Call sent out in advance of the WGEEL meeting. This Data Call is a joint call from ICES, EIFAAC and GFCM, facilitated by ICES and is intended to formalize data reporting across those countries having natural production of European eel.

Much of the historic eel data are available to WGEEL already, but often in multiple versions, some with subtle differences and with limited information from which to identify the most up-to-date version. Furthermore, the descriptions of methods used to collect and process the data are often held separately in some Country Reports, and without the contact details of data stewards. These associated 'metadata' should be held alongside the 'eel data'

Some data such as landings, recruitment, aquaculture production, etc. are requested every year, whereas silver eel escapement biomasses (3Bs) and anthropogenic mortality rates (F, H and A) are requested every three years in line with the Eel Regulation reporting schedule, and other data such as fishing effort are requested on an ad hoc basis.

5.1.2 The eel Data Call in years 1, 2 and 3

The introduction of the Data Call was phased in over three years (2017, 2018, 2019). In 2017, the Data Call focused on data directly required to achieve the annual stock assessment in support of the ICES Advice. In 2018, it included the request for data on silver eel stock indicators, biomass production and escapement and anthropogenic mortality rates, etc. as specified by the Eel Regulation (European Council, 2007) and associated EMPs. According to this Regulation and the Joint Declaration between the EU and Member States (December 2017), these data are to be reported every three years.

In 2019, in addition to the annual update on data required for the stock assessment (recruitment, landings, releases and restocking, and aquaculture data), the Data Call included a request for data concerning silver eel escapement and yellow eel abundance time-series and information on fishing effort from eel fisheries in all waters. See Appendix SA3 for a list of the terms used in the Data Call and their definitions.

5.1.2.1 Definitions and uses of data

Data are reported in so-called Annexes which consist of Excel files containing the data input sheets as well as reference tables and instructions are found in a readme section.

Each annex corresponds to a data type which is listed below:

- Recruitment (glass eel and yellow eel recruitment Time-series);
- Yellow eel abundance indices (measures of the standing stock and not yellow eel recruitment);
- Silver eel abundance indices;
- Landings for commercial fisheries;
- Landings for recreational fisheries;

- Landings related to transport/relocations operation (when eels have been collected somewhere in traps and transported to other places where they appear as release);
- Releases;
- Aquaculture production.

Alongside each of these eel data, the following metadata are requested:

- Data Steward: name and email address of a person who can be contacted about the datasheet.
- Method used: short description of the method used to collect the data.
- Indication on whether there was change brought to existing data.

Silver eel stock indicators (requested every three years) are defined as follows:

Biomass indicators

▪B_0 The amount of silver eel biomass that would have existed if no anthropogenic influences had impacted the stock;

▪$B_{current}$ The amount of silver eel biomass that currently escapes to the sea to spawn;

▪B_{best} The amount of silver eel biomass that would have existed if no anthropogenic influences had impacted the current stock, included restocking practices, hence only natural mortality operating on stock.

Habitat Wetted Area

▪The Habitat_Wetted_Area is used for indicating the potential available area used as a habitat for the eels.

▪It is used to provide data on the available areas of all possible habitat types, such as Freshwater (F), Marine open sea (MO), WFD Transitional (T), WFD Coastal (C) and an aggregate of all the above.

▪This value is important for the calculation of the biomass indicators.

▪The unit of area should be the hectare (ha).

Mortality as silver eel equivalents biomass

Biomass all measured in kg.

◎SEE_com	Commercial fishery silver eel equivalents.
◎SEE rec	Recreational fishery silver eel equivalents
◎SEE_hydro	Silver eel equivalents relating to hydropower and water intakes, etc.
◎SEE_habitat	Silver eel equivalents relating to anthropogenic influences on habitat (quantity/quality).
◎SEE_stocking	Silver eel equivalents relating to restocking activity.
◎SEE_other	Silver eel equivalents from `other` sources.

Public status of data

This defines whether data can be used in the WGEEL report and displayed in the database visualization tool.

Eel fishing effort

This consists in a description of the eel fisheries present in every country, but also in the data representing effort (type and number of gears, days, etc.)

Codes for completing blank entries

The Data Call uses a series of 'N codes' (NP, ND, NR, etc) to fill cells where a quantitative 0 would not be appropriate. These are defined in the Data Call and in Appendix SA3 here.

5.2 Databases to store and analyse the data

5.2.1 Introduction

Ultimately, the output from these Data Calls is a database for European Eel stock, and complying with data quality standards for a PostgreSQL database. This database is used as a basis for timely and efficient drafting of stock status reports for ICES, the European Commission including fisheries and trade matters, and the provision of regional and whole stock advice across the natural range of the European eel. The Workshop on designing eel Data Call (WKEELDATA2) has further developed the Data Call procedures and the database, to automate data extraction, implement restrictions concerning the public status of data and ensure the functionality of the database suitable for WGEEL (ICES, 2019c).

5.2.2 GitHub depository for analytical methods and registering developments

A git repository hosts the code for WGEEL for recruitment analysis and data processing and to facilitate scientific collaboration:

https://github.com/ices-eg/wg_WGEEL

"Git" is a version control system that manages and stores revisions of projects. GitHub is a Git repository hosting service. It provides a Web-based graphical interface, access control and several collaboration features, such as a wikis and basic task management tools for every project.

The relevant data (landings, restocking, mortality rates, biomass indicators) provided through the Data Call are integrated into the existing WGEEL database using a shiny application. The idea is (1) to let WGEEL experts carry out checks on the new files, (2) help national correspondents to qualify their data for quality (3) compare the new data with the existing data in the database and check for duplicates. There are two applications, one to edit data straight into the database, and display graphs to check for duplicates once data are submitted. Detailed information can be found on the website:

https://github.com/ices-eg/wg_WGEEL/tree/master/R/shiny_data_integration

The second shiny application is used to visualize and analyse the data provided. It can be found at:

http://185.135.126.249:8080/shiny_dv/

5.3 Data Quality Assessment and Missing Data

Assurance of data quality is handled at several levels before, during and after the integration process (Figure 14). First, the Annex templates are pre-filled and provide examples to ensure consistency. Some fields contain drop-down menus and/or cells are constrained to limit the type and range of the data filled in by the users. Once the data are submitted to the stock assessors, they are first integrated in the shiny application where visualization of the data is possible providing a preliminary quality check by primarily removing duplicate data entries. Before the data are uploaded into the database, queries generate tables to make sure that the data are not already present in the database.

