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# Joint EIFAAC/ICES/GFCM Working Group on Eels (WGEEL)

**Amilhat, Elsa; Basic, Tea; Beaulaton, Laurent; Belpaire, Claude; Bernotas, Priit; Briand, Cédric; Bryhn, Andreas; Capoccioni, Fabrizio; Ciccotti, Eleonora; Dekker, Willem**

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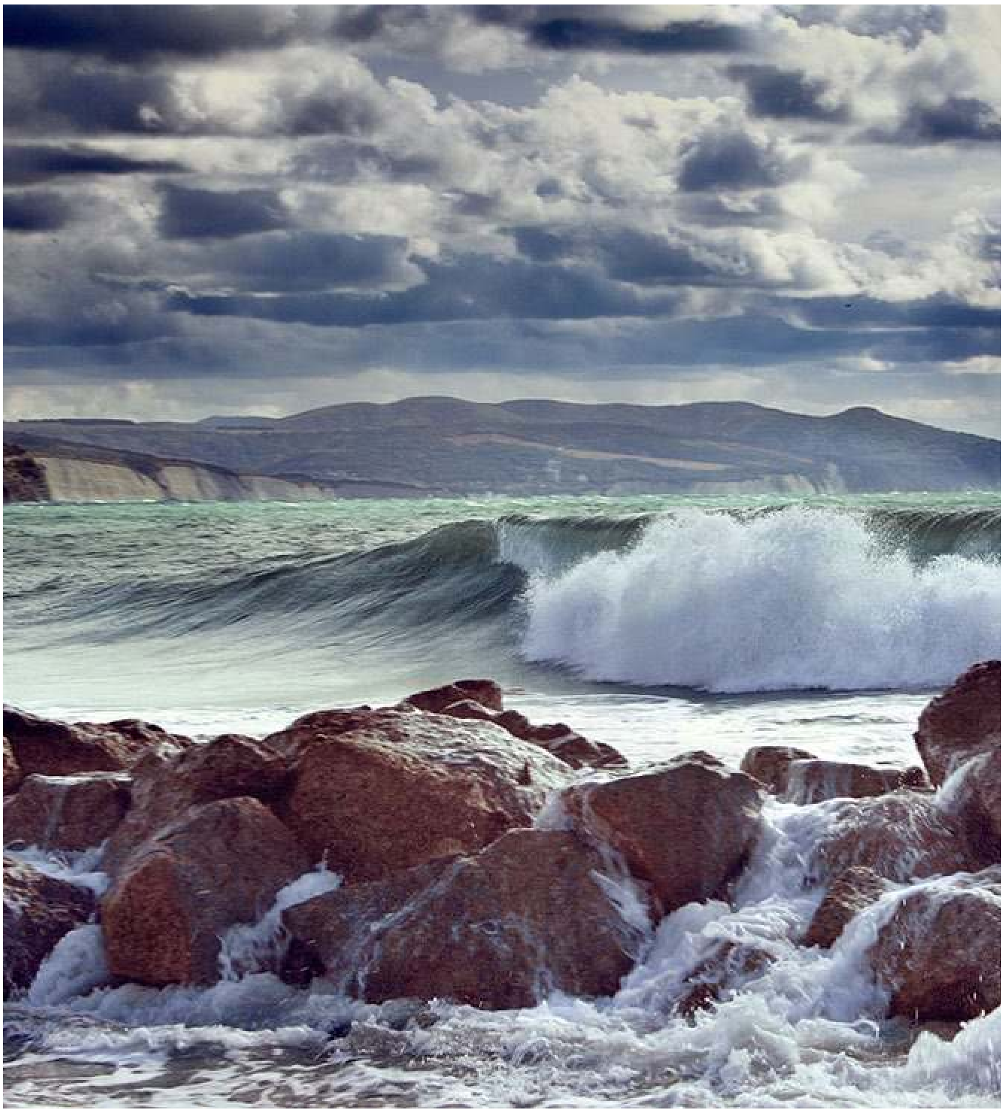

ICES INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA
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International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk



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## Editors

Alan Walker

## Authors

Elsa Amilhat • Tea Basic • Laurent Beaulaton • Claude Belpaire • Priit Bernotas • Cedric Briand • Andreas Bryhn • Fabrizio Capoccioni • Eleonora Ciccotti • Willem Dekker • Estibaliz Diaz • Isabel Domingos • Hilaire Drouineau • Caroline Durif • Derek Evans • Lukasz Giedrojc • Matthew Gollock • Tessa van der Hammen • Reinhold Hanel • Lisa Horn • Chiara Leone • Linas Lozys • Lasse Marohn • Tomasz Nermer • Ciara O'Leary • Michael Ingemann Pedersen • Jan-Dag Pohlmann • Russell Poole • Justas Povliûnas • Robert Rosell • Mehis Rohtla • Argyris Sapoundis • Janek Simon • Josefin Sundin • Arvydas Svagzydys • Eva Thorstad • Sami Vesala • Alan Walker • Håkan Wickström¶

International Council for the Exploration of the Sea
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# Contents

# i Executive summary

The WGEEL has this year adjusted the manner in which it reports data in time-series. First, readers should note that some data reported to the WGEEL in the most recent year are always provisional but are then finalised in the report of the following year. Where data have been updated from those reported in the 2018 report this is indicated in the 2019 report; and provisional data are similarly highlighted. Second, the mean of the previous 5 years data is also presented to help place the data from the most recent year(s) in context of this most recent period.

The recruitment of European eel from the ocean remained low in 2019. The glass eel recruitment compared to the 1960–1979 in the 'North Sea' index area was 1.4% in 2019 (provisional), 1.9% in 2018 (finalised) and the previous 5-year mean was 1.7% (2012-2016); and in the 'Elsewhere Europe' index series it was 6.0% in 2019 (provisional), 8.9% in 2018 (final) and the previous 5-year mean was 8.7%, based on available dataseries. For the yellow eel dataseries, recruitment for 2018 was 26.4% of the 1960–1979 level and the previous 5-year mean was 16.6% (2013–2017); 2019 data collection is ongoing so data not available at time of writing.

Statistical analyses of time-series from 1980–2019 show that there was a change in the trend of glass eel recruitment indices in 2011; the recruitment has stopped decreasing and has been increasing in the period 2011–2019 with a rate statistically significantly different from zero. The highest point during the period from 2011–2019 was in 2014.

Landings data were updated according to those reported to the WGEEL, either through responses to the 2019 Data call or Country Reports, or integrated by the WGEEL using data from its previous reports. When data are absent and presumed missing for a country or year, a predicted (reconstructed) catch is used to account for non-reporting, but this is not a complete solution and therefore even the raised estimates should be considered as minima. Here we present both reported and reconstructed values.

Glass eel fisheries within the EU take place in France, UK, Spain, Portugal and Italy. Glass eel landings have declined sharply from 1980, when reported and reconstructed landings were larger than 2000 tonnes, to 62.2 t in 2018 (final, full reporting), 58.6 t in 2019 (provisional, no reconstruction), and a mean for the previous 5 years (2013–2017) of 56.5 t (full reporting).

Yellow and silver eel landings are not always reported separately, so are combined here. The WGEEL has reconstructed the time-series to fill in some gaps in reporting. Reconstructed total commercial landings of yellow and silver eels were around 20 000 t in the 1950s to 2000–3500 t around 2009, most recently being 2393 t in 2017 (final), 2694 t in 2018 (provisional) and a mean of 2729 t for the preceding 5 years (2012–2016). The reported landings were around 10 000 to 12 000 t in the 1950s, declining to 2000 to 3000 t around 2009, and more recently being 2249 t in 2017 (final), 2375 t in 2018 (provisional, only 14 countries reported) and a mean of 2729 t for the preceding 5 years (2012–2016).

Recreational catches and landings are poorly reported, so amounts must be treated as minima. Spain reports a recreational fishery for glass eel, with landings estimated as 0.9 t for 2019 (provisional), with a mean of 2 t for the preceding 5 years (2014–2018). Recreational landings for yellow and silver eel combined were 543 t for 2016 (ten countries reporting), 195 t for 2017 (eight countries reported) and 148 t for 2018 (five countries reported). Overall, the impact of recreational fisheries on the eel stock remains largely unquantified although landings can be thought to be at a similar order of magnitude to those of commercial fisheries.

Aquaculture production of eel is presented from 1984 onwards. It increased until the mid-2000s, peaking around 8000 t. Production was reported in 2017 (the most recent year of most countries

reporting: 10) as 5497 t in 2017 and the preceding 5-year mean was 6429 t (2012–2016). It should be noted that eel aquaculture is based on wild recruits, and part of the production is subsequently released as on-grown eel for stocking.

Restocking (the process of capture, translocation and restocking to new locations in the wild) of eel increased after the implementation of management plans in EU Member States in 2009. Although the definition of restocking is clear, the process is complex with a varied and broad sequence of steps and even life stages. As there is still some variation in the way that countries report some of these actions, the WGEEL broadly categorises them as RELEASES, though the term RESTOCKING is still used here for some circumstances. Most recent relatively complete data show 36.3 million glass eel (2017, 15 countries), 14 million yellow eels (2016, six countries) and about 0.25 million silver eels (2018, three countries) were restocked or released (combined).

The WG has made substantial progress in developing the use of the Data call and database to refine data submission, checking, analyses and reporting. The Data call for 2020 will request updates for recruitment, landings, aquaculture and releases, plus abundance indices for yellow and silver eels.

The emerging threats and opportunities reported by WGEEL in each of the last three years continue to develop/evolve from their initial reporting. In addition, a new eel virus (picornavirus EPV-1) has been detected in eels in several German waters.

The WG has a new standing annual activity to examine quantification of the impacts of non-fishery factors, and to review methods for reducing these mortalities. A crude estimate of loss to all non-fishery anthropogenic factors (largely hydropower and pumps) of eel was estimated from reported mortality indicators from approximately half of countries reporting to WG. This amounted to 1625 tonnes annually. Given better and more consistent data, this estimate could be improved in the future.

Evidence on the impacts of hydropower facilities and water pumps was reviewed, with new studies ranging from direct measurements of eel mortality at individual facilities, through models to extend empirical data at individual sites to estimate impacts to regional levels, to overarching reviews and national and international advisory reports. Ranges of mortality as eel pass by or through hydropower stations are highly variable, and within previously published ranges. Mitigation measures to reduce eel losses from hydropower and pumping facilities provide clear technical scope for individual site and collective actions to reduce current losses.

The WG considered the potential impact of changes to fishery regulations on the time-series used in support of the ICES advice. Many fishery-based time-series are used to assess temporal trends in recruitment and escapement. This is especially true for recruitment in the so-called 'Elsewhere Europe' area. New fishery regulations might introduce biases in those time-series and compromise their use in the analyses. Losing fishery-based indices would increase the noise in the stock assessment. As such, it seems worthwhile implementing new fishery-independent time-series.

The WG considered the consequences of the Precautionary Approach on advice for European eel. Based on the FAO Code of Conduct, the ICES form of advice, and the EU Eel Regulation, the WG developed a proposal for a coherent framework for advice on eel, consisting of a double-tiered approach: an international tier focused on the status of the whole stock and the long-term objectives (overall stock status, recruitment trends, biomass reference points), and a national (or lower) tier focused on mortality levels and related management actions, addressed per management unit. This proposal suggests adoption of the reference point of the Eel Regulation, as $B_{mgt}$ = 40% escapement of pristine, and a corresponding mortality limit of $\Sigma A_{mgt} = 0.92$. Below $B_{mgt}$, mortality should be reduced further, to allow recovery of the stock. It is suggested to adopt a provisional time frame in terms of number of generations for this, which would translate into a corresponding mortality limit for each management unit. Noting that the proposed comprehensive framework for advice deviates from conventional ICES approaches, it is concluded that a follow-up workshop convened by ACOM might be appropriate, to discuss and evaluate the proposed framework and consider any now unforeseen or unintentional consequences. An international process of Quality Assurance of national assessments and stock indicators is also required as a matter of urgency.

The WG considered the challenge of quantifying the effort that is undertaken in the commercial eel fisheries around Europe, based on new data provided by countries through the Data call. It was concluded that for many countries, the licensing of commercial eel fisheries needs to be improved in order to supply fishery managers and WGEEL with the appropriate information to assess the state of the stock. Difficulties encountered include inadequate reporting of levels of effort, lack of recording on number of gears per licence and generic multispecies licensing. The level of reporting can be at the national, regional or local level and this has resulted in some countries having different licence requirements per waterbody. The WGEEL has recommended a workshop on harmonising the reporting of fishing effort.

# ii Expert group information

| | |
|---|---|
| **Expert group name** | Joint EIFAAC/ICES/GFCM Working Group on Eels (WGEEL) |
| **Expert group cycle** | Annual |
| **Year cycle started** | 2019 |
| **Reporting year in cycle** | 1/1 |
| **Chair** | Alan Walker, UK |
| **Meeting venue and dates** | 27 August–2 September, Bergen, Norway, 41 participants |

# 1 Introduction

## 1.1 Main tasks

The Joint EIFAAC/ICES/GFCM Working Group on Eel [WGEEL] (chaired by: Alan Walker, UK) met in Bergen, Norway, from 27th August to 2nd September 2019 to address the terms of reference (ToR) set by ICES, EIFAAC and GFCM.

The agenda for the meeting is provided in Annex 4. The terms of reference were met.

The report chapters are linked to ToR, as indicated in the table below.

| | Term of Reference | |
|---|---|---|
| ToR A | Address the generic EG ToRs from ICES, and any requests from EIFAAC or GFCM | Chapter 2 |
| ToR B | Report on developments in the state of the European eel (*Anguilla anguilla*) stock, the fisheries on it and other anthropogenic impacts | Chapter 3 |
| ToR C | Report on updates to the scientific basis of the advice, including any new or emerging threats or opportunities | Chapter 4 |
| ToR D | Consider the consequences of the Precautionary Approach on advice for European eel | Chapter 5 |
| ToR E | Address the task of quantifying the effort that is undertaken in the commercial eel fisheries around Europe | Chapter 6 |

In response to the ToR, the Working Group used data and information provided in response to the Eel Data call 2019 (from 20 countries) and 17 Country Report Working Documents submitted by participants (Annex 5); other references cited in the Report are given in Annex 1. A list of acronyms and glossary of terms used within this document is provided in Annex 2.

## 1.2 Participants

Thirty-nine experts attended the meeting, representing 19 countries, along with an observer from the European Commission DG MARE and an observer from Chou University, Japan. A list of the meeting participants is provided in Annex 3.

The Working Group was saddened by the death this year of Professor T. Kieran McCarthy of the National University of Ireland. Kieran was a longstanding participant of the EIFAAC working parties on eel for more than 35 years and was still an active researcher on eel and many other biological/ecological topics until the end. May he rest in peace.

## 1.3 ICES Code of Conduct

In 2018, ICES introduced a Code of Conduct that provides guidelines to its expert groups on identifying and handling actual, potential or perceived Conflicts of Interest (CoI). It further defines the standard for behaviours of experts contributing to ICES science. The aim is to safeguard the reputation of ICES as an impartial knowledge provider by ensuring the credibility, salience, legitimacy, transparency, and accountability in ICES work. Therefore, all contributors to ICES work are required to abide by the ICES Code of Conduct.

At the beginning of the 2019 WGEEL meeting, and for all newcomers later in the meeting, the chair raised the ICES Code of Conduct with all attending member experts. In particular, they were asked if they would identify and disclose an actual, potential or perceived CoI as described in the Code of Conduct. After reflection, none of the members identified a CoI that challenged the scientific independence, integrity, and impartiality of ICES. One member declared an occasional commission to provide independent scientific advice to an NGO, but this was on a strictly independent and impartial basis. The Chair's evaluation of potential CoI resulted in there being none. However, during the working group, the potential for a perceived CoI arose for two members and they therefore removed themselves from any discussions and decisions related to the specific topic.

## 1.4 The European eel: Stock Annex

A Stock Annex for the European eel was drafted by the WGEEL 2015 meeting, finalised in 2016 and is available from the ICES website (see link in Annex 7). This Stock Annex is intended as a reference document providing the background to the European eel. It describes the eel stock, the development of eel advice, the management frameworks for eel and the analysis of the recruitment for the provision of ICES Stock Advice. In principle, information contained in the Stock Annex should not be repeated in the annual reports of the WGEEL. However, some information is reported here where the WGEEL considered it appropriate.

The stock annex is due for review and revision in 2020.

## 1.5 The European eel: life history and production

The European eel (*Anguilla anguilla*) is distributed across the majority of coastal countries in Europe and North Africa, with its southern limit in Mauritania (30°N) and its northern limit situated in the Barents Sea (72°N) and spanning the entire Mediterranean basin.

European eel life history is complex, being a long-lived semelparous and widely dispersed stock. The shared single stock is genetically panmictic and data indicate the spawning area is in the southwestern part of the Sargasso Sea and therefore outside Community Waters. The newly hatched leptocephalus larvae drift with the ocean currents to the continental shelf of Europe and North Africa, where they metamorphose into glass eels and enter continental waters. The growth stage, known as yellow eel, may take place in marine, brackish (transitional), or freshwaters. This stage may last typically from two to 25 years (and could exceed 50 years) prior to metamorphosis to the "silver eel" stage and maturation. Age-at-maturity varies according to temperature (latitude and longitude), ecosystem characteristics, and density-dependent processes. The European eel life cycle is shorter for populations in the southern part of their range compared to the north.

The amount of glass eel arriving in continental waters declined dramatically in the early 1980s to a low point in 2011. The reasons for this decline are uncertain but may include overexploitation, pollution, non-native parasites, diseases, migratory barriers and other habitat loss, mortality during passage through turbines or pumps, and/or oceanic factors affecting migrations. These factors will affect local production differently throughout the eel's range. In the planning and execution of measures for the protection and sustainable use of European eel, management must therefore take into account the diversity of regional conditions.

## 1.6 Anthropogenic impacts on the stock

Anthropogenic mortality may be inflicted on eel by fisheries (including where catches supply aquaculture for consumption), hydropower turbines and pumps, pollution and indirectly by other forms of habitat modification and obstacles to migration.

Fisheries exploit all continental life phases: glass eel recruiting to continental waters, the immature growing yellow eel and the maturing silver eel. There are multiple commercial and recreational fisheries: with registered and non-registered vessels using nets and/or longlines; without vessels using fixed traps and nets; with mobile (bank-based) net gears, and rod and line. The exploited life stage and the gear types employed vary between local habitat, river, country and international regions.

## 1.7 The management framework of eel

### 1.7.1 EU and Member State waters

The European eel is a panmictic stock with widespread distribution. Within EU and Member State waters, the stock, fisheries and other anthropogenic impacts, are currently managed in accordance with the European Eel Regulation EC No 1100/2007, "*establishing measures for the recovery of the stock of European eel*" (European Council, 2007). This regulation sets a framework for the protection and sustainable use of the stock of European eel of the species *Anguilla anguilla* in Community Waters, in coastal lagoons, in estuaries, and in rivers and communicating inland waters of Member States that flow into the seas in ICES Areas 3, 4, 6, 7, 8, 9 or into the Mediterranean Sea.