Data such as stock indicators, landings and aquaculture are given a quality level (1 = good quality, 2 = missing data, 3 = problem not to be used, 4 = quality problem but still used). If they later on prove to be problematic (possibly mentioned by the data provider), these are not discarded but are reassigned a code (19, 20, 21) to indicate that the value has been replaced by a new one. The code 19, 20 21 correspond to the year the data were removed. Concerning Time-series, data are updated, but their quality is checked line by line according to the comments from national delegates.

Finally, the automatically generated reports available on the GitHub are verified by the country delegates. These reports and the data visualization are linked to the database and are automatically updated if a change has been made in the database.

Concerning missing data, these are taken care of during data analysis. For landings, this “correction” is based on a simple GLM extrapolation of the log-transformed landings (after Dekker, 2003), with year and countries as the explanatory factors. This is applied to account for non-reporting, but it is not a complete solution. See Section 4.4. for details of the procedure used for the recruitment indices.

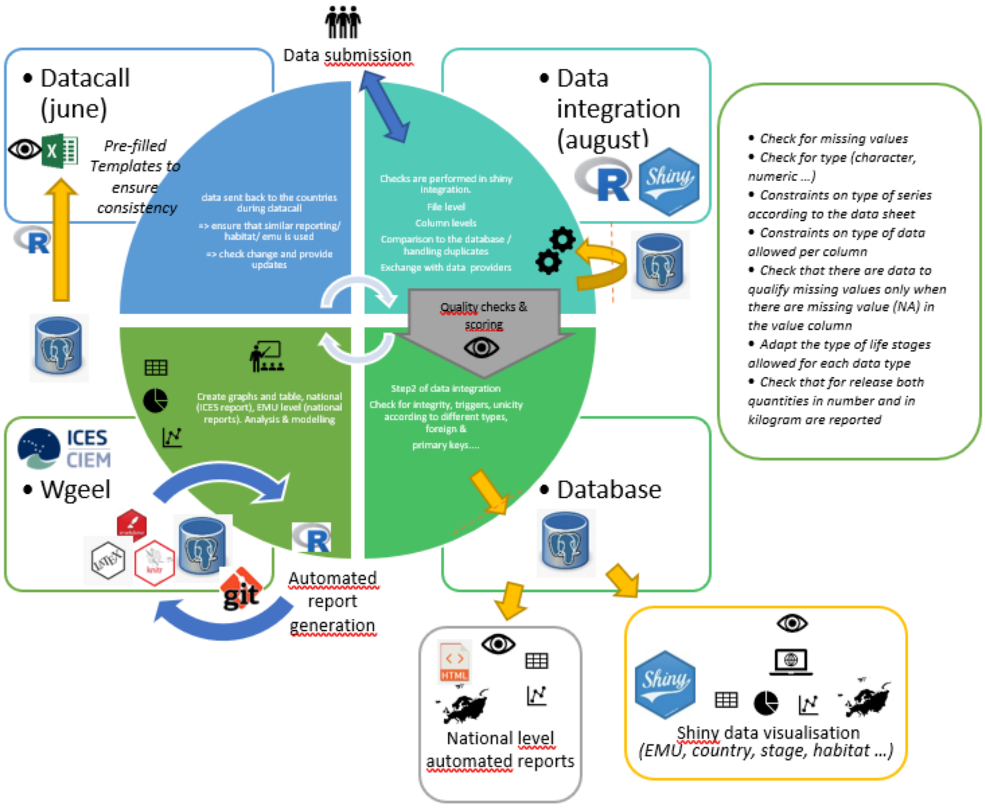


Figure14. Schematic outlining the four main steps of data entry and quality assurance used by the WGEEL.

5.4 The Eel Quality Database (EQD)

There has been a growing awareness that reduced spawner quality might be an essential element in the decline of the species, and may also hinder a recovery. 'Spawner quality' describes the capacity of silver eels to reach spawning areas and to produce viable offspring (FAO, EIFAAC and ICES, 2006). Poor condition of silver eels migrating to the oceanic spawning grounds might be a factor in explaining the stock decline. Getting a comprehensive overview of the quality (including contamination levels, biomarker responses, lipid content and condition) of the silver eel population across its natural range seems to be an essential objective for managing the recovery of the stock. However, the challenge of incorporating eel quality into the assessments remains.

Following the need to collect and report on data on the health status of the eel on international level, ICES (2007c) initiated an Eel Quality Database (EQD). Its objective was to congregate recent data of contaminants and diseases measured or assessed in anguillid eels. The EQD was further developed in the WGEEL during following years. The database represented the first comprehensive compilation of eel health data, including data from over 10 000 eels from approximately 1200 sites over 14 countries. Further description of the database is presented in Belpaire *et al.* (2011). A major bottleneck for further sustainable long-term management of the EQD is the lack of resources on an open time frame basis. ICES (2009) suggested that the EQD should be managed at an international level (e.g. by ICES or some European agency, with long-term funding options and database management expertise). The Workshop of a Planning Group on the Monitoring of Eel Quality under the subject "Development of standardized and harmonized protocols for the estimation of eel quality" (WKPGMEQ, ICES, 2015c) reiterated this recommendation.