EU Member States must adopt national objectives, set out in Eel Management Plans (EMPs) in accordance with Article 2.4 of the Regulation 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 EMPs)… shall be prepared with the purpose of achieving this objective in the long term*." Each EMP constitutes a management plan adopted at national level within the framework of an EU conservation measure.

Under Article 9 of the Regulation, Member States must report on the monitoring, effectiveness and outcomes of EMPs, including: the proportion of silver eel biomass (relative to the target level of escapement) that escapes to the sea to spawn or leaves the national territory; the level of fishing effort that catches eel each year; the level(s) of anthropogenic mortality outside the fishery; the amount of eel less than 12 cm in length caught; and the proportions utilized for different purposes. These reporting requirements were further developed by the European Commission in 2011/2012 and published as guidance for the production of the 2012 reports. This guidance adds the requirement to report fishing catches (as well as effort) and explains the various biomass, mortality rates and restocking metrics using the following definitions:

- 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, including no restocking practices, hence only natural mortality operating on stock.

- Anthropogenic mortality (impacts):
  - ΣF The fishing mortality rate, summed over the age groups in the stock;
  - ΣH The anthropogenic mortality rate outside the fishery, summed over the age groups in the stock;
  - ΣA The sum of anthropogenic mortalities, i.e. ΣA = ΣF + ΣH. It refers to mortalities summed over the age groups in the stock.
- Stocking requirements:
  - R(s) The amount of eel (<20 cm) 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 stocking is a symbol devised to differentiate from "R" which is usually considered to represent Recruitment of eel to continental waters.

In July 2012, Member States first reported on the actions taken, the reduction in anthropogenic mortalities achieved, and the state of their stock relative to their targets. In May 2013, ICES evaluated these progress reports in terms of the technical implementation of actions (ICES, 2013). In October 2014, the European Commission reported to the European Parliament and the European Council with a statistical and scientific evaluation of the outcome of the implementation of the Eel Management Plans. EU Member States again reported on progress with implementing their EMPs in 2015 and most recently in 2018. ICES conducted a partial post-evaluation of the 2018 reports (ICES, 2018a), and consultants for the European Commission post-evaluated other parts of the reports and a resulting report from the European Commission is anticipated later in 2019.

### 1.7.2 Non-EU states

The EC Eel Regulation only applies to EU Member States, but the eel distribution extends much further than this. Some non-EU countries provide data to the WGEEL and more countries are being supported to achieve this through efforts of the General Fisheries Commission of the Mediterranean (GFCM). Most non-EU areas have only recently been involved in this data provision, 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.

#### 1.7.2.1 GFCM Research Programme on European eel: towards coordination of European eel (*Anguilla anguilla*) stock management and recovery in the Mediterranean

The critical status of the European eel stock has been acknowledged for the Mediterranean since 2010, and with it the necessity for integration of the Mediterranean Region within the stock-wide coordination of actions for the European eel (Aalto *et al.*, 2016). In this regard, the GFCM Secretariat undertook a number of steps, and at its 37th session (2013), the GFCM Commission agreed to support an Eel Pilot Action to build a coordinated management framework for the European eel in the Mediterranean Sea.

This led to the formation of a Joint EIFAAC/ICES/GFCM Working Group on European Eel, to a first tentative assessment of the European eel stock in the Mediterranean and to a Liaison Action to focus discussion on the basic needs to build a Mediterranean Eel Management Plan. In this respect, the intention of proposing a management plan for European eel in 2018 was brought forward at the 41st session of the GFCM Commission (FAO, 2018), to be based on the findings summarized within the framework of a dedicated working group on European eel. The elements for such a plan were prepared at WKMEASURES-EEL 2018 (GFCM, 2018) and presented to the

42nd Commission (FAO, 2019). The Commission thus approved Recommendation GFCM/42/2018/1 on a multiannual management plan for European eel in the Mediterranean Sea, that details the scope, general and operational objectives, transitional management measures, and also addresses the need for improved scientific advice. In this respect, in Part IV of Recommendation GFCM/42/2018/1 it is specified that the GFCM Secretariat shall provide terms of reference for the implementation of a research project on European eel in the Mediterranean Sea, to be launched in 2019 and completed in 2021, at the latest six months before the 45th session of the GFCM.

The general objective is to deal with issues relevant to the setting up of a coordinated framework for management, and specific goals should be to:

- collect and update data concerning eel stock and eel habitats in the Mediterranean Region;
- establish a common framework for eel stock assessment;
- establish a common framework for long-term monitoring of eel in the Mediterranean;
- identify and appraise management and protection measures for the eel stock recovery relevant to the Mediterranean.

The project shall be carried out within a strong coordination framework, also relying on international and national networking. The work-plan foresees four main Actions: 1) Data collection, 2) Establishing a framework for stock assessment, 3) Establishing a framework for long-term monitoring and 4) Evaluation of management and protection measures for the stock recovery. Within each Action, research teams shall share methodologies, data and expertise.

### 1.7.3 Other international drivers

The European eel was listed in Appendix II of the Convention on International Trade in Endangered Species (CITES) in 2007, although this listing did not come into force until March 2009. Since then, any international trade in this species needs to be accompanied by a permit. ICES (2015a) recently advised the European Commission CITES SRG on criteria and thresholds that might be used in forming a future application for a Non-Detriment Finding (NDF). At the 18th Conference of the Parties (2019), a Decision was adopted that included the request to range states to: 'share information on stock assessments, harvests, the results of monitoring and other relevant data with the Joint Working Group on Eels (WGEEL) of the European Inland Fisheries and Aquaculture Advisory Commission, the International Council for the Exploration of the Seas and the General Fisheries Commission for the Mediterranean (EIFAAC/ICES/GFCM), so that a full and complete picture of the state of the European eel stock can be established.'

The International Union for the Conservation of Nature (IUCN) has assessed the European eel as 'critically endangered' and included it on its Red List in 2009. It renewed this listing in 2014 but recognised that: "*if the recently observed increase in recruitment continues, management actions relating to anthropogenic threats prove effective, and/or there are positive effects of natural influences on the various life stages of this species, a listing of Endangered would be achievable*" and therefore "*strongly recommend an update of the status in five years*." The Red List assessments of all Anguillid eels are presently being reviewed by IUCN.

In 2014, the European eel was added to Appendix II of the Convention on Migratory Species (CMS), whereby Parties (covering almost the entire distribution of European eel) to the Convention call for cooperative conservation actions to be developed among Range States. A third range state meeting was held in 2019 with a view to proposing the development of an action plan at the 13th Conference of the Parties (2020).

## 1.8 Assessments to meet management needs

The European Commission obtains recurring scientific advice from ICES on the state of the eel stock, the management of the fisheries and other anthropogenic factors that impact it, as specified in the Administrative Agreement between European Commission and ICES for 2019 (ICES and EU, 2019). In support of this advice, ICES is asked to provide the European Commission with: estimates of catches; fishing mortality; recruitment and spawning stock; relevant reference points for management; information about the level of confidence in parameters underlying the scientific advice and the origins and causes of the main uncertainties in the information available (e.g. data quality, data availability, gaps in methodology and knowledge). The European Commission is required to arrange, through Member States or directly, for any data collected through the Data Collection Framework (DCF) and legally disclosable for scientific purposes to be available to ICES.

ICES requests information from national representatives to the WGEEL on the status of national eel production each year. ICES issued a Data call to request some of this information in June 2019, and this call was also advertised by EIFAAC and GFCM to their memberships (see below for further details).

The status of eel production in EU-EMUs and non-EU Eel Assessment Units (Figure 1.1) is assessed by national or sub-national fishery and/or environment management agencies. The terminology Eel Management Unit (EMU) has been used by WGEEL and others for several years now but with various and unrecorded definitions leading to some confusion. It mostly represents the management area corresponding to the "eel river basin" as defined in the EC Eel Regulation (EC No 1100/2007). But, in cases of stock assessments at other spatial scales, and for stock parts lying outside the EU, EMUs have also been defined, either as being the management units used by the country (e.g. Tunisia) or to the whole country. In practice, geographical units have also been provided that refer to more consistent geographical areas, with the objective of providing consistent spatial units to assess shared stock subunits. This is, for instance, the case for Sweden where the EMU is national, but data can be provided to the WGEEL according to Inland, West and East coasts subunits. The catch from coastal areas does include eels migrating from other countries or parts of the Baltic.

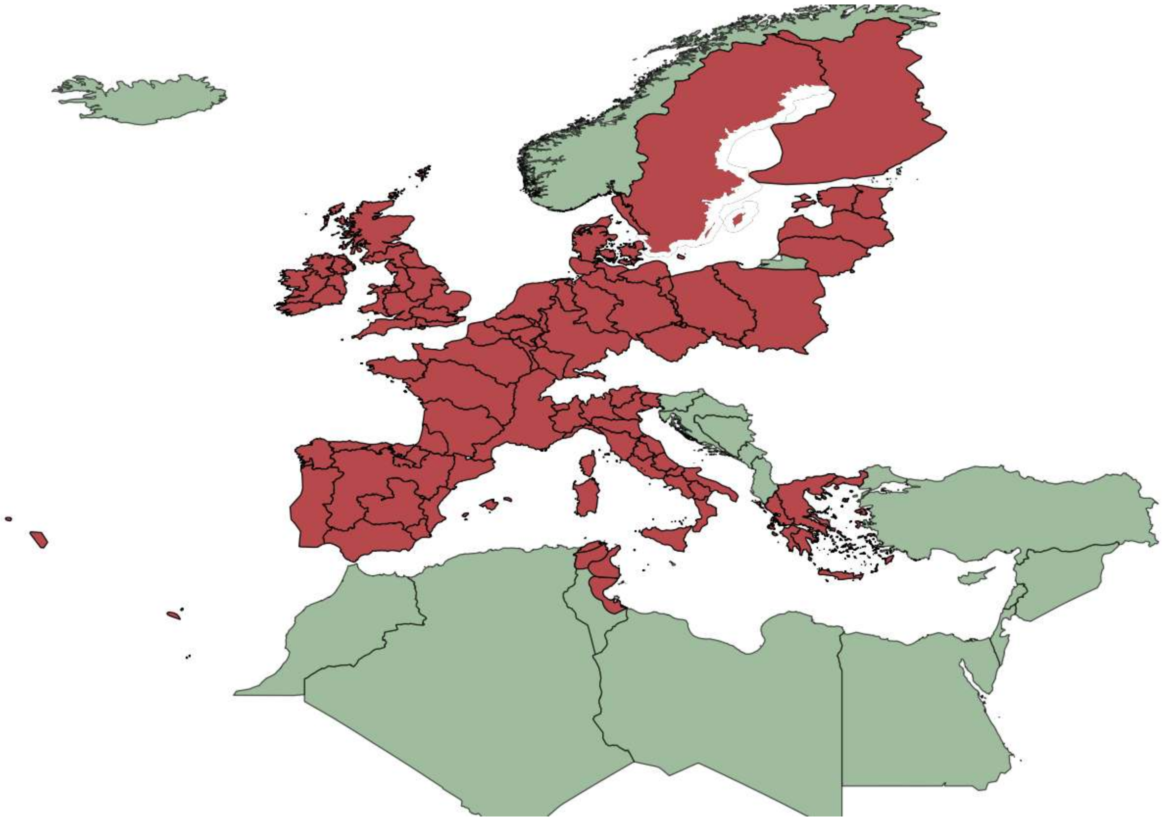

**Figure 1.1. Current map of Eel Management Units (EMUs) as reported by EU countries or corresponding to national entities where no EMU is described at the national level. In grey, countries with EMU covering the whole country. In red, countries with territories split into several EMUs.**

The setting for data collection varies considerably between, and sometimes within, countries, depending on the management actions taken, the presence or absence of various anthropogenic impacts, but also on the type of assessment procedure applied. Accordingly, a range of methods may be employed to establish silver eel escapement limits (e.g. the EC Eel Regulation's 40% of $B_0$), management targets for individual rivers, river basins, river basin districts, EMUs and nations, and for assessing compliance of current escapement with these limits/targets (e.g. for the EC Eel Regulation comparing $B_{current}$). These methods require data on various combinations of catch, recruitment indices, length/age structure, recruitment, abundance (as biomass and/or density), maturity ogives, to estimate silver eel biomass, fishing and other anthropogenic mortality rates.

The ICES Study Group on International Post-Evaluation of Eel (SGIPEE) (ICES, 2010a; 2011a) and WGEEL (FAO and ICES, 2010; 2011) derived a framework for post hoc combination of EMU / national 'stock indicators' of silver eel escapement biomass and anthropogenic mortality rates to an international total.

## 1.9 Data call

The WGEEL annually collates data on recruitment, landings from commercial and recreational fisheries, restocking, aquaculture production, etc. Prior to 2017, these data had been provided by countries attending the WGEEL in many complex spreadsheets, and reporting was incomplete both because of some countries not participating in the WGEEL and some partial reporting by participating countries. A Data call hosted by ICES, EIFAAC and GFCM and covering all natural range states of the European eel is considered an effective mechanism to significantly improve the situation of data provision and use.

The Data call 2017 (Part 1 of the two-year plan) requested data describing: recruitment; fishery catches; fishery landings (killed); aquaculture production and restocking. These data were requested for as far back as available, to form a starting point for the creation of a database. The call also required the provision of metadata associated with all data.

The WGEEL 2017 meeting, and a subsequent Workshop on Tools for Eels (WKTEEL), (chaired by: Laurent Beaulaton, France), that met in Rennes, France, from 2 to 6 June 2018 developed Part 2 of the Data call, requesting data on the stock indicators (biomass) and mortality estimates, wetted area and silver eel time-series, as well as the annual update on recruitment data, landings (not catch), aquaculture production and restocking, and the data integration, analysis and visualisation tools to be used by WGEEL to automate this process.

The WGEEL 2018 meeting, and a subsequent Workshop on Eel Data (WKEELDATA2), (chaired by: Cedric Briand, France and Jan-Dag Pohlman, Germany), that met in Rennes, France from 18 to 22 March 2019, further developed Part 1 of the Data call plus additional requests.

In response to the 2019 Data call, all national representatives gave their consent to the public use of the data stored in the database and used in the report.

## 1.10 Concluding remarks

This report of the Joint EIFAAC/ICES/GFCM Working Group on Eel is a further step in an ongoing process of documenting the stock of the European eel, associated fisheries and other anthropogenic impacts and developing methodologies for giving scientific advice on management to effect a recovery in the international, panmictic stock. Scientific advice has traditionally been issued by ICES under the Administrative Agreement (AA) with the European Commission, and that advice has been given on a stock-wide basis.

The current Chair of WGEEL, Dr Alan Walker from CEFAS UK, is leaving not only the position but also WGEEL at the end of this year’s reporting cycle. The members of WGEEL wish to mark Alan’s departure from our group by thanking him for his contributions to the Working Group, his leadership over a six-year period, whilst acknowledging his group handling skills, best described as his mastery at “herding Cats”. We wish him well and look forward to seeing him at other Groups within the wider ICES organisation.

# 2 ToR A: Address the generic EG ToRs from ICES, and any requests from EIFAAC or GFCM

## 2.1 ICES Generic ToRs for Expert (Working) Groups

ICES set generic ToR for Expert Groups in 2019. Those that were considered by the WGEEL are listed below, with responses provided either following the generic ToR, in subsequent chapters of this report, or in separate documents provided to ICES.

a) Consider and comment on Ecosystem and Fisheries overviews where available;

*WGEEL response: where eel-specific texts were appropriate to add to Ecosystem and Fisheries Overviews, these are presented in Annex 9.*

b) For the aim of providing input for the Fisheries Overviews, consider and comment for the fisheries relevant to the working group on:

1. descriptions of ecosystem impacts of fisheries;
2. descriptions of developments and recent changes to the fisheries;
3. mixed fisheries considerations; and
4. emerging issues of relevance for the management of the fisheries.

*WGEEL response: 1. text for the ecosystem overviews has been drafted is provided here in Annex 9; 2. both the EU and GFCM have introduced seasonal closures of fisheries across some, and all, waters respectively; the potential effect of such closures on the availability of data for assessments is considered in Chapter 3 of this report; 3. although some eel fisheries may take a bycatch of fish and/or invertebrate species, these are typically not considered as mixed fisheries considerations; 4. Chapter 4 of this report details on emerging issues of relevance to eel in general.*

c) Conduct an assessment on the stock(s) to be addressed in 2019 using the method (analytical, forecast or trends indicators) as described in the stock annex and produce a brief report of the work carried out regarding the stock, summarising where the item is relevant:

1. Input data and examination of data quality;

*WGEEL response: see Chapter 3.*

2. Where misreporting of catches is significant, provide qualitative and where possible quantitative information and describe the methods used to obtain the information;

*WGEEL response: see Chapter 3.*

3. For relevant stocks (i.e. all stocks with catches in the NEAFC Regulatory Area) estimate the percentage of the total catch that has been taken in the NEAFC Regulatory Area in 2018.

*WGEEL response: NEAFC stretches from southern tip of Greenland, east to the Barents Sea and south to Portugal (from their website) but the map shows that it is only outside the national waters. There is no eel fishing in the NEAFC area.*

4. Estimate MSY proxy reference points for the category 3 and 4 stocks

*WGEEL response: it is not possible to estimate MSY proxy reference points for the European eel; however, Chapter 5 of this report includes some discussion of work towards developing eel reference points.*

5. The developments in spawning–stock biomass, total stock biomass, fishing mortality, catches (wanted and unwanted landings and discards) using the method described in the stock annex;

*WGEEL response: see Chapter 3.*

6. The state of the stocks against relevant reference points;

*WGEEL response: see Chapter 3.*

7. Catch scenarios for next year(s) for the stocks for which ICES has been requested to provide advice on fishing opportunities;

*WGEEL response: Total landings and effort data are incomplete. In addition, there is great heterogeneity among the time-series of landings due to inconsistencies in reporting by, and between, countries. Changes in management practices have also affected the reporting of commercial and non-commercial/recreational fisheries. Therefore, ICES does not have the information needed to provide a reliable estimate of total catches of eel. Furthermore, the understanding of the stock dynamic relationship is not sufficient to determine/estimate the level of impact that fisheries or non-fisheries anthropogenic factors (at the glass, yellow, or silver eel stage) have on the reproductive capacity of the stock.*

8. Historical and analytical performance of the assessment and catch options with a succinct description of quality issues with these. For the analytical performance of category 1 and 2 age-structured assessment, report the mean Mohn's rho (assessment retrospective (bias) analysis) values for R, SSB and F. The WG report should include a plot of this retrospective analysis. The values should be calculated in accordance with the "Guidance for completing ToR viii) of the Generic ToRs for Regional and Species Working Groups - Retrospective bias in assessment" and reported using the ICES application for this purpose. Produce a first draft of the advice on the stocks under considerations according to ACOM guidelines.

*WGEEL response: The performance of the assessment and catch options has not been reviewed. A first draft of the advice on the European eel stock has been provided to ICES as a separate document.*

d) Review progress on benchmark processes of relevance to the Expert Group;

*WGEEL response: The European eel has not been benchmarked and this is not scheduled on the ICES calendar in the next few years. However, a process for an eel benchmark is outlined in Chapter 5.*

e) Prepare the data calls for the next year update assessment and for planned data evaluation workshops;

*WGEEL response: see Annex 5.*

f) Identify research needs of relevance for the work of the Expert Group.