6 Other aspects related to stock assessments

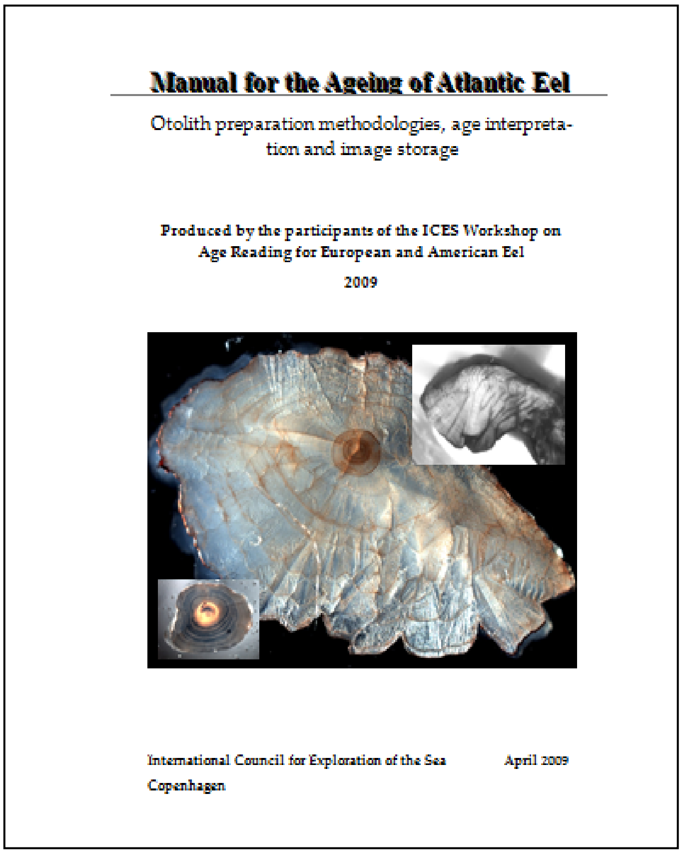
6.1 Age

6.1.1 Introduction

Eel age determination for Atlantic eel has long been problematic with much debate on both the techniques and the interpretation with relatively few validation studies. Validation is difficult given the terminal nature of ageing with otoliths and the relatively slow growth and long life cycle often involving different habitats. Ageing using sagittal otoliths, rather than other structures such as scales and opercular bones, appears to be the only viable option for eel and the extraction of eel otoliths was described by Moriarty (1973).

The results obtained using different preparation methods may vary considerably (Moriarty and Steinmetz, 1979; Moriarty, 1983; Berg, 1985; Vøllestad, 1985; Vøllestad and Næsje, 1988; Fontenelle, 1991; Poole *et al*., 1996b) but few have been validated. The ageing of slow growing eels and the occurrence of supernumerary zones has caused much confusion (Dahl, 1967; Moriarty, 1972, 1983; Deelder, 1981; Poole *et al*., 1992) although subsequently, the 'burning and cracking' method was validated in some situations (Moriarty and Steinmetz, 1979; Moriarty, 1983; Vøllestad and Næsje, 1988; Poole *et al*., 1996a).

Burning and cracking was recommended by an EIFAAC eel age workshop in 1987 as the best option for ageing eels (Vøllestad *et al*., 1988), particularly for the slow growing and older specimens (e.g. Vøllestad and Næsje, 1988). There have been many developments since 1988, both in improved otolith preparation techniques, imaging, and validations along with the use of eels of known age and chemical marking of otoliths.



Manual for the Ageing of Atlantic Eel

Otolith preparation methodologies, age interpretation and image storage

Produced by the participants of the ICES Workshop on Age Reading for European and American Eel

2009

International Council for Exploration of the Sea Copenhagen April 2009

Two ICES Workshops, WKAREA (Working Group on Age Reading of European and American Eel) and WKAREAII, produced protocols and a Manual for the extraction, preparation and reading of otoliths (ICES, 2009, 2011c). The workshops also carried out intercalibration between methods and between readers. It was recommended that the User Manual developed by the Workshop should be followed for eel age determination. It is also recommended that periodic updating of the manual should take place and reader verification and intercalibration should be routinely organised. Therefore, WKAREA met again in 2019. The group conducted a collective reading of European eel otoliths extracted from eels sampled in six aquatic systems from the South West Europe area (SUDOE area), which had been poorly represented in previous workshops.

6.1.2 Age reading

The two main otolith preparation protocols for the Atlantic species of eel, *Anguilla anguilla* and *A. rostrata*, currently in use are, with slight variations between institutes, the burning and cracking (or better now the cutting and burning), and the grinding and polishing (and in most cases staining) protocols. Clearing whole otoliths "*in toto*" has limited use for small eels of young age. A preparation with a transverse section of the otolith should be used for slow growth, or old eels, with burning and cracking.

The estimation of growth is based on the count of winter annuli, excluding the oceanic and glass eel phase. The identification of the zero band may be confirmed by the use of the measurement of the nucleus size, or the average measurement of the radius from the centre of the nucleus to the zero band (170 µm) which is quite consistent for *A. anguilla* and *A. rostrata*, irrespective of the otolith preparation technique used.

The date of reference for age is set as the 1st of January, meaning that a cautious approach is recommended for eels sampled in winter and spring before the period for which the winter annuli is not obvious on the otolith margin. Age estimation should be obtained using both the otolith annuli count and additional data such as location and date of capture, eel life stage (i.e. yellow or silver), length, sex, and previous history if known (e.g. restocked from wild, restocked from aquaculture) as this supports a more accurate interpretation of the growth pattern and helps to discriminate winter annuli from false checks. "Blind reader" tests may be appropriate in some circumstances but for routine age determination, possession of the full information reduces unnecessary misinterpretation and variability. Otoliths from the southern part of the eel range present an overall growth pattern, that is different from otoliths from the northern area, where the annual rings are tightly distributed reflecting shorter seasonal growth periods (ICES, 2020b). There are also problems related to supernumerary rings that may correspond to stress marks (for example due to high temperatures in southern areas). In view of the uncertainty associated with the age estimation of eels in general, there are concerns in the use of age readings data for stock assessment. To further increase precision and reduce the risk of biased growth estimates, it is a priority that mark recapture studies are conducted to ground truth the age and identify patterns of ring formation. Additionally, it may be useful to add a measure of confidence to the age estimate, to identify reliable data (Durif *et al.,* 2020). Reference should be made to the Eel Age Manuals (ICES, 2009, 2011c) for methods, terminology, reference collections and images of ototliths and inter-calibrated readings.