*WGEEL response: see Chapter 4.*

## 2.2 Additional requests from EIFAAC or GFCM

EIFAAC requested ToR E and the WGEEL response is provided in Chapter 6 of this report.

There were no specific requests from GFCM for the WGEEL to address during the 2019 meeting. However, a representative from GFCM presented the latest developments in the proposal for a Research Programme to the whole group (outlined above) and discussed these in further detail with the subset of attendees to whom it was most relevant. The WGEEL recommended that GFCM should seek to be consistent with the EU targets, etc. and to use the eel database already developed by the WGEEL, by adopting the terminology, templates, r-code, etc. This would make future work most efficient for the GFCM and WGEEL. The GFCM should contact the WGEEL Stock Assessor and Data Coordinator to discuss this as soon as possible.

# 3 ToR B: Report on developments in the state of the European eel (*Anguilla anguilla*) stock, the fisheries on it and other anthropogenic impacts

Updates on the state of the eel stock in countries reporting to WGEEL are presented in this chapter, in response to Term of Reference B: Report on developments in the state of the European eel (*Anguilla anguilla*) stock, the fisheries on it and other anthropogenic impacts.

Countries were asked to report time-series of recruitment, catches and landings, aquaculture production and quantities restocked, through the Eel Data call 2019, which was distributed through ICES, EIFAAC and GFCM. Each of the sections below describes trends in the dataseries, comments on any issues with the quality of the data and, where appropriate, explains the consequences for the status of the stock.

## 3.1 Data call treatment and quality assurance

To ensure high quality of data used for the assessment, several measures were implemented during the integration process, as described below.

All spreadsheets provided were screened by the Data Coordinator and/or Stock Assessor for obvious mistakes.

During the integration using the Shiny application, several checks were run on the spreadsheets including correcting the structure of the files as well as potential issues with data format and/or integrity. The checks code is available at this link: https://github.com/ices-eg/wg_WGEEL/blob/master/R/shiny_data_integration/shiny_di/loading_functions.R. It uses utility functions available at : https://github.com/ices-eg/wg_WGEEL/blob/master/R/shiny_data_integration/shiny_di/check_utilities.R. They comprise:

- Initial checks on the number of columns, names of the columns….
- Check for missing values
- Check for type (character, numeric …)
- Constraints on type of series according to the data sheet
- Constraints on type of data allowed per column
- Check that there are data to qualify missing values only when there are missing value (NA) in the value column
- Adapt the type of life stages allowed for each data type
- Check that for release both quantities in number and in kilogram are reported.

This initial filtering is complemented by a fully constrained database.

All data provided in the spreadsheets are compared to the database in order to detect possible duplicates.

Subsequent to the integration, data providers are requested to check whether the integration was performed correctly by scrutinising the tables and figures in the Shiny visualisation tool.

All scripts used for the integration and visualisation are available on gitHub (https://github.com/ices-eg/wg_WGEEL/tree/master/R).

# 3.2 Recruitment

## 3.2.1 Data source

In this section, the latest trends in glass and yellow eel recruitment are addressed. The time-series are derived from fishery-dependent sources (i.e. catch records) and also from fishery-independent surveys across much of the geographical range of European eel. The stages are categorised as:

- glass eel (G) (continental age 0 years),
- a mixture of glass eel and young yellow eel dominated by recruits from the same year (GY), and
- older yellow eel (Y) recruiting to continental habitats. The yellow eel series might consist of yellow eel of several ages. This is certainly the case for all series from the Baltic (mean age up to 6), some Irish sites, and sites located far upstream.

The glass eel recruitment time-series have been grouped into two geographical areas: ′continental North Sea′ (NS) and ′Elsewhere Europe′ (EE) (Figure 3.2.1). Previous analyses by the Working Group (ICES, 2010a, p19, and Bornarel *et al*., 2017) have shown a difference between the two sets. This is mostly due to a more pronounced decline of the 'North Sea' series compared to the 'Elsewhere Europe' area during the 1980s.

The WGEEL has collated information on recruitment from 85 time-series. Some of the time-series date back to the beginning of 20th century (yellow eel, Göta Älv, Sweden) or 1920 (glass eel, Loire, France). Among those series, 60 have been selected for further analysis in the WGEEL indices; see details on data selection and processing below. Depending on the period on which we standardised, the number of series used can be lower and is given for each analysis.

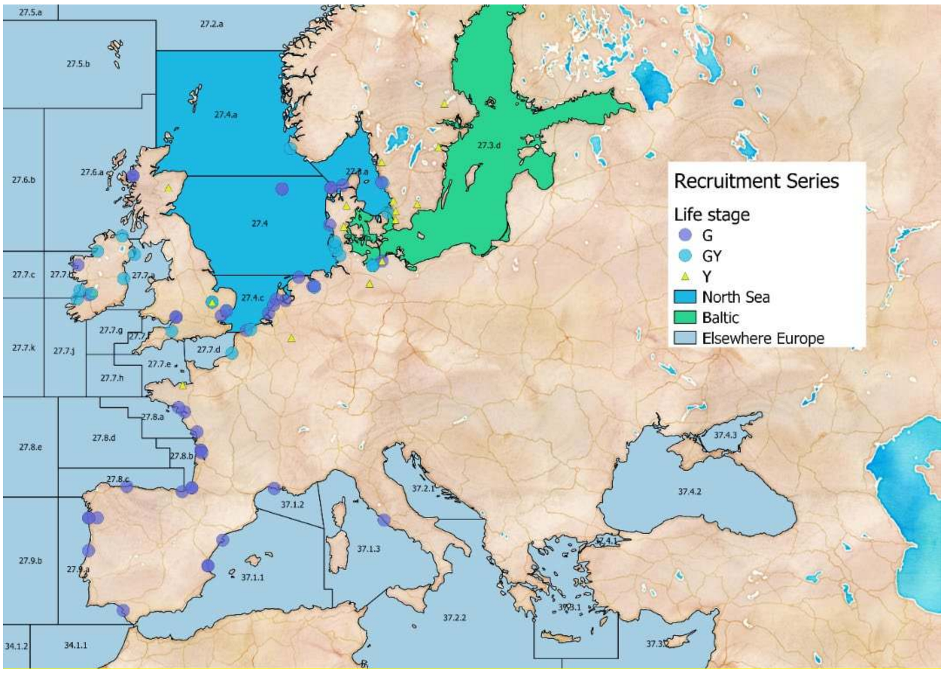


**Figure 3.2.1. Map of recruitment sampling stations; the background source is the stamen watercolour openstreetmap.**

### 3.2.2 Details on data selection and processing

Out of 85 series, 60 were used in the analysis (Table 3.1). Three rules have been used for this selection procedure:

- First, where there may be two or more series from the same location, i.e. they are not independent of each other, we keep only one series. 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. Noting that the 'Severn' here actually represents all the glass eel fisheries for England and Wales but the naming convention has been used for many years so is retained for consistency.
- The second rule is to exclude a series from the analysis when it is less than ten years long. The series are, however, still updated in the database until they can be included.
- Finally, it was also decided to discard recruitment series that were obviously biased by restocking, e.g. Farpener Bach in Germany.

Among the time-series based on trap indices, some have reported preliminary data for 2019 as their trapping season had not finished. As in reports from previous years, the indices given for 2019 are considered to be provisional, especially those for the yellow eel. However, because the deadline for data reporting was earlier this year than before (to provide more time for quality assurance) the 2019 data are especially provisional. The indices for 2018 that were reported as provisional in the WGEEL 2018 report, have been updated and the final values were used in the analyses and reported here.

#### 3.2.2.1 Number of series available

The number of glass eel and glass eel + young yellow eel time-series available has declined from a peak of 40 available in 2008 to 22 in 2019. The maximum number of young yellow eel time-series increased to 13 in 2018. Due to the early timing of the Data call deadline in 2019, only one of the young yellow eel series was reported for 2019 (Figure 3.2.2). Details about the series available in 2019, 2018, and those that were not updated in 2018 are given in Tables 3.2 to 3.4.

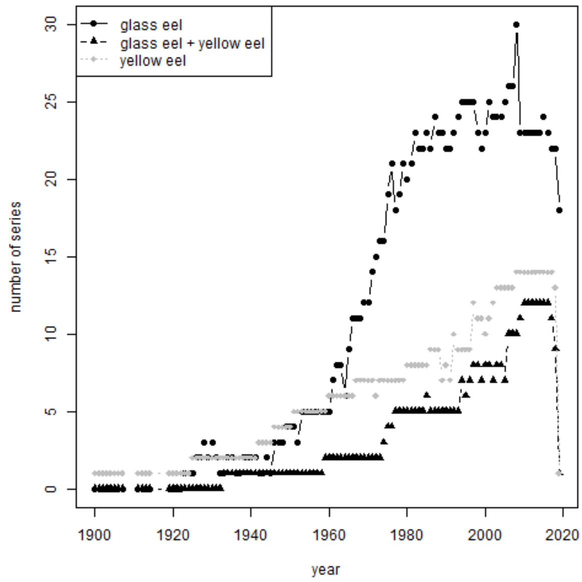


**Figure 3.2.2. Trends in number of glass (black circles), glass+young yellow eel (grey triangles) and young yellow eel (black triangles) time-series giving a report in any specific year.**

### 3.2.2.2 Raw data

The geometric means of all time-series[1] are presented in Figure 3.2.3.

[1] This figure is given as it is consistent with WGEEL from 2002 to 2006. The scaling is performed on the 1979–1994 average of each time-series, and 15 time-series without data during that period are excluded from the analysis. The excluded time-series are: BeeG, Bres, DoEl, FlaE, Fre, Girn, Grey, Inag, Klit, Maig, Nors, Sle, Vac, WiFG, WisW.

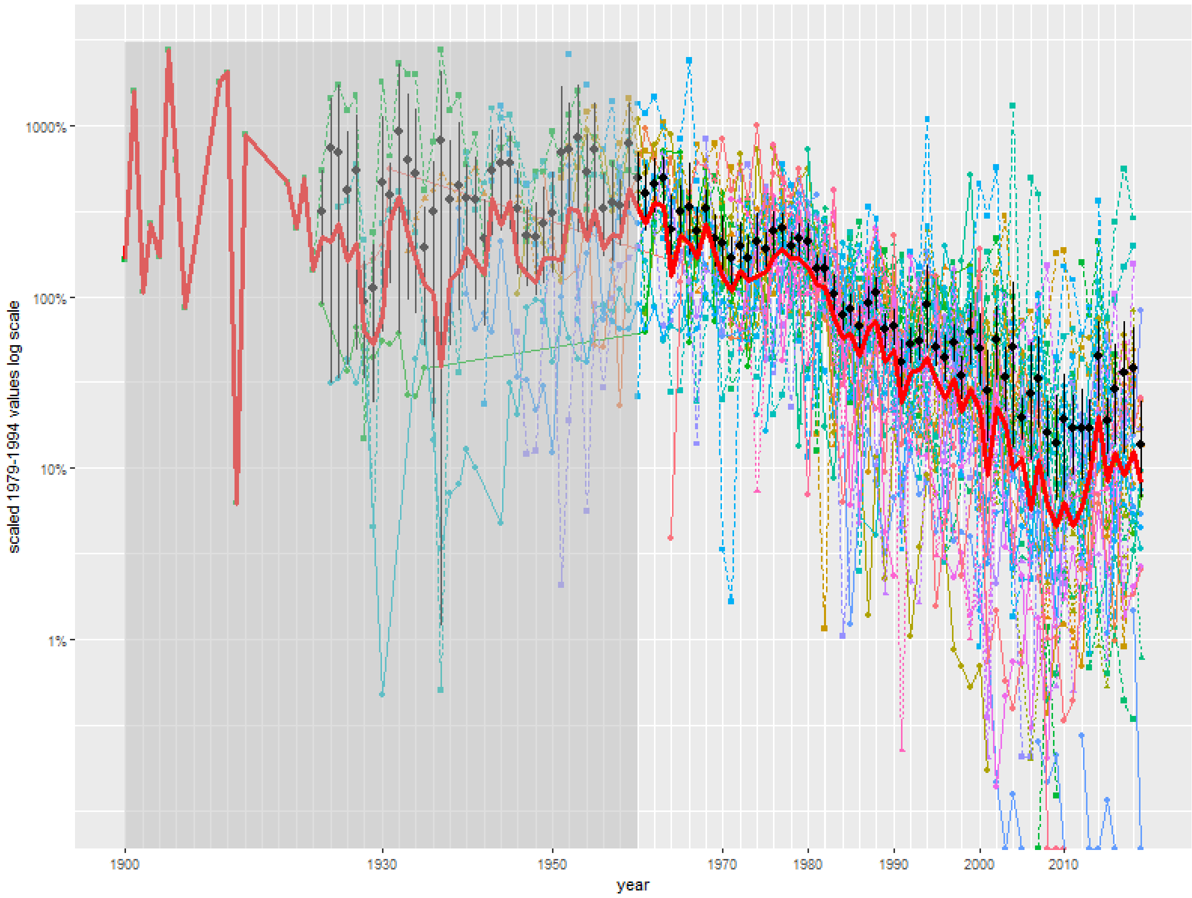


**Figure 3.2.3. Time-series of glass eel and yellow eel recruitment in European rivers with time-series having data for the 1979–1994 period (44 sites). Each time-series has been scaled to its 1979–1994 average. Note the logarithmic scale on the y-axis. The mean values and their bootstrap confidence interval (95%) are represented as black dots and bars. Geometric means are presented in red. Note that the data for 2019 are provisional.**

### 3.2.3 GLM based trend

The WGEEL recruitment index used in the ICES Annual Stock Advice is fitted using a Generalised Linear Model (GLM) with a Gamma distribution and a log link: glass eel ~ year : area + site, where glass eel is individual glass eel time-series, including both pure G series and those identified as a mixture of glass and yellow eel (G+Y), site is the site monitored for recruitment, area is either the continental 'North Sea' or 'Elsewhere Europe', and year is the year coded as a categorical value. For yellow eel time-series, only one estimate is provided: yellow eel ~ year + site.

**Table 3.1. Short description of the sampling sites for European eel recruitment data. Area: NS = 'North Sea', EE = 'Elsewhere Europe'. First year and Last year indicate the first year and last year in the records, and the values given in the n+ and n- columns indicate the number of years with values and the number of years when there are missing data within the series, respectively. Life stage: GY = glass eel and young yellow eel, G = glass eel, Y = yellow eel. Unit for the data collected is given (nr = number; index = calculated value following a specified protocol, nr/m$^2$ = number per square metre, nr/h = number per hour, kg/boat/d = kg per boat per day). Habitat: C = coastal water (according to the EU Water Framework Directive, WFD), F = freshwater, MO = marine water (open sea), T = transitional water with lower salinity (according to WFD). Kept = 1 means that the dataseries is used in recruitment analyses.**

| Code | Area | First year | Last year | n+ | n- | Life stage | Sampling type | Unit | Habitat | Kept |
|---|---|---|---|---|---|---|---|---|---|---|
| YFS1 | NS | 1975 | 1989 | 15 | 0 | G | sci. surv. | index | MO | 1 |
| YFS2 | NS | 1991 | 2019 | 29 | 2 | G | sci. surv. | index | MO | 1 |
| Ring | NS | 1981 | 2019 | 39 | 0 | G | sci. surv. | index | C | 1 |
| Sle | NS | 2008 | 2019 | 12 | 0 | G | sci. surv. | nr/m2 | F | 1 |
| Klit | NS | 2008 | 2019 | 12 | 0 | G | sci. surv. | nr/m2 | F | 1 |
| Nors | NS | 2008 | 2019 | 12 | 0 | G | sci. surv. | nr/m2 | F | 1 |
| Burr | EE | 1987 | 2018 | 32 | 0 | G | trap | kg | F | 1 |
| Maig | EE | 1994 | 2018 | 25 | 2 | G | trap | kg | F | 1 |
| SeEA | EE | 1972 | 2019 | 48 | 0 | G | com. catch | t | T | 1 |
| SeHM | EE | 1979 | 2017 | 39 | 0 | G | com. catch | t | T | 0 |
| ShiM | EE | 2014 | 2018 | 5 | 0 | G | trap | nr | T | 0 |
| ShiF | EE | 2017 | 2018 | 2 | 0 | G | trap | nr | F | 0 |
| FlaG | NS | 2007 | 2018 | 12 | 2 | G | trap | . | F | 0 |
| BeeG | NS | 2006 | 2018 | 13 | 0 | G | trap | . | F | 1 |
| Vida | NS | 1971 | 1990 | 20 | 0 | G | com. catch | kg | T | 1 |
| Ems | NS | 1946 | 2001 | 56 | 0 | G | com. catch | kg | T | 1 |
| WaSG | NS | 2015 | 2018 | 4 | 0 | G | sci. surv. | nr | T | 0 |
| EmsH | NS | 2014 | 2018 | 5 | 0 | G | trap | nr | T | 0 |
| Lauw | NS | 1976 | 2019 | 44 | 2 | G | sci. surv. | nr/h | T | 1 |
| RhDO | NS | 1938 | 2019 | 82 | 0 | G | sci. surv. | index | T | 1 |
| RhIj | NS | 1969 | 2019 | 51 | 4 | G | sci. surv. | index | T | 1 |
| Katw | NS | 1977 | 2019 | 43 | 0 | G | sci. surv. | index | T | 1 |
| Stel | NS | 1971 | 2019 | 49 | 17 | G | sci. surv. | index | T | 1 |
| Yser | NS | 1964 | 2019 | 56 | 1 | G | sci. surv. | kg | T | 1 |
| Vil | EE | 1971 | 2015 | 45 | 0 | G | trap | t | T | 1 |

| Code | Area | First year | Last year | n+ | n- | Life stage | Sampling type | Unit | Habitat | Kept |
|---|---|---|---|---|---|---|---|---|---|---|
| Loi | EE | 1924 | 2008 | 85 | 0 | G | com. catch | kg | T | 1 |
| GiSc | EE | 1992 | 2019 | 28 | 0 | G | sci. surv. | index | T | 1 |
| GiTC | EE | 1923 | 2008 | 86 | 0 | G | com. catch | t | T | 1 |
| GiCP | EE | 1961 | 2008 | 48 | 0 | G | com. cpue | kg/boat/d | T | 1 |
| AdTC | EE | 1986 | 2008 | 23 | 0 | G | com. catch | t | T | 1 |
| Oria | EE | 2005 | 2018 | 14 | 6 | G | sci. surv. | nr/m3 | T | 0 |
| AdCP | EE | 1928 | 2008 | 81 | 0 | G | com. cpue | kg/boat/d | T | 1 |
| Nalo | EE | 1953 | 2019 | 67 | 0 | G | com. catch | kg | T | 1 |
| MiSp | EE | 1975 | 2018 | 44 | 0 | G | com. catch | kg | T | 1 |
| MiPo | EE | 1974 | 2019 | 46 | 0 | G | com. catch | kg | T | 1 |
| Mond | EE | 1989 | 2019 | 31 | 0 | G | sci. surv. | kg/d | T | 0 |
| Guad | EE | 1998 | 2007 | 10 | 0 | G | sci. surv. | index | T | 0 |
| Albu | EE | 1949 | 2019 | 71 | 0 | G | com. catch | kg | T | 1 |
| Ebro | EE | 1966 | 2019 | 54 | 0 | G | com. catch | kg | T | 1 |
| AlCP | EE | 1982 | 2019 | 38 | 1 | G | com. cpue | kg/boat/d | T | 1 |
| Vac | EE | 2004 | 2019 | 16 | 0 | G | trap | nr | T | 1 |
| Tibe | EE | 1975 | 2006 | 32 | 0 | G | com. catch | t | T | 1 |