6.2 Maturity/silver determination

The eel is semelparous and undergoes a period of maturation, known as silvering, before and during its migration from its continental habitat to the ocean. Determining the silvering stage is important in quantifying the proportion of eels likely to finally silver and migrate as potential spawners.

Methods used for determination of silvering stage were reviewed by the WGEEL (ICES, 2010b) and compared to assess their practicality and efficiency as tools to evaluate the number of potential spawners in a sample. Methods using external objective criteria (such as body measurements) are more accurate than observations based on skin colour or the visibility of the lateral line. The silvering index (Durif *et al*., 2005, 2009), based on eye diameters, pectoral fin length, body length and body weight, was preferred for an accurate description of the sample (ICES, 2010b; Table 8). Practical guidelines are specified to measure body parameters.

The pectoral fin length is measured from the insertion to the tip of the fin and corresponds to the greatest possible length (Figure 15). The mean eye diameter is calculated using vertical (Dv) and horizontal (Dh) eye diameters, measured along the visible part of the cornea.

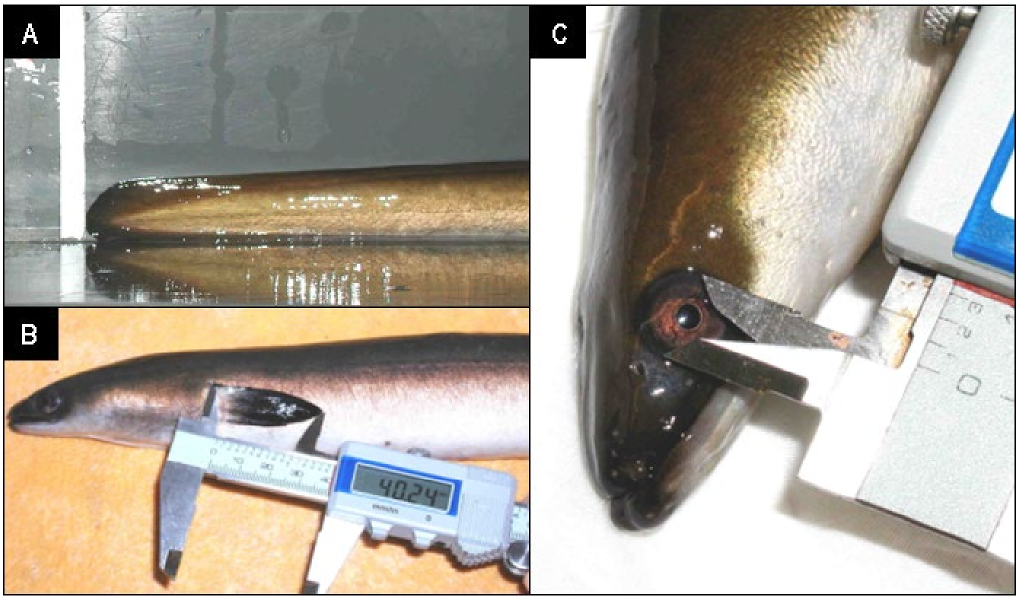


Figure 15. Details of the body measurements (A. body length B. pectoral fin length; C. Horizontal eye diameter). Durif *et al.*, 2009.

Table 8. Classification functions for stage determination (I to FV and MII) of eels. Values correspond to the weights to be assigned to each variable. c: Constant, BL (body length in mm), W (body weight in g), MD (mean eye diameter in mm), FL (fin length in mm).

	Yellow eels		Pre-silver females	Silver females		Silver males
	I	FII	FIII	FIV	FV	MII
c	-61.276	-87.995	-109.014	-113.556	-128.204	-84.672
BL	0.242	0.286	0.280	0.218	0.242	0.176
W	-0.108	-0.125	-0.127	-0.103	-0.136	-0.116
MD	5.546	6.627	9.108	12.187	12.504	12.218
FL	0.614	0.838	1.182	1.230	1.821	1.295

Classification scores for each case are computed for each stage according to the formula:

$$S_i = c_i + w_{i1}*x_1 + w_{i2}*x_2 + \dots + w_{in}*x_n$$

An R script is available for stage determination using this approach (Beaulaton, personal communication), and an excel macro is available from Durif. Where I denotes the respective stage, *n* denotes the *n* variables, *c* is a constant (Table 2), w_{in} is the weight for the n^{th} variable in the computation of the classification score for the i^{th} group, and x_n is the observed value for the respective case for the n^{th} variable. S_i is the resultant classification score. An eel was assigned to the stage for which it had the highest S_i. The efficiency of the analysis was evaluated through a classification matrix, which indicated the number of eels that were correctly classified and those that were misclassified.

7 Next steps for developing the Eel Stock Annex

The further development of this Stock Annex will depend largely on the development of the stock assessment procedures in support of the ICES stock advice. The forthcoming Workshop on the Future of Eel Advice (WKFEA) and its outcomes are anticipated to be the next major revision to this process.

However, a new section describing briefly how each Country derives its escapement biomass and mortality rate stock indicators would be very useful as a reference source. Such descriptions should include sections on data collection methods, data analysis and quality assurance procedures.

8 European eel in ICES Ecosystem and Fisheries Overviews

8.1 Ecosystem overviews

Azores: The European eel is present in this ecosystem but is not listed in the overview.

Baltic Sea: The European eel is listed under sections on "Key signals within the environment and ecosystem"; "Selective extraction of species, including incidental non-target catch"; and, "Impacts on threatened and declining fish species".

Barents Sea: The European eel is listed under section "Threatened and declining species and habitats".

Bay of Biscay and the Iberian Coast: The European eel is listed under sections on "Selective extraction of species: Impacts on commercial stocks"; "Impacts on threatened and declining fish species"; State of the ecosystem: fish"; and, "Threatened and declining species and habitats".

Celtic Seas: The European is eel listed under section "Threatened and declining species and habitats".

Greater North Sea: The European eel is listed under section "Threatened and declining species and habitats".

Icelandic Waters: The European eel is listed under section "Threatened and declining species and habitats".

Norwegian Sea: The European eel is listed under section "Threatened and declining species and habitats".

Oceanic Northeast Atlantic: The European eel is listed under sections "State of the ecosystem: Fish"; and "Threatened and declining species and habitats".

8.2 Fisheries Overviews

Baltic Sea**:** The European eel is listed under sections "Who is fishing: Denmark; Poland; Sweden"; "Catches over time"; "Description of the fisheries: Longline; Trapnets and fykenets"; and, "Summary of Baltic Sea stocks in 2019".

Barents Sea**:** The European eel is listed under sections "Status of the fishery resources" and, "List of stocks".

Bay of Biscay and Iberian Coast Region**:** The European eel is listed under sections "Description of the fisheries: Artisanal"; "Status of the resource"; and "List of stocks".

Celtic Seas**:** The European eel is listed under sections "Description of the fisheries: Other fisheries"; "Status of the resource"; "Summary of Celtic Seas ecoregion stocks in 2019" and, "Scientific names of species".

Greater North Sea**:** The European eel is listed under sections "Description of the fisheries"; "Status of the resource"; "Summary of Greater North Sea ecoregion stocks in 2019" and, "Scientific names of species".

Icelandic Waters**:** The European eel is not mentioned.

Norwegian Sea**:** The European eel is listed under sections "Bycatch of protected, endangered, and threatened species"; "Status of the resource" and, "Scientific names of species".

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Appendix SA1: Abbreviations and acronyms

Acronyms	Definition
AA	Administrative Agreement, typically the recurring agreement between ICES and the EC
ACFM (ICES)	Advisory Committee on Fisheries Management
ACOM (ICES)	Advisory Committee on Management
ADGEEL	Advice drafting group on eel, for ICES
AIC	Akaike Information Criterion
AngHV-1	Anguillid herpes virus 1
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
BERT	Bayesian Eel Recruitment Trend model
BIC	Bayesian Information Criterion
CCM	Catchment Characterisation and Modelling
CITES	Convention on International Trade in Endangered Species of Flora and Fauna
CMS	Convention on the Conservation of Migratory Species of Wild Animals
COMM	European Commission, also EC is used.
CPUE	Catch per unit of effort
CR	Country Report
C&R	Catch and release
CUSUM	Cumulative Sum Control Chart
DAERA	Department of Agriculture, Environment and Rural Affairs (N. Ireland)
DBEEL	Database on Eel (from EU POSE project)
DCF	Data Collection Framework of the European Union
DEMCAM	Demographic Camargue Model
DG-MARE	Directorate-General for Maritime Affairs and Fisheries, European Commission
DLS	Data-Limited Stocks
EC	European Commission, also COMM is used.
e-DNA	Environmental DNA
EDA	Eel Density Analysis (model, France)
EIFAAC	European Inland Fisheries & Aquaculture Advisory Commission
EIFAC	European Inland Fisheries Advisory Commission – became EIFAAC in 2008
EMP	Eel Managment Plan
EMU	Eel Management Unit
EFF	European Fisheries Fund
EQD	Eel Quality Database
EROD	Ethoxyresorufin-O-deethylase
ESAM	Eel Stock Assessment Model
EU	European Union
EU MAP	The European Multiannual Plan, previously the DCF
EVEX	Eel Virus European X
FAO	Food and Agriculture Organisation
FEAP	The Federation of European Aquaculture Producers
GAM	Generalised Additive Model
GEM	German Eel Model
GFCM	General Fisheries Commission of the Mediterranean
GIS	Geographic Information Systems
GLM	Generalised Linear Model
GlobAng	French Model of Eel Population Dynamics
GST	Glutathione-S-transferase
HPS	Hydropower Station
ICES	International Council for the Exploration of the Sea

Acronyms	Definition
IMESE	Irish model for estimating silver eel escapement
IUCN	International Union for the Conservation of Nature
IUU	Illegal, Unreported and Unregulated fisheries
LAM	Lifetime anthropogenic mortalities
LHT	Life History Trait
LVPA	Length-based Virtual Population Assessment
L50	L50 = the length (L) at which half (50%) of a fish species may be able to spawn
MS	Member State, typically used in reference to EU Member States but not only
MSY	Maximum Sustainable Yield
NAO	North Atlantic Oscillation
NA	Not applicable
NC	Not collected, code to explain an empty data value cell
ND	No data, code to explain an empty data value cell
NDF	Non-detriment Finding
NP	Not pertinent, code to explain an empty data value cell
NR	Not recorded, code to explain an empty data value cell
POSE	Pilot projects to estimate potential and actual escapement of silver eel (EU project)
RBD	River Basin District, typically as defined according to the EU Water Framework Directive
RGMAREEL	Workshop on Fisheries Related Impacts on Silver eels 2017
RG-TEMPP	Review of the Trans-border management plan for European eel, *Anguilla anguilla*, in the Polish-Russian zone of the Pregola River basin and Vistula Lagoon
RS_EMP	Review Service – Evaluation of Eel management Plans 2010
SAC	The GFCM Scientific and Advisory Committee on Fisheries
SCICOM	The Science Committee of ICES
SGAESAW	Study Group on anguillid eels in saline waters 2009
SGIPEE	Study Group on International Post-Evaluation on Eels 2010, 2011
SLIME	Restoration the European Eel population; pilot studies for a scientific framework in support of sustainable management (EU project)
SMEP II	Scenario-based Model for Eel Populations, vII (model applied in England and Wales, UK)
SPR	Estimate of spawner production per recruiting individual.
SQL	Special purpose programming language for managing data
SRG	Scientific Review Group of the European Commission
SSB	Spawning–Stock Biomass
STECF	Scientific, Technical and Economic Committee for Fisheries, European Commission
ToR	Terms of Reference
VPA	Virtual Population Analysis
WG	Working Group
WFD	Water Framework Directive, European Directive
WGEEL	Joint EIFAAC/ICES/GFCM Working Group on Eels
WKBALTEEL	Workshop on Baltic Eel 2010
WKBECEEL	Working Group on Biological Effects of Contaminants in Eel 2016
WKEELCITES	Workshop on Eel and CITES 2015
WKEELDATA	Workshop on Designing an Eel Data Call 2017
WKEELDATA2	Second Workshop on designing an Eel Data Call 2019
WKEELMIGRATION	Workshop on the Temporal Migration patterns of European Eels 2020
WKEMP	Workshop on Evaluating Management Plans – 2018
WKEPEMP	The Workshop on Evaluating Progress with Eel Management Plans 2013
WKESDCF	Workshop on Eels and Salmon in the Data Collection Framework 2012
WKFEA	Workshop on the future of eel advice 2021
WKLIFE	Workshop on the Development of Assessments based on LIFE-history traits and Exploitation Characteristics
WKPGMEQ	Workshop of a Planning Group on the Monitoring of Eel Quality under the subject "Development of standardized and harmonized protocols for the estimation of eel quality"