**Table 3.1. Continued. Short description of the recruitment sites (continued: mixed glass and yellow eel series).**

| Code | Area | First year | Last year | N+ | n- | Life stage | Sampling type | Unit | Habitat | Kept |
|---|---|---|---|---|---|---|---|---|---|---|
| Imsa | NS | 1975 | 2019 | 45 | 0 | GY | trap | nr | F | 1 |
| Visk | NS | 1972 | 2018 | 47 | 0 | GY | trap | kg | F | 1 |
| Hell | NS | 2011 | 2018 | 8 | 0 | GY | sci. surv. | nr | T | 0 |
| Bann | EE | 1933 | 2019 | 87 | 11 | GY | trap | kg | F | 1 |
| Erne | EE | 1959 | 2018 | 60 | 0 | GY | trap | kg | F | 1 |
| Liff | EE | 2012 | 2018 | 7 | 0 | GY | trap | kg | F | 0 |
| Feal | EE | 1985 | 2018 | 34 | 1 | GY | trap | kg | F | 1 |
| Inag | EE | 1996 | 2018 | 23 | 2 | GY | trap | kg | F | 1 |
| ShaA | EE | 1977 | 2018 | 42 | 0 | GY | trap | kg | F | 1 |
| FlaE | NS | 2007 | 2018 | 12 | 2 | GY | trap | . | F | 1 |
| BroG | NS | 2011 | 2018 | 8 | 0 | GY | trap | . | F | 0 |
| BroE | NS | 2011 | 2018 | 8 | 0 | GY | trap | . | F | 0 |
| Grey | EE | 2009 | 2018 | 10 | 0 | GY | trap | . | F | 1 |
| Stra | EE | 2012 | 2019 | 8 | 0 | GY | trap | . | F | 0 |
| Verl | NS | 2010 | 2019 | 10 | 0 | GY | trap | nr | T | 1 |
| HHK | NS | 2010 | 2013 | 4 | 0 | GY | trap | nr | T | 0 |
| HoS | NS | 2010 | 2010 | 1 | 0 | GY | trap | nr | T | 0 |
| Brok | NS | 2012 | 2019 | 8 | 0 | GY | trap | nr | T | 0 |
| Lang | NS | 2015 | 2019 | 5 | 0 | GY | trap | nr | T | 0 |
| Farp | NS | 2007 | 2018 | 12 | 0 | GY | trap | nr | F | 0 |
| WiFG | NS | 2006 | 2018 | 13 | 0 | GY | trap | nr | T | 1 |
| WisW | NS | 2004 | 2018 | 15 | 0 | GY | trap | nr | F | 1 |
| EmsB | NS | 2013 | 2018 | 6 | 0 | GY | trap | nr | F | 0 |
| VeAm | NS | 2017 | 2019 | 3 | 0 | GY | trap | t | T | 0 |
| Bres | EE | 1994 | 2018 | 25 | 0 | GY | trap | nr | F | 1 |

**Table 3.1. Continued: Short description of the recruitment sites (yellow eel series).**

| Code | Area | First year | Last year | n+ | n- | Life stage | Sampling type | Unit | Habitat | Kept |
|---|---|---|---|---|---|---|---|---|---|---|
| Girn | NS | 2008 | 2018 | 11 | 1 | Y | trap | nr | F | 1 |
| WaSE | NS | 2015 | 2018 | 4 | 0 | Y | sci. surv. | nr | T | 0 |
| DoFp | NS | 2003 | 2018 | 16 | 1 | Y | trap | nr | F | 0 |
| DoEl | NS | 2003 | 2018 | 16 | 1 | Y | trap | nr | F | 1 |
| Dala | NS | 1951 | 2018 | 68 | 0 | Y | trap | kg | F | 1 |
| Mota | NS | 1942 | 2018 | 77 | 0 | Y | trap | kg | F | 1 |
| Morr | NS | 1960 | 2018 | 59 | 0 | Y | trap | kg | F | 1 |
| Kavl | NS | 1992 | 2018 | 27 | 0 | Y | trap | kg | F | 1 |
| Ronn | NS | 1946 | 2018 | 73 | 0 | Y | trap | kg | F | 1 |
| Laga | NS | 1925 | 2018 | 94 | 0 | Y | trap | kg | F | 1 |
| Gota | NS | 1900 | 2019 | 120 | 4 | Y | trap | kg | F | 1 |
| ShaP | EE | 1985 | 2018 | 34 | 0 | Y | trap | kg | F | 1 |
| BroY | NS | 2011 | 2018 | 8 | 0 | Y | trap | . | F | 0 |
| Gude | NS | 1980 | 2018 | 39 | 4 | Y | trap | kg | F | 1 |
| Hart | NS | 1967 | 2018 | 52 | 0 | Y | trap | kg | F | 1 |
| Meus | NS | 1992 | 2019 | 28 | 0 | Y | trap | nr | F | 4 |
| Fre | EE | 1997 | 2018 | 22 | 0 | Y | trap | nr | F | 1 |

**Table 3.2. Series updated to 2019, though noting some may have been partial counts and therefore data are provisional. Codes for stages are G = glass eel, GY = glass eel + young yellow eel, Y = yellow eel, Area NS = 'North Sea', EE = 'Elsewhere Europe', Division = FAO marine division. Series ordered by stage and from north to south.**

| Site | Name | Country | Stage | Area | Division |
|---|---|---|---|---|---|
| YFS2 | IYFS2 scientific estimate | SE | G | NS | 27.3.a |
| Ring | Ringhals scientific survey | SE | G | NS | 27.3.a |
| Sle | Slette A | DK | G | NS | 27.4.a |
| Klit | Klitmoeller A | DK | G | NS | 27.3.b |
| Nors | Nors A | DK | G | NS | 27.3.b |
| SeEA | Severn EA commercial catch | GB | G | EE | 27.7.e |
| Lauw | Lauwersoog scientific estimate | NL | G | NS | 27.4.b |
| RhDO | Rhine DenOever scientific estimate | NL | G | NS | 27.4.c |
| RhIj | Rhine Ijmuiden scientific estimate | NL | G | NS | 27.4.c |
| Katw | Katwijk scientific estimate | NL | G | NS | 27.4.c |
| Stel | Stellendam scientific estimate | NL | G | NS | 27.4.c |
| Yser | Ijzer Nieuwpoort scientific estimate | BE | G | NS | 27.4.c |
| GiSc | Gironde scientific estimate | FR | G | EE | 27.8.b |
| Nalo | Nalon Estuary commercial catch | ES | G | EE | 27.8.c |
| MiPo | Minho Portugese part commercial catch | PT | G | EE | 27.9.a |
| Albu | Albufera de Valencia commercial catch | ES | G | EE | 37.1.1 |
| Ebro | Ebro delta lagoons | ES | G | EE | 37.1.1 |
| AlCP | Albufera de Valencia commercial CPUE | ES | G | EE | 37.1.1 |
| Vac | Vaccares | FR | G | EE | 37.1.2 |
| Imsa | Imsa Near Sandnes trapping all | NO | GY | NS | 27.4.a |
| Bann | Bann Coleraine trapping partial | GB | GY | EE | 27.6.a |
| Verl | Verlath Pumping Station | DE | GY | NS | 27.4.b |
| Gota | Gota Alv trapping all | SE | Y | NS | 27.3.a |

**Table 3.3. Series updated to 2018 see Table 3.1 for codes. Series ordered from north to south.**

| Site | Name | Country | Stage | Area | Division |
|---|---|---|---|---|---|
| Burr | Burrishoole | IE | G | EE | 27.7.b |
| Maig | River Maigue | IE | G | EE | 27.7.b |
| BeeG | Beeleigh Glass <80 mm | GB | G | NS | 27.4.c |
| MiSp | Minho Spanish part commercial catch | ES | G | EE | 27.9.a |
| Visk | Viskan trapping all | SE | GY | NS | 27.3.a |
| Erne | Erne Ballyshannon trapping all | IE | GY | EE | 27.7.b |
| Feal | River Feale | IE | GY | EE | 27.7.j |
| Inag | River Inagh | IE | GY | EE | 27.7.b |
| ShaA | Shannon Ardnacrusha trapping all | IE | GY | EE | 27.7.b |
| FlaE | Flatford Elvers >80<120 mm | GB | GY | NS | 27.4.c |
| Grey | Greylakes Elvers (<120 mm) | GB | GY | EE | 27.7.f |
| WiFG | Frische Grube | DE | GY | NS | 27.3.b, c |
| WisW | Wallensteingraben | DE | GY | NS | 27.3.b, c |
| Bres | Bresle | FR | GY | EE | 27.7.d |
| Girn | Girnock Burn trap scientific estimate | GB | Y | NS | 27.4.b |
| DoEl | Dove Elde eel ladder | DE | Y | NS | 27.4.b |
| Dala | Dalalven trapping all | SE | Y | NS | 27.3.d |
| Mota | Motala Strom trapping all | SE | Y | NS | 27.3.d |
| Morr | Morrumsan trapping all | SE | Y | NS | 27.3.d |
| Kavl | Kavlingean trapping all | SE | Y | NS | 27.3.b, c |
| Ronn | Ronne A trapping all | SE | Y | NS | 27.3.a |
| Laga | Lagan trapping all | SE | Y | NS | 27.3.a |
| ShaP | Shannon Parteen trapping partial | IE | Y | EE | 27.7.b |
| Gude | Guden A Tange trapping all | DK | Y | NS | 27.3.a |
| Hart | Harte trapping all | DK | Y | NS | 27.3.b, c |
| Fre | Fremur | FR | Y | EE | 27.7.e |

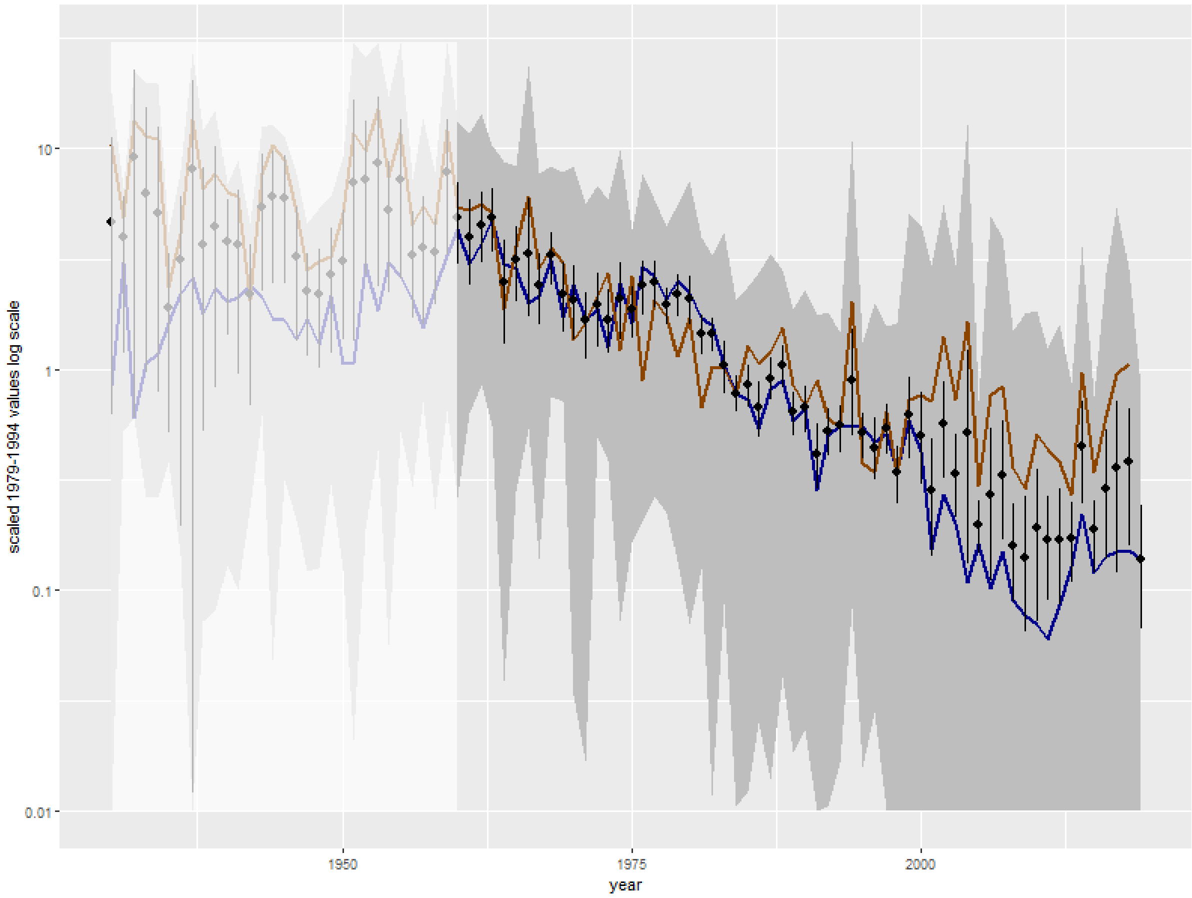


**Figure 3.2.4. Time-series of glass eel and yellow eel recruitment in Europe with 44 time-series out of the 84 available to the Working Group. Each time-series has been scaled to its 1979–1994 average. The mean values of combined yellow and glass eel time-series and their bootstrap confidence interval (95%) are represented as black dots and bars. The brown line represents the mean value for yellow eel. The blue line represents the mean value for glass eel time-series. The range of these time-series is indicated by a grey shade. Note that individual time-series from Figure 3.2.3 were removed to make the mean value clearer, the logarithmic scale on the y-axis and that the data for 2019 are provisional.**

**Table 3.4. Series stopped or not updated to 2018, see Table 3.1 for codes. Series ordered by last year.**

| Site | Name | Country | Stage | Area | Division | Last Year |
|---|---|---|---|---|---|---|
| YFS1 | IYFS scientific estimate | SE | G | NS | 27.3.a | 1989 |
| Vida | Vidaa Hojer sluice commercial catch | DK | G | NS | 27.4.b | 1990 |
| Ems | Ems Herbrum commercial catch | DE | G | NS | 27.4.b | 2001 |
| Tibe | Tiber Fiumara Grande commercial catch | IT | G | EE | 37.1.3 | 2006 |
| AdCP | Adour Estuary (CPUE) commercial CPUE | FR | G | EE | 27.8.b | 2008 |
| AdTC | Adour Estuary (catch) commercial catch | FR | G | EE | 27.8.b | 2008 |
| GiCP | Gironde Estuary (CPUE) commercial CPUE | FR | G | EE | 27.8.b | 2008 |
| GiTC | Gironde Estuary (catch) commercial catch | FR | G | EE | 27.8.b | 2008 |
| Loi | Loire Estuary commercial catch | FR | G | EE | 27.8.a | 2008 |
| SevN | Sevres Niortaise Estuary commercial CPUE | FR | G | EE | 27.8.a | 2008 |
| Vil | Vilaine Arzal trapping all | FR | G | EE | 27.8.a | 2015 |

The trend was hindcast using the predictions from 1960 onwards for 47 glass eel time-series and from 1950 onwards for 13 yellow eel time-series. Some zero values have been excluded from the GLM analysis: 16 for the glass eel model and 14 for the yellow eel model. This treatment is parsimonious and tests showed that it has no effect on the trend (ICES, 2017). The predictions are given in reference to the geometric mean of the 1960–1979 period.

The 2018 report gave provisional data for the 2018 values. These values are now updated from provisional counts. As a consequence, the level of European eel recruitment in 2018 compared to the 1960–1979 average has changed compared to last year's report. The final 2018 values have decreased from the provisional values reported last year, from 2.1 to 1.9% in the 'North Sea' and from 9.6% to 8.9% for the 'Elsewhere Europe' area.

For 2019, data are provisional and give estimates at 1.4% for the 'North Sea' series and 6.0% for the 'Elsewhere Europe' area series, but some of the series are not yet complete (Figure 3.2.6, Table 3.6).

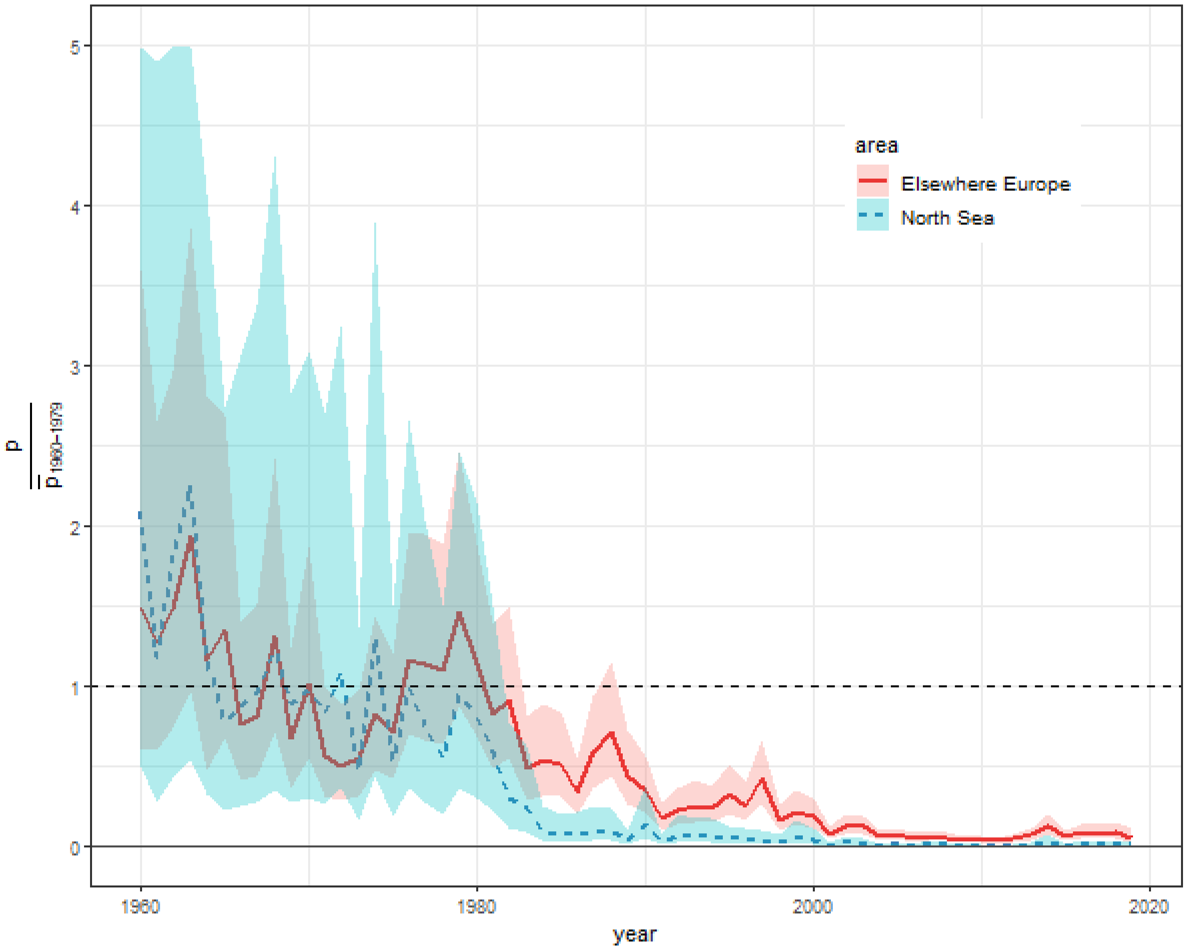


**Figure 3.2.6. WGEEL recruitment index: estimated (GLM) glass eel recruitment for the continental 'North Sea' and 'Elsewhere Europe' series with 95% confidence intervals updated to 2019. The GLM (glasseel ~ area : year + site) was fitted on 47 time-series comprising either pure glass eel or a mixture of glass eels and yellow eels. The predictions (p) have been scaled to the 1960–1979 average ¯p1960–1979 (the dashed line). In the Baltic area, recruitment occurs in the yellow eel stage only and so does not feature in this Figure.**

For yellow eel series, the 2019 ascent has not been recorded yet and most of the series have reported data until the middle of the summer, so these are provisional. However, the provisional data for 2018 used in last year's report have been updated and finalised: the 2018 yellow eel index was at 26.4% of the 1960–1979 baseline (Figure 3.2.7).