Acronyms	Definition
WKSTOCKEEL	Workshop on Eel Stocking 2016
WKTEEL	Workshop on Tools for Eel 2018
WGRFS	Working Group on Recreational Fisheries Surveys
YFS1	Young Fish Survey: North Sea Survey location
IYFS	International Young Fish Survey

Appendix SA2: Glossary

ANTHROPOGENIC	CAUSED BY HUMANS.
Assisted migration	The practice of trapping and transporting juvenile eel within the same river catchment to assist their upstream migration at difficult or impassable barriers, without significantly altering the production potential (B_{best}) of the catchment
Bootlace, fingerling	Intermediate sized eels, approx. 10–25 cm in length. These terms are most often used in relation to restocking. The exact size of the eels may vary considerably. Thus, it is a confusing term.
Catch	The WGEEL uses the term catch(es) to mean fish that are caught but not necessarily landed. See landings below
Depensation	The effect on a population when a decrease in spawners leads to a faster decline in the number of offspring than in the number of adults.
Eel River Basin or Eel Management Unit	"Member States shall identify and define the individual river basins lying within their national territory that constitute natural habitats for the European eel (eel river basins) which may include maritime waters. If appropriate justification is provided, a Member State may designate the whole of its national territory or an existing regional administrative unit as one eel river basin. In defining eel river basins, Member States shall have the maximum possible regard for the administrative arrangements referred to in Article 3 of Directive 2000/60/EC [i.e. River Basin Districts of the Water Framework Directive]." EC No. 1100/2007.
Elver	Young eel, in its first year following recruitment from the ocean. The elver stage is sometimes considered to exclude the glass eel stage, but not by everyone. To avoid confusion, pigmented 0+cohort age eel are included in the glass eel term.
Escapement	The amount of eel that leaves (escapes) a waterbody, after taking account of all natural and anthropogenic losses. Most commonly used with reference to silver eel – silver eel escapement.
Glass eel	Young, unpigmented eel, recruiting from the sea into continental waters. WGEEL consider the glass eel term to include all recruits of the 0+ cohort age group, including some pigmented eel.
Index river	*Definition to be discussed with ISSG-diadromous*
Landings	The WGEEL uses the term Landings to mean fish that are brought ashore.
Leptocephalus	Flat and transparent marine larval stage of eel, on migration from spawning ground to continental waters, between pre-Leptocephalus and metamorphosis to glass eel
Lifestage	Defined stage in the lifecycle of eel, whether leptocephalus, glass eel, yellow eel, or silver eel.
Limit reference point	A Limit Reference Point indicates a state of a fishery and/or a resource which is considered to be undesirable and which management action should avoid.
Non-detriment finding (NDF)	In relation to CITES, the competent scientific authority has advised in writing that the capture or collection of the specimens in the wild or 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.
Ongrown eels	Eels that are grown in culture facilities for some time before being restocked. Whether the time is to meet quarantine requirements, for the receiving environment conditions to be suitable, or as part of the culture and grading purpose.
Pre-leptocephalus	First larval stage of eel, between hatching from ovum and leptocephalus
Production	The amount of fish produced from a waterbody. Sometimes referred to for silver eel in terms as escapement + anthropogenic losses, or production – anthropogenic losses = escapement.
River Basin District (RBD)	The area of land and sea, made up of one or more neighbouring river basins together with their associated surface and groundwaters, transitional and coastal waters, which is identified under Article 3(1) of the Water Framework Directive as the main unit for management of river basins. The term is used in relation to the EU Water Framework Directive.
Restocking	The practice of adding fish [eels] to a waterbody from another source, to supplement existing populations or to create a population where none exists
Silver eel	Migratory phase following the yellow eel phase. Eel in this phase are characterized by darkened back, silvery belly with a clearly contrasting black lateral line, enlarged eyes. Silver eel undertake downstream migration towards the sea, and subsequently westwards. This phase mainly occurs in the second half of calendar years, although some are observed throughout winter and following spring.
Target reference point	A Target Reference Point indicates to a state of fishing and/or a resource which is considered to be desirable and at which management action, whether during development or stock rebuilding, should aim. FAO, 1995.

Anthropogenic	Caused by humans.
To silver (silvering)	Silvering is a requirement for downstream migration and reproduction. It marks the end of the growth phase and the onset of sexual maturation. This true metamorphosis involves a number of different physiological functions (osmoregulatory, reproductive), which prepare the eel for the long return trip to the Sargasso Sea. Unlike smoltification in salmonids, silvering of eels is largely unpredictable. It occurs at various ages (females: 4 – 20 years; males 2 – 15 years) and sizes (body length of females: 50 – 100 cm; males: 35 – 46 cm) (Tesch, 2003).
Trap and Transport	Capturing downstream migrating silver eel for transportation around hydropower turbines
Yellow eel	Life-stage resident in continental waters. Often defined as a sedentary phase, but migration within and between rivers, and to and from coastal waters occurs and therefore includes young pigmented eels ('elvers' and bootlace).

Appendix SA3: Stock Reference Points and Data Call terms

Age	The age of eel in years., with part years as plus growth (e.g, 0+, 1+), starting at recruitment to coastal waters. Glass eel are defined as 0+.
Aggregate habitat (AL)	Data Call term for aggregrated habitats where data is commined across habitat categories.
A_{lim}	Limit anthropogenic mortality: Anthropogenic mortality, above which the capacity of self-renewal of the stock is considered to be endangered and conservation measures are requested (Cadima, 2003).
A_{pa}	Precautionary anthropogenic mortality: Anthropogenic mortality, above which the capacity of self-renewal of the stock is considered to be endangered, taking into consideration the uncertainty in the estimate of the current stock status.
Aquaculture production	The biomass of eel harvested in aquaculture during a time frame; e.g., a year.
Baltic region	The countries bordering the Baltic Sea; sometimes other countries in the catchment are also included.
bio_age	mean age.
bio_g_in_gy	proportion (in %) of glass eel [100 for only glass eel ; 0 for only yellow eel ; the proportion if mix of glass and yellow eel].
bio_length	mean length in mm.
bio_sex_ratio	sex ratio express as a proportion of female; between 0 (all males) and 100 (all females).
bio_year	year during which biological samples where collected.
bio_weight	mean individual weight in g.
$B_{current}$ or B_{curr}	The Current escapement biomass: The amount of silver eel biomass that currently escapes to the sea to spawn, corressponding to the assessment year.
B_{best}	The amount of silver eel biomass that would have existed if no anthropogenic influences had impacted the current stock, included re-stocking practices, hence only natural mortality operating on stock. The Best achievable escapement biomass under present conditions: escapement biomass corresponding to recent natural recruitment that would have survived if there was only natural mortality and no restocking, corressponding to the assessment year.
B_0	The amount of silver eel biomass that would have existed if no anthropogenic influences had impacted the stock. Reference point for the theoretical maximum quantity of silver eel expressed as biomass that would have escaped from a defined eel producing area, in the absence of any anthropogenic impacts.
B_{lim}	Limit spawner escapement biomass, below which the capacity of self-renewal of the stock is considered to be endangered and conservation measures are requested (Cadima, 2003).
B_{MSY}	Spawning stock biomass (SSB) that is associated with the Maximum Sustainable Yield.
$B_{MSY-trigger}$	Value of spawning–stock biomass (SSB) which triggers a specific management action, in particular: triggering a lower limit for mortality to achieve recovery of the stock.
B_{pa}	Precautionary spawner escapement biomass: The spawner escapement biomass, below which the capacity of self-renewal of the stock is considered to be endangered, taking into consideration the uncertainty in the estimate of the current stock status.
Commercial Fisheries	Fisheries with sale of catch for commercial gain.
Coastal waters	WFD coastal waters.
das_comment	Comment (including comments about data quality for this year) (note das is short for dataseries).
das_effort	Effort (if used).
das_value	Value.
das_year	Year.
Eel mannagement unit (EMU)	Eel management unit defined in an Eel Management plan under the Eel Regulation 1100/2007.
F	Fishing mortality rate.
FAO areas	See http://www.fao.org/fishery/area/search/en
F_{lim}	F_{lim} is the fishing mortality which in the long term will result in an average stock size at B_{lim}.

F_{pa}	ICES applies a precautionary buffer F_{pa} to avoid that true fishing mortality is above F_{lim}.
F-rec	recreational fishing mortality, per reporting year, in kg.
Fresh waters	Waters with zero salinity.
F_{MSY}	F_{MSY} is estimated as the fishing mortality with a given fishing pattern and current environmental conditions that gives the long-term maximum yield.
G	Code in Data Call for data comprising Glass eel only as defined in Glossary.
G+Y	Code in Data Call for data comprising a Glass eel with yellow eel mix.
GEE-n	Glass eel equivalents in numbers – the quantity of eel expressed as equivalent number of glass eel. Method provided in ICES (2013) report p103.
Glass eel recruitment series	Time-series enumerating glass eel recruiting from the sea into continental waters.
GLM	Generalized linear model (used by ICES to predict and fill in gaps in the data).
Habitat	Waters occupied by eel, whether fresh, transitional, coastal or marine.
ICES statistical rectangles	See http://gis.ices.dk/sf/index.html?widget=StatRec
Inland waters	Fresh waters, not under the jurisdiction of Marine fisheries management (i.e. the CFP).
Landings from fisheries	Commercial landings include any eel taken from the water and landed on the market. Recreational landings include any eel taken from the water by recreational fisheries. Other landings include eel caught for assisted migration, translocation.
Length in mm	Total length measured from tip of nose to tip of tail (TL).
Longitude	x (longitude) EPSG:4326. WGS 84 (Google it).
Latitude	y (latitude) EPSG:4326. WGS 84 (Google it).
M	Natural Mortality.
North Sea	For the purposes of ICES eel management, taken as ICES sea areas IV $_a$, IV $_b$, IV $_c$ and inflowing fresh water systems.
Marine waters	(Abbreviated MO) Open marine waters.
q_aqua_kg	Aquaculture production (kg) in reporting year.
q_aqua_n	Aquaculture production (number of eel) in reportng year.
Fisheries - Recreational	Recreational (= non-commercial) fishing is the capture or attempted capture of living aquatic resources mainly for leisure and/or personal consumption.
Releases	Eel released to the wild after capture.
R_{target}	The Geometric Mean of observed recruitment between 1960 and 1979, periods in which the stock was considered healthy.
R(s)	The amount of eel (<20 cm) restocked into national waters annually.
S	Code in Data Call for data comprising Silver eel.
Sea region (division)	ICES Sea area statisitical rectangle. Where required for freshwater eel habitats, is the sea area the River basin drains to.
SEE–n	Silver eel equivalents in numbers – the quantity of eel expressed as equivalent number of silver eel.
SEE_com	Commercial fishery silver eel equivalents.
SEE rec	Recreational fishery silver eel equivalents).
SEE_hydro	Mortility in hydropower, pumps and water intakes etc expressed as Silver eel equivalents.
SEE_habitat	Silver eel equivalents relating to anthropogenic influences on habitat (quantity/quality).
SEE_release	Silver eel equivalents relating to release activity.
SEE_other	Silver eel equivalents from `other` sources.
Silver eel abundance series	Time-series of abundance of silver eel determined by consistent regular count or survey (usually by capturing migrating silver eel).
ser_nameshort	short name of the recruitment series, this must be 4 letters + stage name, e.g. VilG, LiffGY, FremS, the first letter is capitalised and the stage name too.
ser_namelong	long name of the recuitment series eg `Vilaine estuary` for the Vilaine;
ser_typ_id	type of series 1= recruitment series, 2 = yellow eel standing stock series, 3 silver eel series.