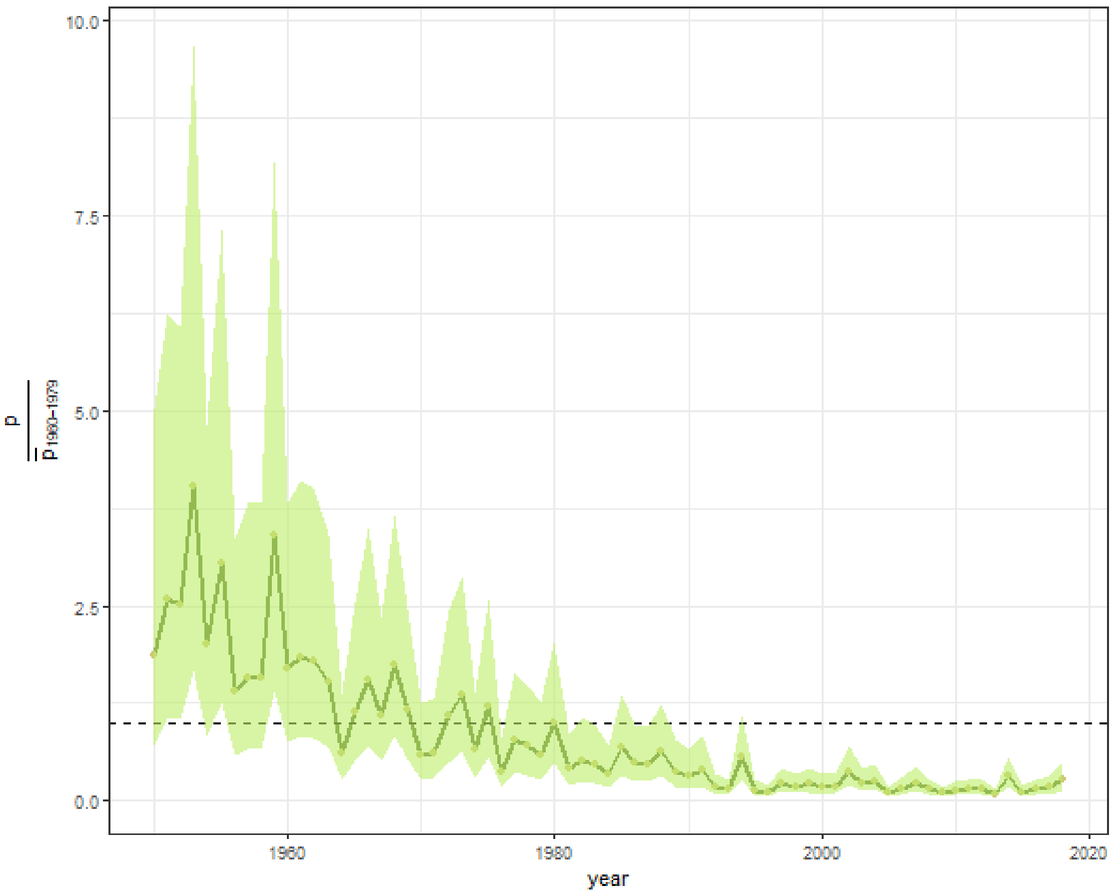


**Figure 3.2.7. Yellow eel GLM recruitment trend and 95% confidence interval for Europe updated to 2019. The GLM (yellow eel ~ year + site) was fitted to 13 yellow eel time-series (p) and scaled to the 1960–1979 average ¯p1960–1979 (the dashed line).**

## 3.2.4 Is there a positive trend in glass eel recruitment indices?

After high levels in the late 1970s, the recruitment indices declined and the glass eel indices have been very low for all years after 2000. In 2014, ICES tested whether there was a change in the trend of glass eel recruitment indices. One of the tests used to show that change was based on the SGIPEE (ICES, 2011a) study group. That approach has been updated 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, whereas it was treated as a factor in the GLM for recruitment, and the years are restricted to decreasing part of the recruitment (after 1980).

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

- where glass eel is 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.

The parameters 'γarea' are highly significant both in the 'Elsewhere Europe' area ($p = 9x10^{-13}$ and for the 'North Sea' $p = 7x10^{-26}$). This result confirms that there has been a change in the recruitment slope, though a further test was required to determine the direction of that change.

To test whether there is an increase in recruitment since 2011, the slope of βarea + γarea, i.e., the slope of the recent increase in recruitment is positive, the NULL hypothesis H0: b > 0 has been tested. The results show a value for the trend after 2011, which is statistically significant for both the 'North Sea' and 'Elsewhere Europe' areas (Table 3.5). The slope of the decreasing and increasing trends are of about the same rate, and the rate of the increase is higher in the 'North Sea' series.

**Table 3.5. Slope of the decreasing and increasing trends of the linear model.**

| | Slope of the decreasing trend (log scale)<br>1980–2011<br>γarea | Slope of the increasing trend<br>(log scale)<br>>2011<br>γarea + βarea |
|---|---|---|
| 'Elsewhere Europe' | -0.10(0.0049) | 0.1 (0.2) p < 0.05 |
| 'North Sea' | -0.14 (0.006) | 0.17 (0.03) p < 0.001 |

To summarise, there has been a change in the trend in 2011; the recruitment has stopped decreasing, and has been increasing in the period 2011–2019 with a rate significantly different from zero. However, all series have not been reported for 2019 and the results might change when missing data are incorporated into the analysis. Secondly, recruitment remains very low at 1.4% for the 'North Sea' and 6.0% for the 'Elsewhere Europe' area, compared to the reference period. Recruitment indices had been continually decreasing from 1980 to 2011 (31 years), and during the 2011–2019 period, the maximum index values were reached in 2014.

**Table 3.6. GLM glass eel ~ year: area + site geometric means of predicted values for 47 glass eel series, values given in percentage of the 1960–1979 period.**

| | 1960 | | 1970 | | 1980 | | 1990 | | 2000 | | 2010 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EE | NS | EE | NS | EE | NS | EE | NS | EE | NS | EE | NS |
| 0 | 149 | 209 | 102 | 97 | 114 | 81 | 35 | 14 | 19.1 | 4.7 | 4.5 | 0.7 |
| 1 | 127 | 117 | 56 | 85 | 83 | 59 | 17 | 3 | 7.9 | 1 | 3.6 | 0.4 |
| 2 | 149 | 180 | 50 | 109 | 91 | 30 | 23 | 8 | 13.1 | 2.6 | 5.1 | 0.4 |
| 3 | 193 | 225 | 56 | 48 | 49 | 24 | 26 | 7 | 12.5 | 2 | 7.4 | 1.4 |
| 4 | 117 | 117 | 83 | 130 | 54 | 10 | 24 | 7 | 6.8 | 0.6 | 12.6 | 3.1 |
| 5 | 135 | 78 | 72 | 54 | 52 | 8 | 32 | 5 | 7.6 | 1.1 | 6.8 | 0.9 |
| 6 | 77 | 88 | 117 | 99 | 34 | 8 | 25 | 5 | 5.5 | 0.4 | 8.6 | 1.7 |
| 7 | 82 | 97 | 114 | 76 | 59 | 10 | 42 | 4 | 6.3 | 1.8 | 8.4 | 1.3 |
| 8 | 132 | 123 | 110 | 56 | 71 | 9 | 16 | 3 | 5.7 | 1.1 | 8.9 | 1.9 |
| 9 | 68 | 89 | 147 | 95 | 45 | 4 | 22 | 6 | 4.4 | 0.8 | 6 | 1.4 |

**Table 3.7. GLM yellow eel ~ year + site geometric means of predicted values for 13 yellow eel series, values given in percentage of the 1960–1979 period.**

| | 1950 | 1960 | 1970 | 1980 | 1990 | 2000 | 2010 |
|---|---|---|---|---|---|---|---|
| 0 | 187 | 170 | 59 | 100 | 32 | 18 | 13 |
| 1 | 260 | 183 | 62 | 41 | 39 | 18 | 15 |
| 2 | 252 | 179 | 109 | 52 | 18 | 38 | 15 |
| 3 | 403 | 152 | 135 | 47 | 14 | 23 | 9 |
| 4 | 200 | 61 | 65 | 35 | 55 | 26 | 32 |
| 5 | 305 | 114 | 122 | 67 | 14 | 10 | 11 |
| 6 | 140 | 156 | 37 | 49 | 10 | 16 | 15 |
| 7 | 158 | 110 | 77 | 48 | 22 | 23 | 17 |
| 8 | 158 | 173 | 69 | 62 | 18 | 16 | 26 |
| 9 | 341 | 116 | 59 | 37 | 22 | 10 | |

## 3.3 Abundance of Yellow and Silver eel series

The 2019 Data call requested all available data on the yellow and silver eel abundance indices to determine local trends in the standing stock. These data relate to standing stock abundance and silver eel escapement and are different from the young yellow eel series collected as part of the recruitment estimation in the previous subchapter.

For yellow eels, data are reported as numbers, biomass (kg) or indices by year and site, with associated sampling effort, and biometry data (average length, weight, and age) where available.

For silver eels, the same data as for yellow eel series are reported, plus data on sex ratio where available.

During the meeting, scripts for integrating these yellow eel indices into the database were produced and stored in github (Y_S_series_connection; Y_S_series_function; Y_S_series_integration). The use of a shiny app to integrate recruitment, yellow and silver eel series into the shiny app is still to be completed, but functions have been developed that will facilitate that development.

Yellow eel abundance data present information on long-term monitoring of yellow eel abundance across various habitats at 70 sites (Figure 3.3.1). Methodologies vary from electrofishing and traps in rivers to beach-seines, fykenets and trawls in larger waterbodies. In some cases, detailed information on catches and effort in commercial fisheries are combined to give estimates on local abundance. The longest non-fishery dependent data on subpopulations of marine yellow eel are available from Skagerrak beach-seine surveys in Norway since 1925.

Silver eel abundance data representing long-term series of the migratory life stage across different habitats were reported for 28 sites (Figure 3.3.2). Data are available from as early as 1966 from Girnoch Burn in Scotland until 2019. Methods vary from electrofishing surveys and traps in freshwater to fykenets and trawls in transitional and coastal waters.

The WGEEL will analyse these yellow and silver eel time-series for any trends in future years. However, it is noted that there have been changes to methodologies in some dataseries, which will have to be taken into account in any future trend analyses. Data providers must always be consulted before using any of these data.

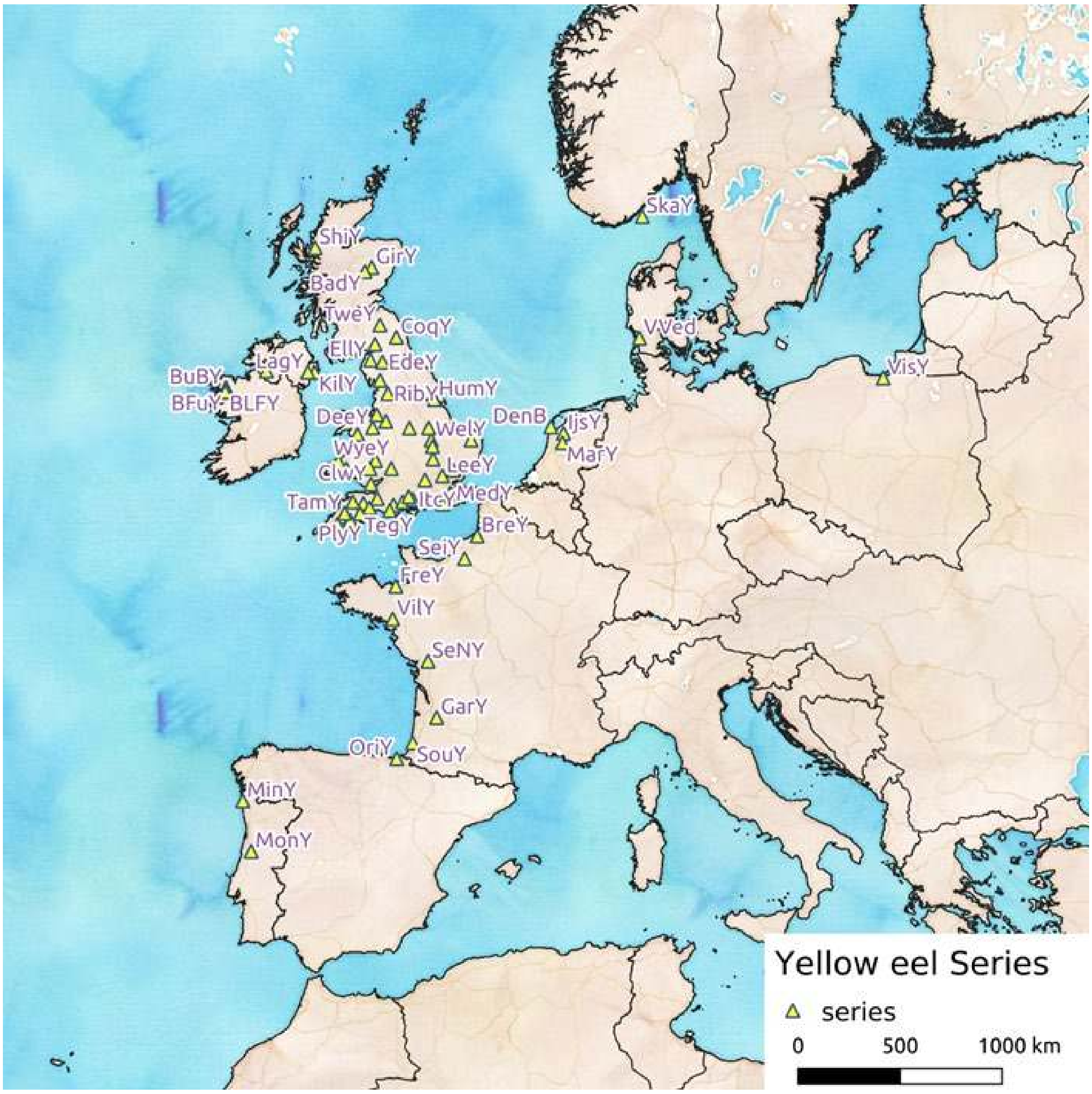


**Figure 3.3.1. Location of yellow eel abundance surveys (not all series, integration not finished).**

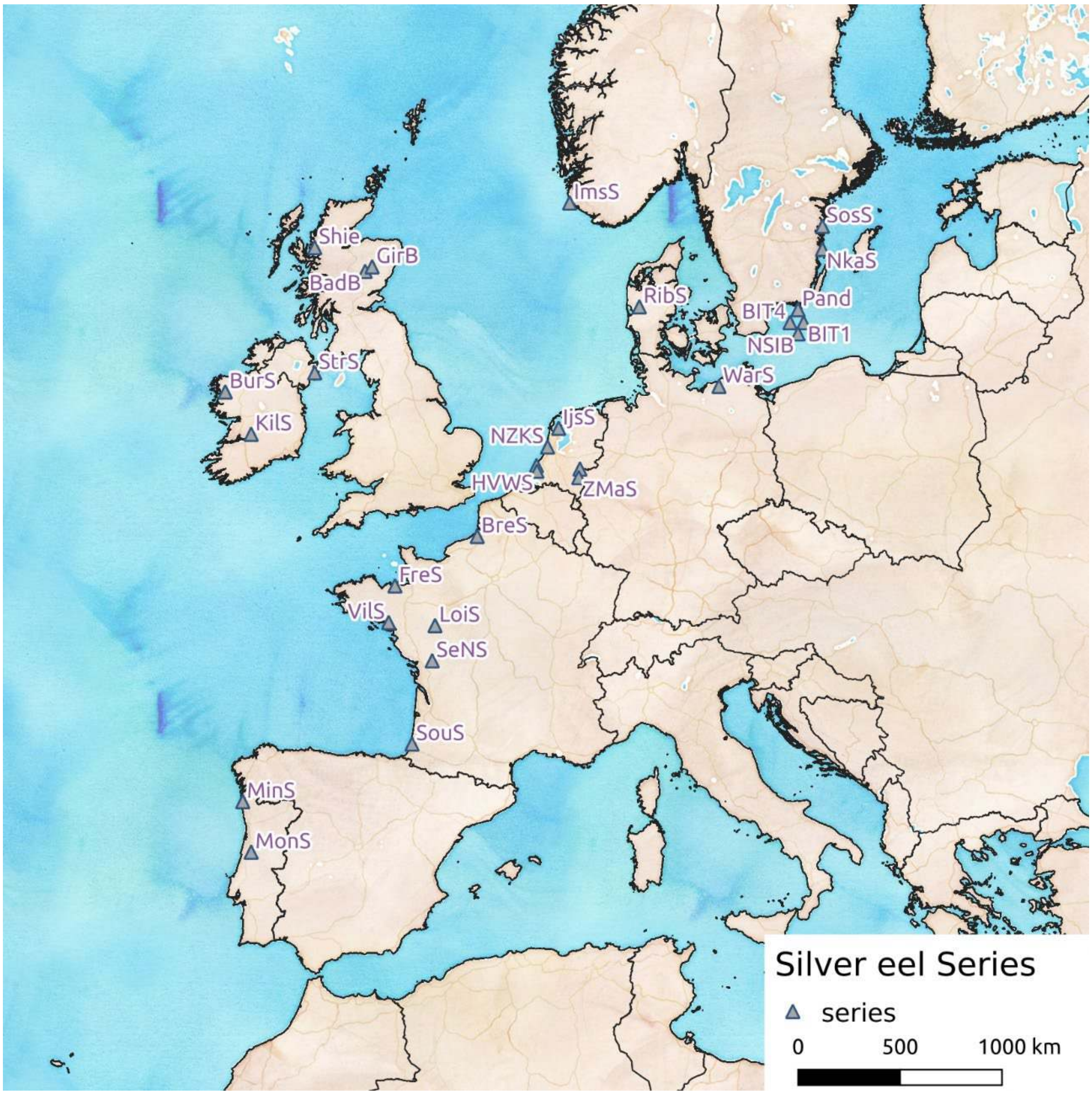


**Figure 3.3.2. Location of silver eel abundance surveys.**

## 3.4 Trend in fisheries

This section presents and describes data from commercial, recreational and non-commercial fisheries, aquaculture production and restocking of eel. Data can be reported by eel life stage (glass, yellow, silver), habitat type (freshwater, tidal, marine) and by EMU where possible. Historical series for which these details are not available are reported by country. The current database structure will allow aggregation by country or region if necessary. The landings data presented are those available to the WGEEL, either through responses to the 2019 Data call, or integrated earlier by WGEEL.