ser_effort_uni_code	unit used for effort, it is different from the unit used in the series, for instance some of the Dutch series rely on the number hauls made to collect the glass eel to qualify the series, see units sheet.
ser_comment	This comment should at least include a short description of the methods, give an idea on the size of the eels and the proportion of glass eel, whether it is mixed (e.g. glass and yellow) or not, possible biases (e.g. by restocking) and a mention if the series is special in any way (e.g. very old/long).. Note that this text will be displayed as a description of the series in the shiny app, thus consider the "readability".
ser_uni_code	Units used in the series, see tr_units_uni sheet.
ser_lfs_code	Lifestage see tr_lifestage_lfs sheet.
ser_hty_code	Habitat type see tr_habitattype_hty (F=Freshwater, MO=Marine Open,T=transitional, AL=aggregate...).
ser_locationdescription	This should provide a description of the site, e.g. if ist far inland, in the middle of a river, near a dam etc. Also please specify the adjectant marine region (Baltic, North Sea) etc. (e.g. "Bresle river trap 3 km from the sea" or IYFS/IBTS sampling in the Skagerrak-Kattegat" Note that this text will be displayed as a description of the site in the shiny app, thus consier the "readability".
ser_emu_nameshort	The codes of the emu (emu_nameshort) in sheet tr_emu_emu. In case you provide data for each EMU separately then you don't need to fill in for AL and vice versa.
ser_cou_code	The cou_code in the tr_country_cou table.
ser_area_division	Fao code of sea region (division level) see tr_fao_area (column division)(https://github.com/ices-eg/WGEEL/wiki). These codes are for use only in the case of Coastal and Marine Open waters – otherwise you can leave it blank. ICES statistical rectangles (http://gis.ices.dk/sf/index.html?widget=StatRec) and FAO areas map (http://www.fao.org/fishery/area/search/en).
ser_tblcodeid	This should refer to the id of the series once inserted in ICES station table, currently void : ignore.
ser_x	x (longitude) EPSG:4326. WGS 84.
ser_y	y (latitude) EPSG:4326. WGS 84.
ser_sam_id	The sampling type corresponds to trap partial, trap total, see tr_samplingtype_sam (sam_id).
Silver eel abundance series	Time-series of abundance of silver eel determined by consistent regular count or survey (usually by capturing migrating silver eel).
Skagerrak-Kattegat	For the purposes of ICES eel management, taken as ICES Sea areas III_b, III_c and inflowing fresh water systems.
SPR	Spawner per recruit: estimate of spawner production per recruiting individual.
%SPR	Ratio of SPR as currently observed to SPR of the pristine stock, expressed in percentage. %SPR is also known as Spawner Potential Ratio.
Standing stock	The total stock of eel present in a waterbody at a point in time, expressed as a number of individuals or total biomass.
sumA	total Anthropogenic mortality, per reporting year , in kg.
sumF	total Fishing Mortality per reporting year, in kg.
sumH	total non fishing Anthropogenic mortality, per reporting year in kg.
sumF_com	Mortality due to commercial fishery, summed over age groups in the stock.
SumF_rec	Mortality due to recreational fishery, summed over age groups in the stock.
SumH_hydro	Mortality due to hydropower (plus water intakes etc) summed over the age groups in the stock (rate).
SumH_habitat	Mortality due to anthropogenic influence on habitat (quality/qauntity) summed over the age groups in the stock (rate).
SumH_other	Mortality due to other anthropogenic influence summed over the age groups in the stock (rate).
SumH_release	Mortality due to release summed over the age groups in the stock (rate: negative rate indicates positive effect of release).
Transitional waters	WFD transitional waters, implies reduced salinity.
Transport/relocation operations	When eels have been collected somewhere in traps and transported to other places where they appear as "release" for the purposes of data recording.
ΣF	The fishing mortality rate, summed over the age-groups in the stock.

ΣH	The anthropogenic mortality rate outside the fishery, summed over the age-groups in the stock.
ΣA	The sum of anthropogenic mortalities, i.e. ΣA = ΣF + ΣH.
Y	Code in Data Call for data comprising yellow eel only.
Yellow eel abundance series	Time-series of abundance of yellow eel determined by consistent regular count or survey.
Yellow eel recruitment series	Time-series enumerating yellow eel where this life stage is first observed at a site or is the stage at which eel enter freshwaters.
Yellow eel standing stock series	Time-series of abundance of yellow eel determined by consistent regular count or survey.
"3Bs & ΣA"	Refers to the 3 biomass indicators (B_0, B_{best} and $B_{current}$) and anthropogenic mortality rate (ΣA).
40% EU Target	From the Eel regulation (1100/2007): "The objective of each Eel Management Plan shall be to reduce anthropogenic mortalities so as to permit with high probability the escapement to the sea of at least 40% of the silver eel biomass relative to the best estimate of escapement that **would have existed if no** anthropogenic influences had impacted the stock". The WGEEL takes the EU target to be equivalent to a reference limit, rather than a target.