### 3.4.1 Commercial fisheries landings

Landings data for commercial eel fisheries are available from the Eel Data call and from the WGEEL database. When data are absent and presumed missing for a country or year, a predicted catch is used. This "correction" is based on a simple General Linear Model (GLM) extrapolation of the log-transformed landings (after Dekker, 2003a), with year and countries as the explanatory factors. This is applied to account for non-reporting, but it is not a complete solution.

Figure 3.4.1 presents the time-series up to and including 2019 for total glass eel landings as reported by five countries in the Eel Data call and from the WGEEL database. Figure 3.4.2 presents the same time-series but corrected for missing data (see above), with an inset box showing the proportion of data corrected per year. The latter series is limited to after 1970 as French data were not reported before but these dominate the catch since then. Glass eel landings have declined sharply from 1980, when reported and reconstructed landings were larger than 2000 tonnes, to 62.2 t in 2018 (final, full reporting), 58.6 t in 2019 (provisional, no reconstruction), and a mean for the previous five years (2013–2017) of 56.5 t (full reporting).

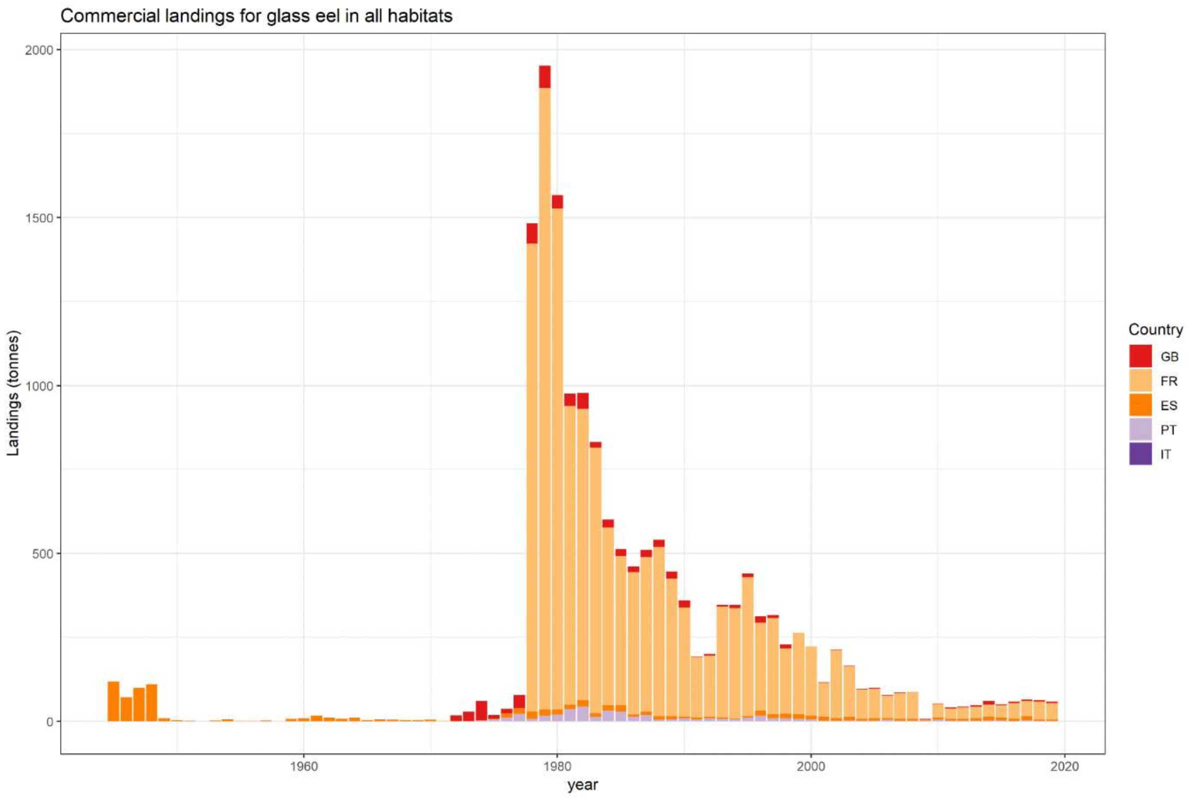


**Figure 3.4.1. Time-series of reported commercial glass eel fishery landings (tonnes) 1945–2019, by country. United Kingdom (GB), France (FR), Spain (ES), Portugal (PT) and Italy (IT) are included combining information from the Data call 2019 and the WGEEL database.**

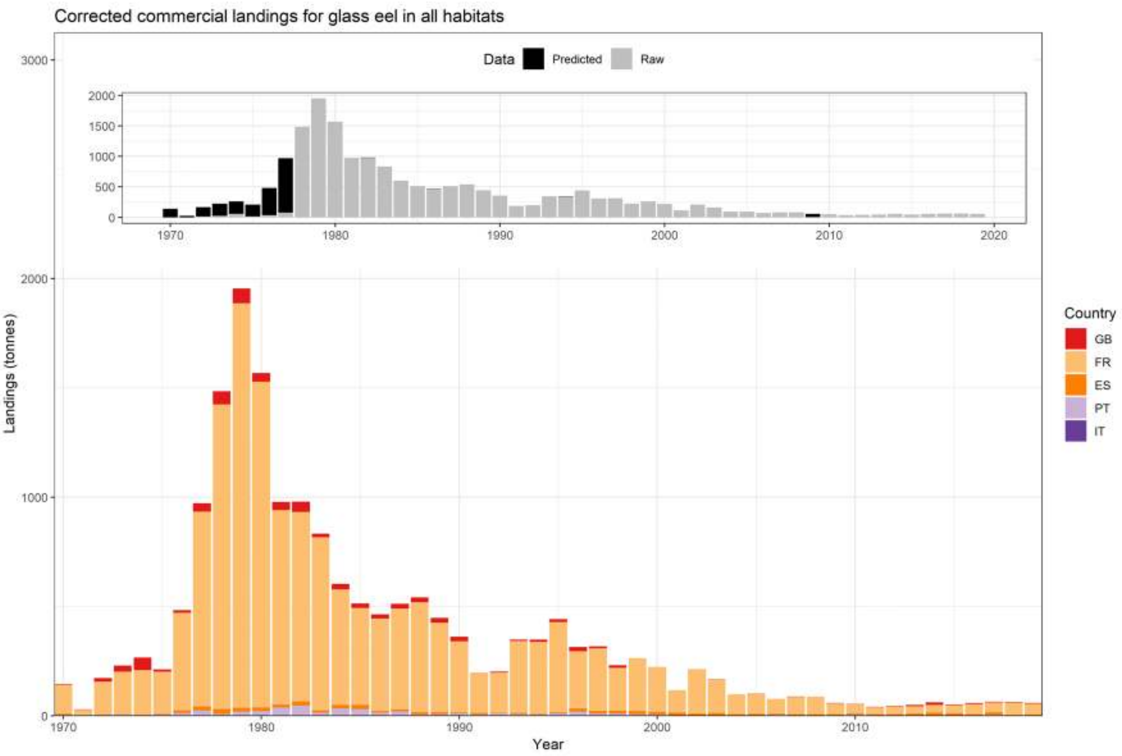


**Figure 3.4.2. Time-series of reported or reconstructed commercial glass eel fishery landings (tonnes) 1970–2019, by country. United Kingdom (GB), France (FR), Spain (ES), Portugal (PT) and Italy (IT), combining information from the Data call 2019 and the WGEEL database, and a reconstruction of the non-reported countries/years combinations (see text). The inset box shows the proportion of data reconstructed per year.**

Figure 3.4.3 presents data for yellow and silver eels aggregated from 20 countries, and Figure 3.4.4 presents the time-series including reconstructed data to fill the gaps. The proportion of "corrected" landings was as high as 50% in the 1950s, but has been low since the mid-1980s.

Reconstructed total commercial landings of yellow and silver eels were around 20 000 t in the 1950s to 2000–3500 t around 2009, most recently being 2393 t in 2017 (final), 2694 t in 2018 (provisional) and a mean of 2729 t for the preceding five years (2012–2016). The reported landings were around 10 000 to 12 000 t in the 1950s, declining to 2000 to 3000 t around 2009, and more recently being 2249 t in 2017 (final), 2375 t in 2018 (provisional, only 14 countries reported) and a mean of 2729 t for the preceding five years (2012–2016). Detailed values per year and per country are provided in Table A8.4 Annex 8.

Care should be taken with the interpretation of the landings as indicators of the stock, since the catch statistics now reflect the status of reduced activity as well as of stock levels.

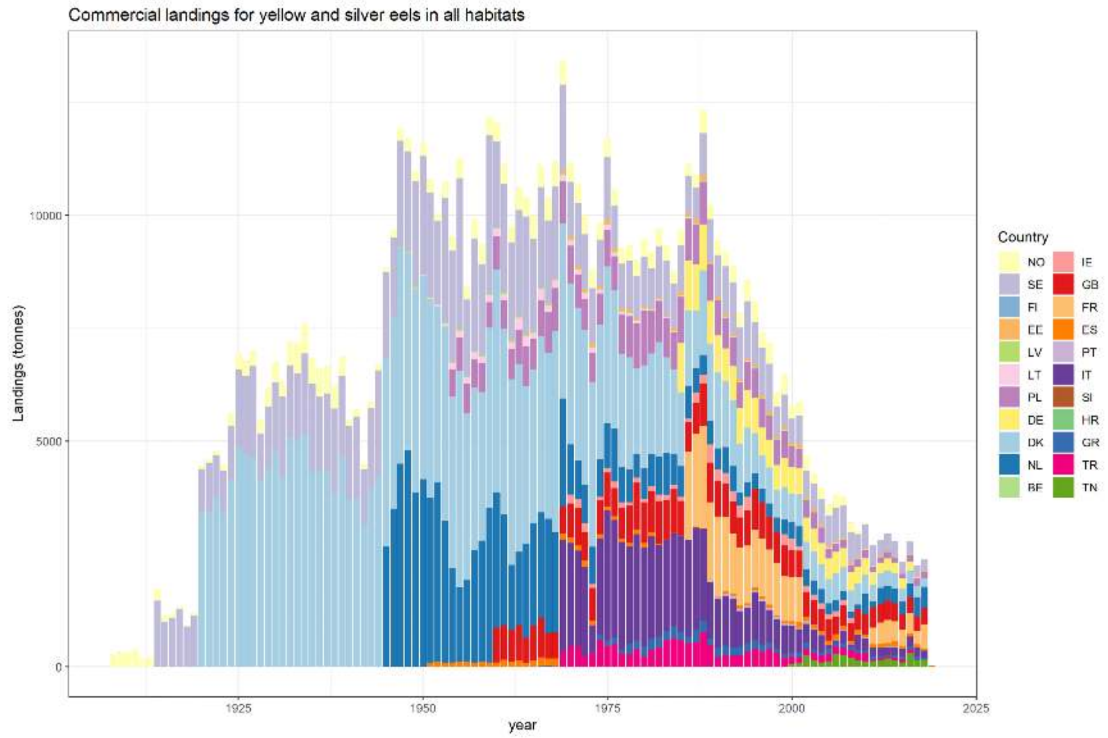


**Figure 3.4.3. Time-series of reported commercial yellow (Y), silver (S) and yellow-silver (YS) eel fishery landings (tonnes) 1908–2018, by country, Norway (NO), Sweden (SE), Finland (FI), Estonia (EE), Latvia (LV), Lithuania (LT), Poland (PL), Germany (DE), Denmark (DK), Netherlands (NL), Ireland (IE), United Kingdom (GB), France (FR), Spain (ES), Portugal (PT), Italy (IT), Slovenia (SI), Croatia (HR), Greece (GR), Turkey (TR) and Tunisia (TN), combining information from the Data call and the WGEEL database.**

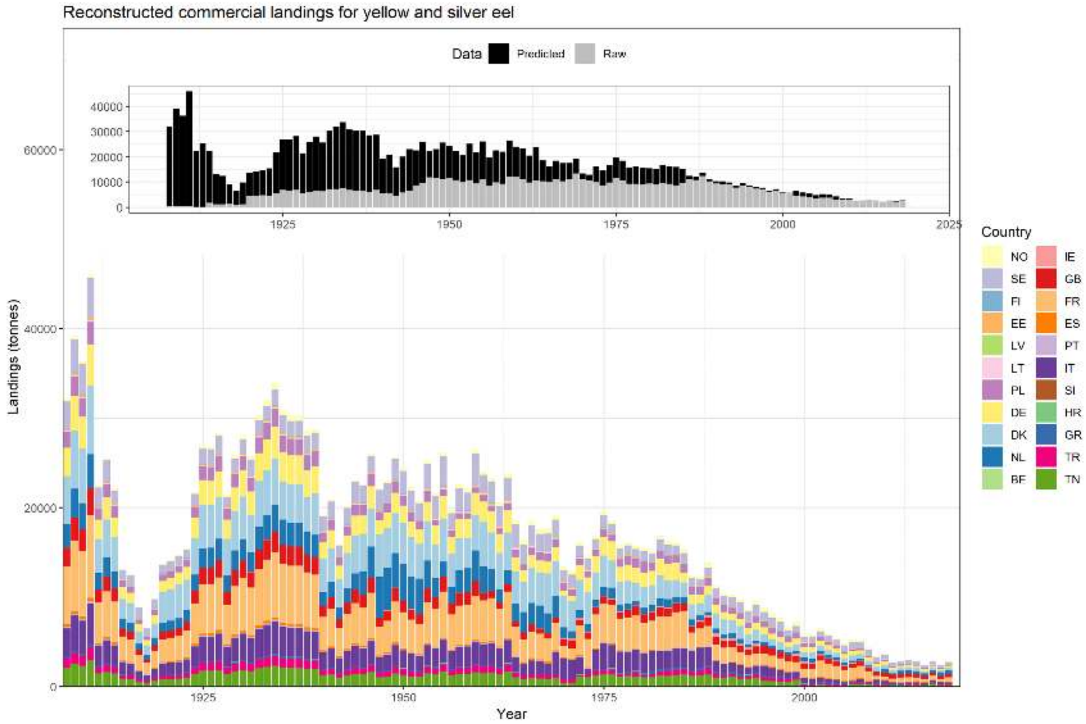


**Figure 3.4.4. Time-series of reported or reconstructed commercial yellow and silver eel fishery landings (tonnes) 1908–2018, by country, Norway (NO), Sweden (SE), Finland (FI), Estonia (EE), Latvia (LV), Lithuania (LT), Poland (PL), Germany (DE), Denmark (DK), Netherlands (NL), Ireland (IE), United Kingdom (GB), France (FR), Spain (ES), Portugal (PT), Italy (IT), Croatia (HR), Slovenia (SI), Greece (GR), Turkey (TR) and Tunisia (TN) combining information from the Data call, the WGEEL database and a reconstruction of the non-reported countries/years combinations. Inset box shows the proportion of reconstructed landings, per year.**

## 3.4.2 Recreational and non-commercial fishing

Recreational and non-commercial fishing is the capture or attempted capture of living aquatic resources mainly for leisure and/or personal consumption. Recreational and non-commercial fishing covers active fishing methods including rod, line, spear, and hand-gathering and passive fishing methods including nets, traps, pots, and setlines. Recreational fisheries for glass eel used to exist in France and Spain but have been forbidden in France from 2010.

Figure 3.4.5 presents the data available to the WGEEL on recreational landings for glass eel; Figure 3.4.6 presents the data available on recreational landings of yellow and silver eel combined. Spain reports a recreational fishery for glass eel, with landings estimated as 0.9 t for 2019 (provisional), with a mean of 2 t for the preceding five years (2014–2018). Recreational landings for yellow and silver eel combined were 543 t for 2016 (ten countries reporting), 195 t for 2017 (eight countries reported) and 148 t for 2018 (five countries reported; no 2019 data available at time of writing).

Data deficiencies were described in the WGEEL 2016 report (ICES, 2016a), and improvements have been evidenced since then. In summary, some countries do not include surveys of all gears and/or habitats and lack estimates of released eel from recreational fisheries. Overall, the impact of recreational fisheries on the eel stock remains largely unquantified although landings can be thought to be at a similar order of magnitude to those of commercial fisheries.

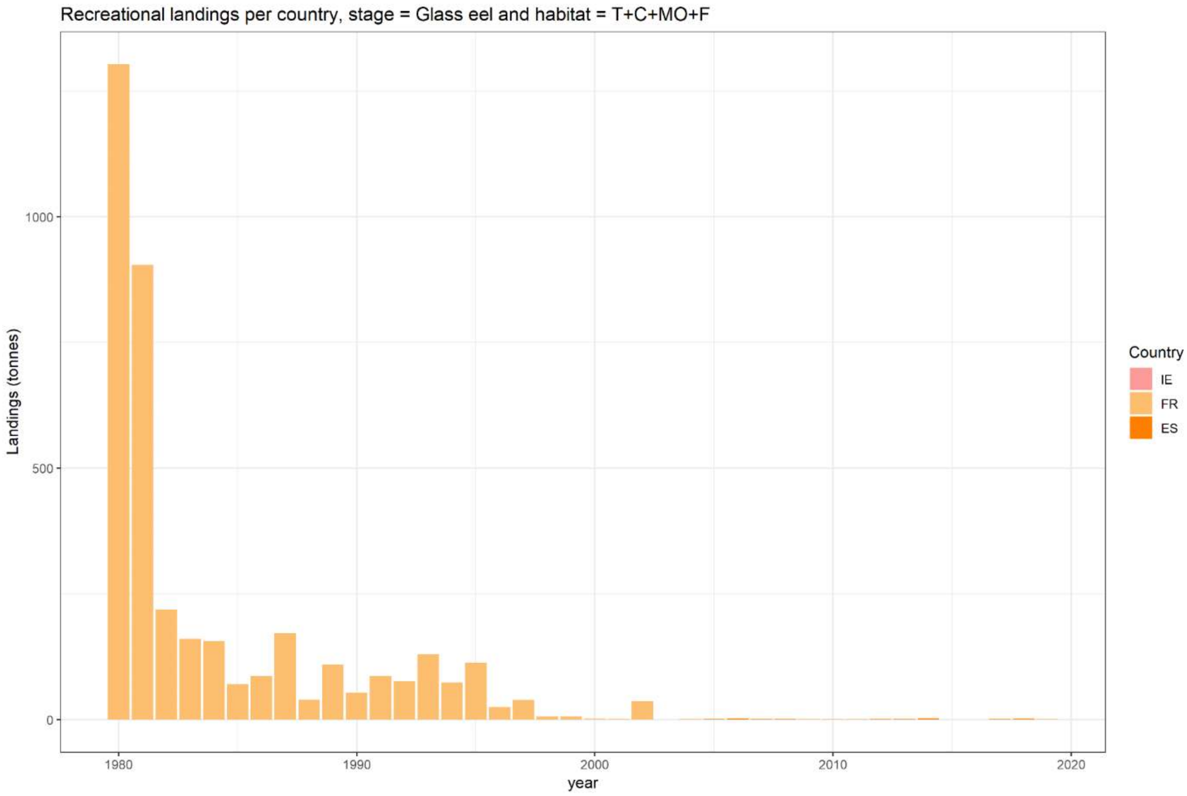


**Figure 3.4.5. Time-series of reported recreational glass eel fishery landings (tonnes) 1978–2018, by country France (FR), Spain (ES), combining information from the Data call and the WGEEL database. NB, IE wrongly shown in the legend.**

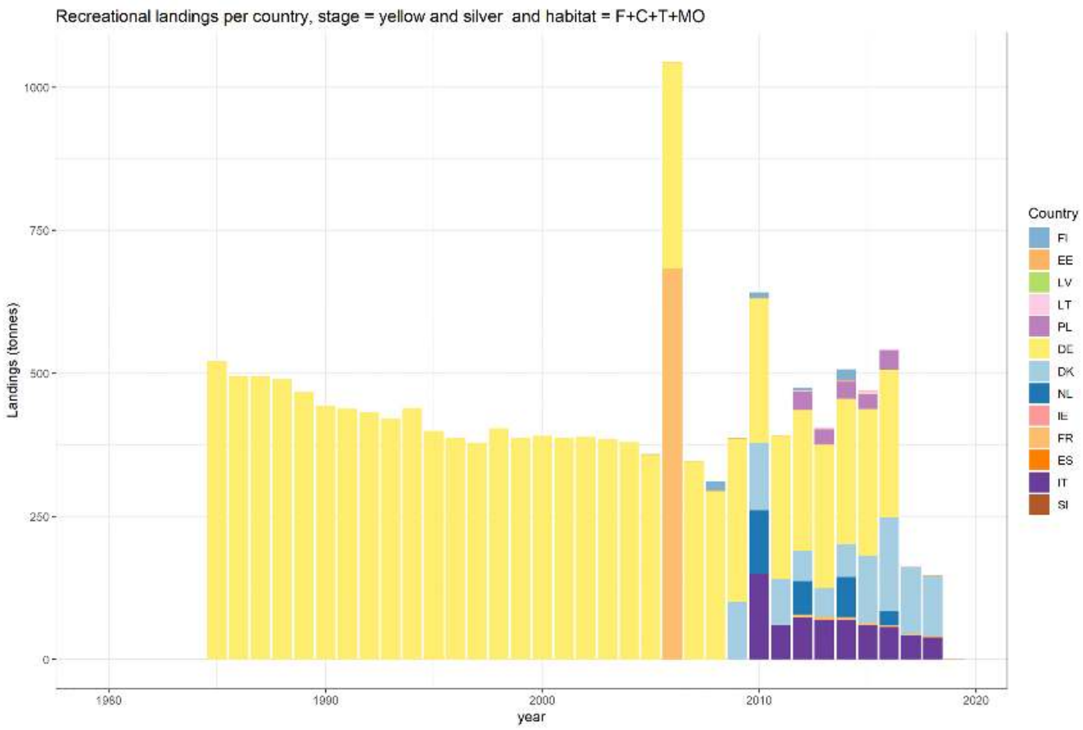


**Figure 3.4.6. Time-series of reported recreational yellow and silver eel fishery landings (tonnes) 1980–2018, by country, Sweden (SE), Finland (FI), Estonia (EE), Latvia (LV), Lithuania (LT), Poland (PL), Germany (DE), Denmark (DK), Netherlands (NL), Ireland (IE), France (FR), Italy (IT) and Slovenia (SI) combining information from the Data call and WGEEL database. Note that some countries are included but have only ever reported 0 values.**

### 3.4.3 Illegal, unreported and unregulated landings

Illegal, unreported and unregulated fishing (IUU) is by its nature very difficult to quantify, and misreporting may therefore be substantial. Most countries did not report any IUU in their Country Reports. However, seizure of illegal gears, or other legal measures were reported from Belgium, Ireland, The Netherlands, and Sweden in their Country Reports. Organized illegal glass eel trade is supplied by legally caught and IUU-caught eel. This trade has high priority by the Europol (the European Union'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. Related police action and court decisions have been covered by a large number of news reports during the past year. 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.

## 3.5 Releases

Restocking (the process of capture, translocation and restocking to new locations in the wild) of eel increased after the implementation of management plans in EU Member States in 2009, because of the inclusion of this as a stock enhancement option in the EC Eel Regulation (EC 1100/2007). 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 (G), or after a quarantine (QG), after a period of some months of growth in aquaculture (OG), at the yellow eel (Y) or silver eel (S) stage or mixed life stages: Glass + Yellow eel (G+Y) and Yellow + Silver eel (Y+S). There is also a spatial element that complicates matters, ranging from the capture and movement of eel only a few 10s or 100s of metres within the same waterbody to bypass an obstacle, to eel being moved several 100 km from one country or ecoregion to another. In the cover letter of the Data call, data on assisted migration (as long as eels are caught and immediately released in the same EMU, with no change in mortality) is no longer requested and this might cause some discontinuities in the data. This point will be addressed the WGEEL next year.

As there is still some inconsistency or variation in the way that countries report some of these actions, the WGEEL broadly categorises them as RELEASES, though the term RESTOCKING is still used here for some circumstances.

Data on the amount of restocked eel were obtained from the responses to the Data call in 2019, however the data for 2019 for restocking are incomplete as (i) restocking programmes in various countries are still underway for the year, and (ii) information from countries (such as Germany), known to have restocking programmes but which did not fully reply to the Data call, were not included.

The Data call requires the provision of both numbers and weights per EMU to evaluate the average weight of each line of data entered. As the database is not structured to handle two different columns for quantities, the initial checks on the consistency are done during data integration.

Although the definition of restocking is clear (above), 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 (G), or after a quarantine (QG), after a period of some months of growth in aquaculture (OG), at the yellow eel (Y) or silver eel (S) stage or a mixed life stages: Glass + Yellow eel (G+Y) and Yellow + Silver eel (Y+S). Some inconsistencies caused by the differing definitions were addressed prior to and during the WG and thus a mix of G+Y is no longer reported. A mix of Y+S eel is only reported by Spain and thus only reported as part of the total releases.

The restocking of glass eel peaked in the 1980s but part of the decrease is not showing as German data are lacking for the period before 1980, followed by a steep decline to a low in 2009 (Figure 3.5.1). The amount of glass eels restocked increased until 2014 when the lower market prices guaranteed a larger number of glass eels could be purchased for fixed restocking budgets. However, glass eel restocking has decreased since then.

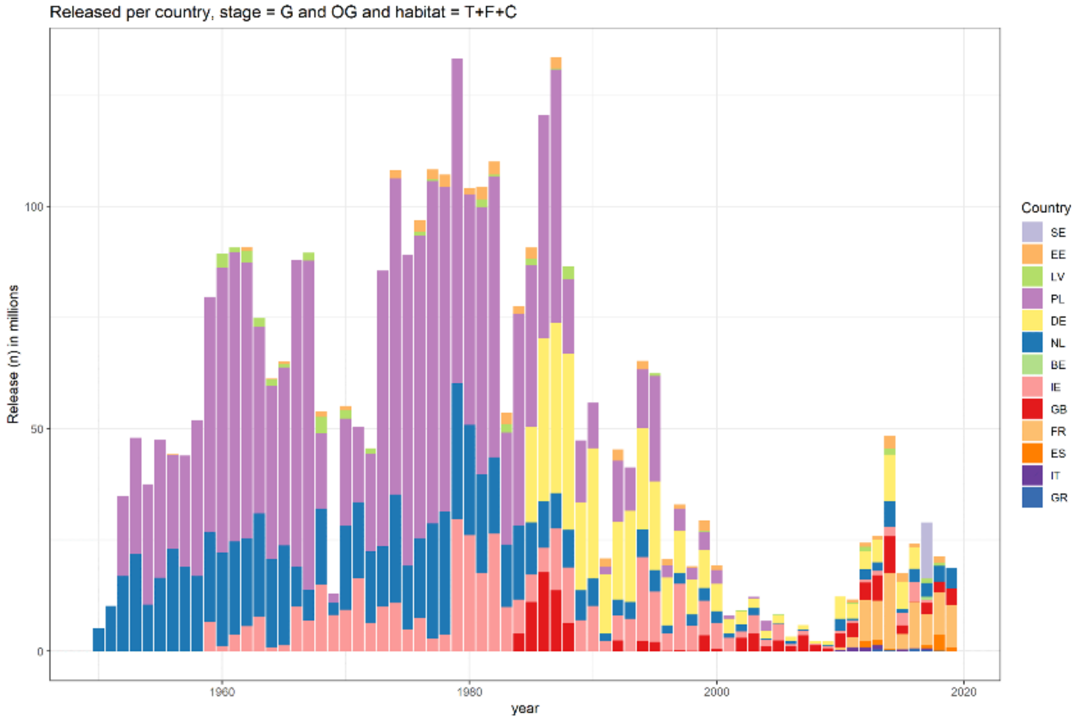


**Figure 3.5.1. Reported restocking of glass eel not including those in quarantine by country (in thousands). 1950–2019, Estonia (EE), Latvia (LV), Poland (PL), Germany (DE), Netherlands (NL), Ireland (IE), United Kingdom (GB), France (FR), Spain (ES), Portugal (PT), Italy (IT) and Greece (GR).**

Only Sweden and Finland have reported quarantined glass eel restocking (Figure 3.5.2). Quarantined glass eel restocking peaked in the 1990s, decreased in the early 2000s and increased again after the implementation of the EC Eel Regulation.

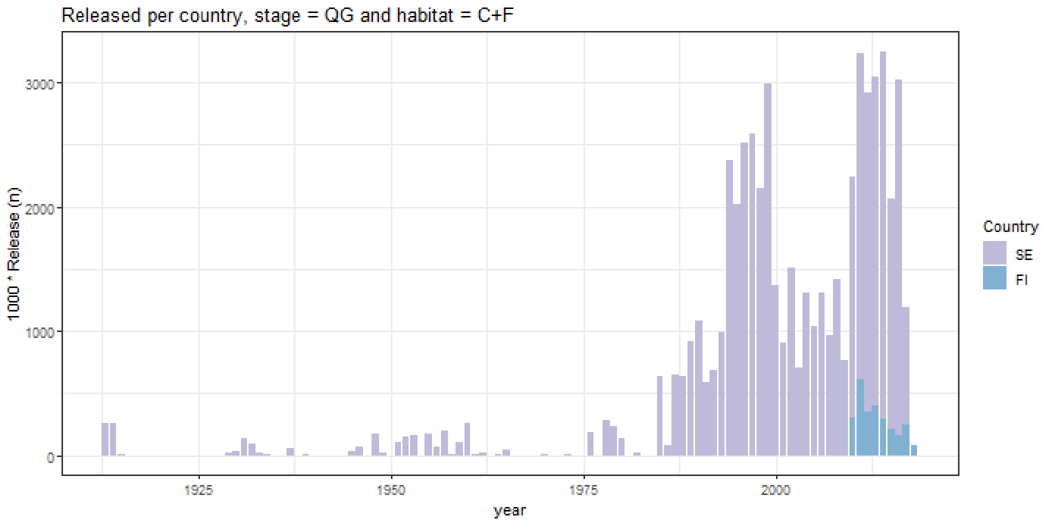


**Figure 3.5.2. Reported restocking of quarantined glass eel by country (in thousand) from 1913–2019 in Sweden (SE) and Finland (FI).**

The restocking of on-grown eels has constantly increased since 2000 and reached a maximum in 2014 (Figure 3.5.3). Poland restocked most on-grown eels until 2016. Denmark has stocked on-grown eels since 1987 (but is missing from the Figure).

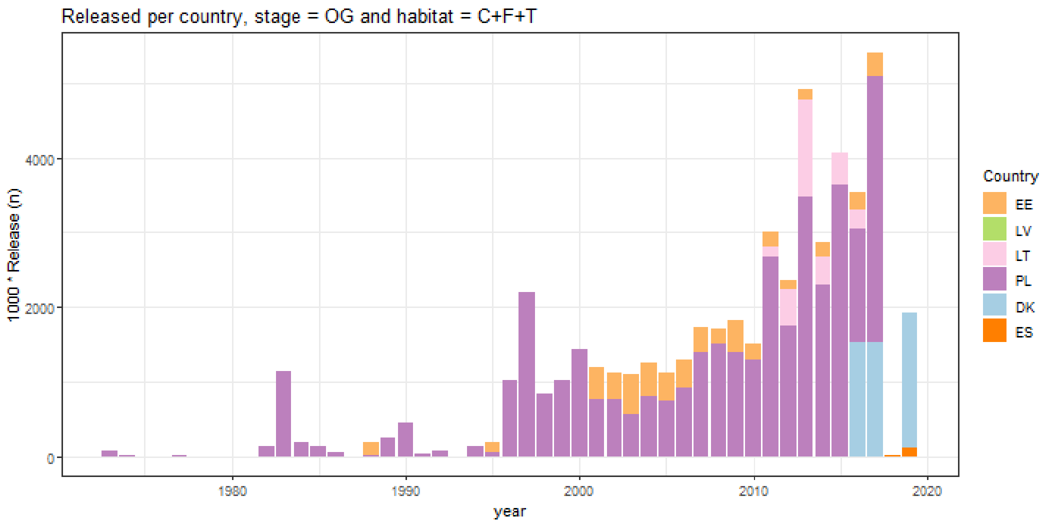


**Figure 3.5.3. Restocking of on-grown eel by country (in thousand) (1973–2018) in Estonia (EE), Latvia (LV), Lithuania (LT), Poland (PL), Denmark (DK) and Spain (ES).**

During the 1940–1960 period, Sweden had a large restocking programme for yellow eel (Figure 3.5.4). The activity decreased in the 1970s and increased again in the 1980s. Germany started to stock yellow eels in 1985 and was responsible for the restocking of large quantities of yellow eels until 2016 when they stopped restocking yellow eel.

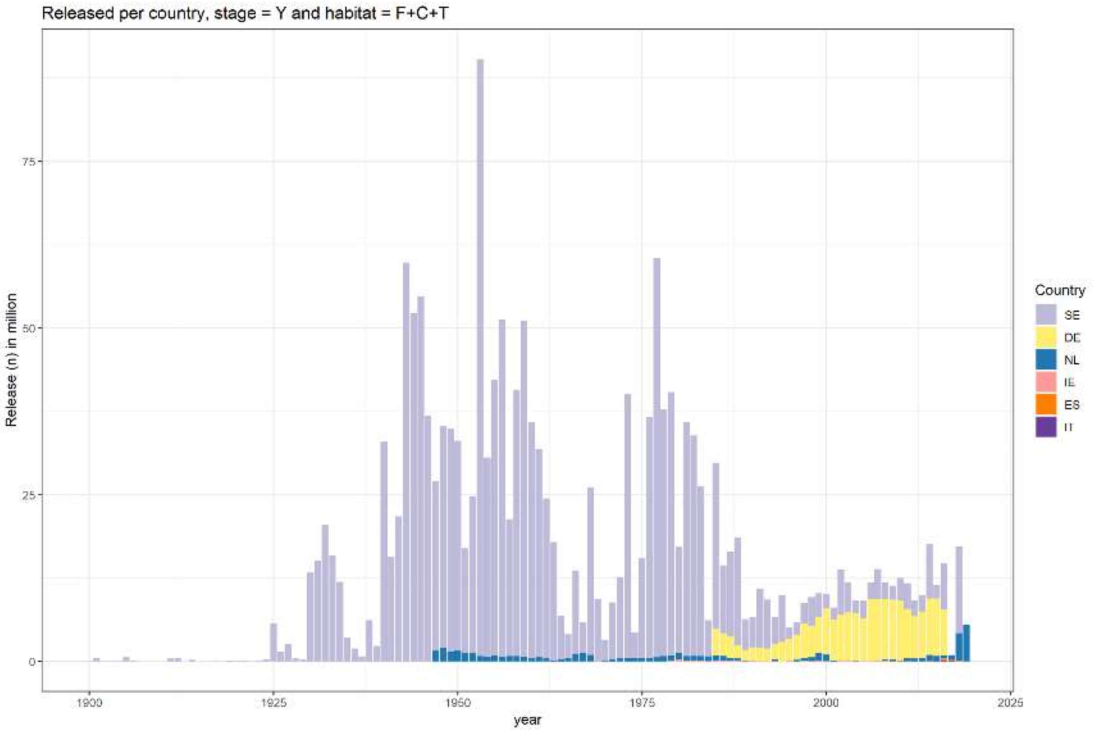


**Figure 3.5.4. Reported release of yellow eel by country (in thousands) from 1947–2019, in Sweden (SE), Germany (DE), Netherlands (NL), Ireland (IE), Spain (ES), and Italy (IT).**

In contrast, some silver eels, caught by the fishery and therefore recorded as landings, are later released in the Mediterranean outside the lagoons in Greece and France. They are reported as released silvers (Figure 3.5.5).

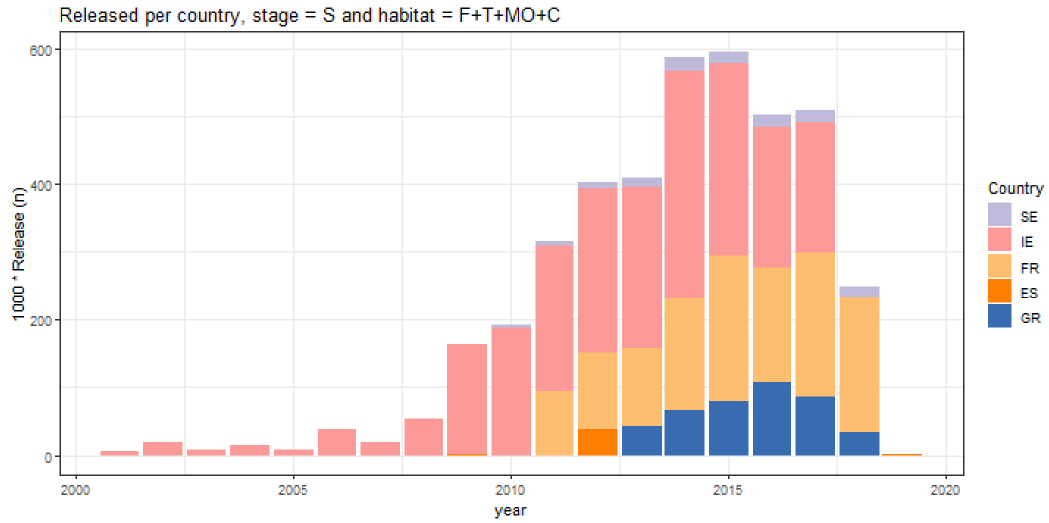


**Figure 3.5.5. Reported released silver eel by country (in thousands) 2000–2019 relocated in Sweden (SE) Ireland (IE), France (FR), Spain (ES), and Greece (GR).**

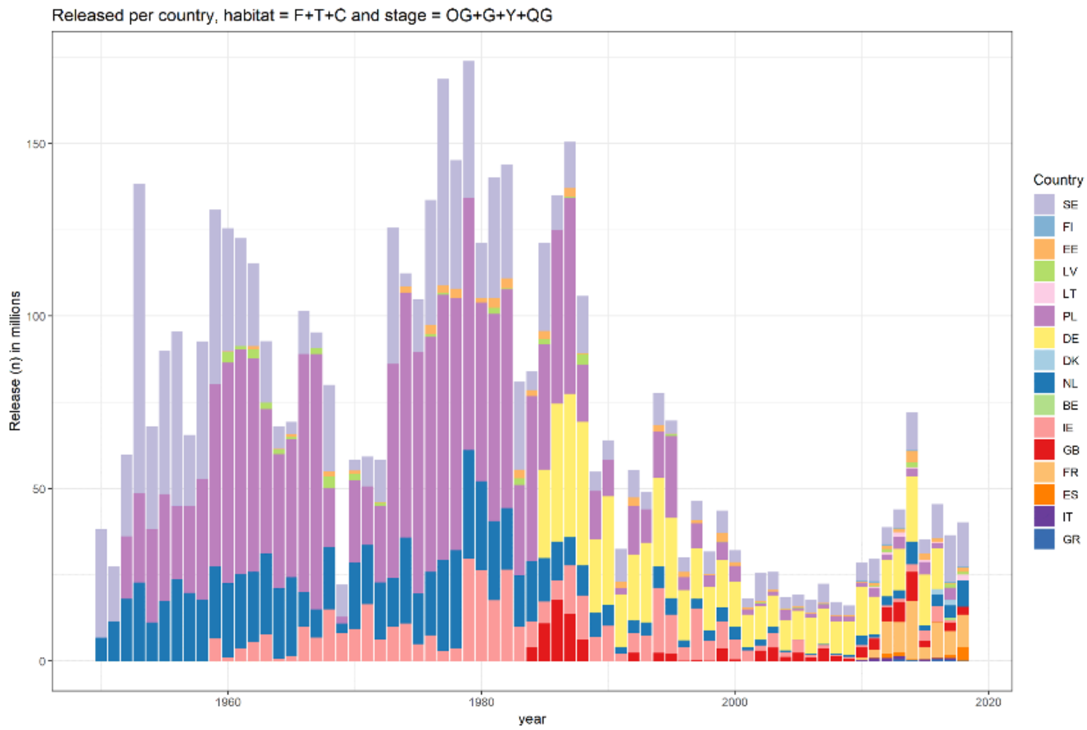


**Figure 3.5.6. Total annual amounts of eel restocked (thousand) per country (all stages excluding Silver) (1950–2019) in Sweden (SE), Finland (FI), Estonia (EE), Latvia (LV), Lithuania (LT), Poland (PL), Germany (DE), Denmark (DK), Netherlands (NL), Ireland (IE), United Kingdom (GB), France (FR), Spain (ES), Portugal (PT), Italy (IT), Greece (GR).**

## 3.6 Aquaculture

Aquaculture production data are derived either from responses to the Data call 2019 or from the Country Reports. Compared to previous WGEEL reports, all the data available to WGEEL are presented here from 1984 onwards, even if data are only complete from 2004 onwards. Data have been provided for ten countries.

Aquaculture production increased from 1984 until the mid-2000s, peaking around 8000 t (Figure 3.6.1). Production was reported in 2017 (the most recent year of most countries reporting: 10) as 5497 t in 2017 and the preceding five-year mean was 6429 t (2012–2016) (Table A7.1 Annex 7).

It should be noted that eel aquaculture is based on wild recruits, and some them are subsequently released as on-grown eel for restocking (around 10 million eels, assuming a mean weight of 20 g would equate to about 200 tonnes).

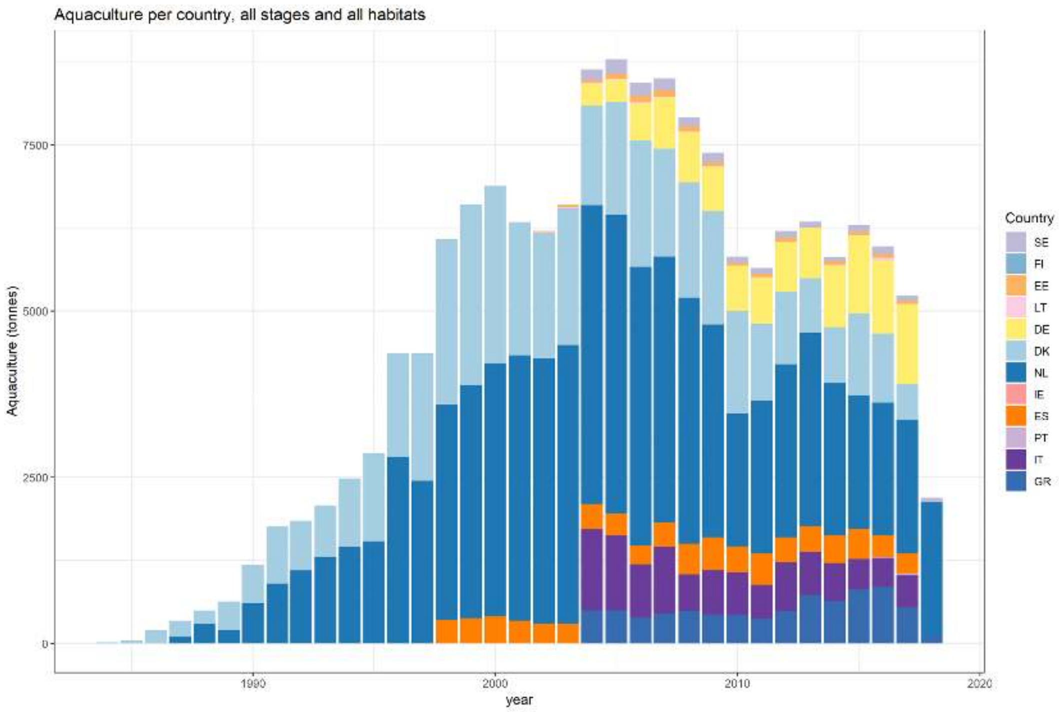


**Figure 3.6.1. Reported aquaculture production of European eel in Europe from 1984 onwards, in tonnes, in Sweden (SE), Finland (FI), Estonia (EE), Lithuania (LT), Germany (DE), Denmark (DK), Netherlands (NL), Spain (ES), Portugal (PT), Italy (IT) and Greece (GR).**

# 4 ToR C: Report on updates to the scientific basis of the advice, including any new or emerging threats or opportunities

The WG has focussed attention this year on three aspects of the scientific basis of the advice: the science of impacts of hydropower, the risks to assessments of data loss due to new fishery regulations, and other new or emerging threats or opportunities. This chapter presents the findings of each in turn.

## 4.1 Summary of new information on impacts of Hydroelectricity generation, pumping stations and other abstractions on eels, relevant to renewed advice on quantification and mitigation of impacts on eels

### 4.1.1 Summary

WGEEL 2018 identified a need for reviewing scientific studies and new data on non-fishery factors contributing to direct and indirect losses of eel, at a frequency appropriate to refreshing advice based on the availability of new information. The group concluded that where the stock-level impact of such factors can be quantified, leading to renewed advice on the benefits of mitigation measures additional to existing fishery controls, a rolling programme of reviews should be undertaken, with a specifically tasked subgroup examining one theme per year.

The first three areas proposed by WGEEL in 2018 for review were (1) impact of hydropower and water pumping operations, (2) loss of eel habitat and (3) effects of contaminants and parasites. This led to inclusion of a review of the impact of hydropower on eel stocks in the 2019 ToR for WGEEL, with the other subjects to follow in subsequent years.

Hydropower impacts on eel were last reviewed by WGEEL for its 2011 report (Lisbon). Between its 2018 and 2019 meetings, WGEEL members have contributed to collation of further published scientific papers, reviews and reports. In addition to a tasked subgroup collating new published material, WGEEL Reportees were also asked to report quantitatively on Hydropower and other water abstraction related impacts on eels under the heading of "entrainment" in country reports to WGEEL, and in the ICES Data call tables under non-fishery anthropogenic mortality rate (∑H). Note that the H in ∑H does not only signify Hydropower but includes all the non-fisheries anthropogenic impacts that countries have quantified.

WGEEL 2019 collated literature on impacts of hydropower, water pumps, and related infrastructure, examining papers, data and other material published since the subject was last summarised as WGEEL in 2011. The new literature features studies ranging from direct measurements of eel mortality at individual hydropower sites, through models to extend empirical data at individual sites to estimate impacts to regional levels, to overarching reviews and national and international advisory reports. A significant review of the subject area is included in a report for the EU PECH committee (Hanel *et al*., 2019). This WGEEL report section is intended as a summary/update on the new material directing advice on actions that can be taken now and over the longer term to mitigate impacts on eel. The reader is directed to individual reports referenced should more detail be required.

Ranges of mortality as eel pass by or through hydropower stations are highly variable. Telemetry studies using tagged eels are now a standard method to measure the direct impact. These studies are however not fool proof; for example, it is obviously not possible to identify and track individual untagged eel as a full control, and in high flow environments dead and moribund eels can carry tags downstream after the initial impact. Longer term survival after apparently successful passage may also be impaired, to an unknown degree. Therefore, much of the data available on direct impact are minimum estimates. Nevertheless, ranges of mortality in studies published since 2011 indicate that most new data lie within the (very wide) bounds of survival/mortality rates already described in earlier reviewed studies, reinforcing the advice that knowledge of individual site characteristics is critical to well-designed mitigation of mortality

Total mortality rates at a power station area 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 bar racks, etc.), and 3) the mortality rate of those using alternative routes (bypass channels, old river bed, etc.). There may also be an increased predation risk at power stations, such as increased predation in slow-flowing reservoirs, or higher predation risk for injured fish.

Models are available and continually being refined to enable prediction of losses of eel at individual sites, based on supporting information of eel population, eel size, migration characteristics and hydropower site descriptors (e.g. turbine type, size, head, proportion of river flow used, racks and screens, bypass opportunities and operating times). Methods are also available to determine when eel will migrate or are migrating to inform fish-friendly management regimes should they be adopted. However, accurate estimates of total mortality caused by a hydropower station usually require site-specific studies, with need for local information.

Wider scale or river system turbine mortality can, to some extent, be estimated from models scaling up from local situations and extrapolating between similar sites, but there is a need for more testing to evaluate such models.

Further, methods are available to measure the impact at individual sites, based on tagging and tracking for direct measurement, using quantitative high frequency acoustic cameras to directly observe behaviour and count fish (McCarthy *et al*., 2014) and application of models where mortality has been measured at similar sites under similar conditions. Under the Ireland/UK(NI) transboundary North-West River International Basin District Eel Management Plan, a combination of measures for the Erne River and Lake System replaced commercial harvest of yellow and silver eel with a fishery to catch silver eel and transport them past two hydroelectricity stations (McCarthy *et al*., 2014). Total escapement is estimated at the quantified trap-and-transport and a modelled survival of the remaining run based on telemetry studies and an acoustic camera-based estimate of eel escaping the fishery. More recent telemetry studies at this site (D. Evans, Pers. Comm.) demonstrate considerable variability in inter-annual post-fishery survival related to flow variation at the time of silver eel migration. High autumn flows necessitating water spillage allow higher survival than literature average-based estimates, whereas passage survival can be at the lower end of known ranges in dry years. This suggests that future escapement modelling at hydropower sites is improved by incorporating flow-weighted passage survival estimates, calibrated using empirical measurements.

Many of the studies now use electronic tags to evaluate mortality of eels at power stations. Such studies require a well-planned study design to obtain reliable estimates. Passage of a tagged eel may not equate to its long-term survival, as eels can drift considerable distances downstream after they have died in a river (>30 km, Havn *et al*., 2017). It can be difficult to identify dead fish, and the exact site and time of death. Furthermore, dead fish can be moved within the river, or taken out of the river, by scavengers (Havn *et al*., 2017). This is often not considered in studies of fish mortality and may lead to survival being over-estimated.

A wide range of technical and management solutions are available to enable mitigation of the impact of hydropower activities on eel and other fish, including screening, deflection or diversion though passes, and trap-and-transport, spillage of water when eels are migrating and the use of fish-friendly designs of turbines and pumps. There is significant untapped potential, through extension of such measures to more sites, to considerably reduce the current level of losses.

In a report for the PECH committee of the European Parliament, Hanel *et al*. (2019) reviewed the impact of in-river constructions and hydropower on escapement and migration of the spawning stock. Estimates of the EU Member States suggest that hydropower mortality accounts for more than 50% of anthropogenic mortality in 33 of 62 EMUs, where data for fishing and hydropower mortality were reported.

Key findings of the PECH study are:

- Upstream eel migration is primarily affected by industrial installations blocking access to freshwater habitats. Obstacles have important effects on population density, and increase susceptibility to predation, overfishing and potentially also changes in sex ratio.
- Given the variety in possible mitigation measures, technical solutions for downstream and upstream migration across obstacles require local expertise, and need to be validated before being adopted or implemented.
- Obstacles to downstream migration, turbines, pumps and reservoirs cause mortality and delay the migration.
- The impact of hydropower plants decreases with distance to the sea.
- In France and Spain, it is estimated that 60% of the national silver eel run is affected by hydropower plants located within 250 km from the sea. It is noted that only 25% of the total hydropower plants lie in this zone and the remainder are further inland with lower collective impact.
- Mitigation measures that can be immediately implemented to reduce the impact of obstacles include: bypasses, fish friendly turbines and pumps, undershot gate management, temporary turbine closures and trap and transport.
- Stocking eels upstream of obstacles requires true validation to show that the provision of otherwise inaccessible habitats can compensate for accompanied mortalities, including indirect mortality during glass eel fishing and transport, as well as turbine passage during downstream migration.

### 4.1.2 Estimating overall impact of hydropower on the spawning escapement

Direct measurement is clearly unfeasible for all hydropower sites and therefore a modelling approach will be the only way of scaling up assessments. The collective data available to WGEEL 2019 including estimates of biomass and mortality rates in the ICES Data calls, country reports, WKEMP report 2018 (ICES, 2018a), published studies and other material combines to a reinforced view that hydropower and pumping stations are collectively a cause of significant direct mortality of eel, particularly on downstream migrating silver eels in freshwater.

As yet however, we lack detailed site-by-site information to collate an accurate estimate of overall impact, and therefore cannot achieve accurate quantification of the potential increase in spawner escapement, that collective targeted mitigation measures could achieve on a stock-wide basis.

#### 4.1.2.1 Estimating losses of eel from ALL sources of non-fisheries anthropogenic impacts, based on the ∑H mortality rate term

Nevertheless, a crude and partial biomass loss-based estimate can be made on the basis of non-fishery anthropogenic mortality (∑H) rates declared by country, combined individually with parallel estimates of potential biomass of eel production from current recruitment ($B_{best}$) (Table 4.1.1). The biomass of ΣH is calculated as ($B_{best}$-$B_{current}$) * (∑H/∑A), where ΣH is the anthropogenic mortality rate outside the fishery, summed over the age groups in the stock. It is important to reinforce the caveat that ΣH does not always equal only the direct impact of hydropower and pumps but includes all other non-fisheries anthropogenic impacts assessed by the country in question. ΣA is the sum of anthropogenic mortalities and it refers to fishery (ΣF) and non-fishery (ΣH) mortalities summed over the age groups in the stock, i.e. ΣA = ΣF + ΣH.

The result of this exercise gives a total potential current loss in the region of 1625 tonnes per year (Table 4.1.2) The scale of this crude estimate of loss and the evidence provided by measured mortality reductions achieved where targeted mitigation action is taken combine to a clear basis for advice that a lot more can be done at most sites.

In the context of the undisputed capacity for adverse impact, there are already non-fishery-specific legislative drivers toward improving the situation (particularly in EU the Water Framework Directive and parallel measures in other regions). In order to assess progress and improvements, methods are required for the documentation and recording of progress as it occurs under these measures to deliver this.

**Table 4.1.1. Estimates of the losses of eel in those countries reporting data enabling estimation of potential biomass of eel lost to non-fisheries anthropogenic impacts. These are derived from ΣH mortality rates, including mortalities from hydropower and pumps, but excluding fishery mortality. The data source is from the Country Reports to WGEEL 2019 or from the ICES Data call 2018.**

| Country | Biomass, tonne |
|---|---|
| Belgium | 16.5 |
| Denmark | 9 |
| Estonia | 5.8 |
| France | 301.2 |
| Germany | 265 |
| United Kingdom | 444.4 |
| Ireland | 14.3 |
| Italy | 86.5 |
| Lithuania | 0.4 |
| Netherlands | 233.1 |
| Poland | 74.7 |
| Sweden | 156 |
| Total | 1625.8 |

Note that in a further eleven countries represented at or reporting to the WGEEL, including some non-EU countries, one or other of the requirements of ΣH or the biomass to which it applies was not reported in either the Country Report or Data call tables submitted, preventing an estimate. Therefore, this can only be considered a partial and minimum estimate and not a whole stock assessment of loss. The analysis is also impacted by variation in direct and indirect hydropower, pump and related impacts included by countries in their ΣH estimate. WGEEL therefore presents this estimate only as a first estimate of the broad scale of the impact.

### 4.1.3 New information on Turbine mortality studies using tagging, telemetry, mathematical modelling and other methods

Significant new literature has become available since WGEEL's last review in 2011 further quantifying impacts of hydropower on eel at individual sites. This reinforces the message that mortality of downstream migrating eel when passing a hydropower station can be high. Total mortality was on average 41% for eels at different power station areas, based on a summary of studies (FAO & ICES, 2011; Eklöv, 2012; Pedersen *et al*., 2012; Calles *et al*., 2013; Mahron *et al*., 2014; Dêbowski *et al*., 2016; Bernas *et al*., 2017; Dainys *et al*., 2017; Trancart *et al*., 2018; Økland *et al*., 2019). The variation in mortality among sites is substantial; at some sites 70–100% of the eels died when attempting to pass the power station area, whereas at other sites nearly all passing eels survived (i.e. direct mortality rate close to 0%).

Between 2011 and 2017, a research program "Krafttag ål" was run in collaboration between the Swedish Agency for Marine and Water Management and a number of private hydropower companies. This program resulted in several papers, mostly as internal reports written in Swedish with summaries in English. The main more recent outcomes are summarized in English in Sandberg (2018). To aid accessibility, some are given in more detail here as summarized in English by Swedish country representatives to WGEEL.

Several of the "Krafttag ål" reports add further measured data or modelled figures for turbine mortality: Calles and Christianson, (2012, 11–70% single site, 97% for three sequential), Leonardsson *et al*., (2017, 36%), Östergren *et al*., (2014, 7–21%), Eklöv (2012, 38–64%. individual, >90% for three sequential).

Jeuthe and Leonardsson (2017) summarize the state of knowledge concerning adaptive hydropower management in connection to eel migration, and evaluate the potential for such mitigating measures to be applied at hydropower facilities in some Swedish eel producing river systems. They considered; adjusted flow, and passage, through the turbines; turbine shutdown (complete or partial) and passage via substantial spill; implementation of temporary intake barriers, and passage via moderate spill. An adaptive hydropower management requires a reliable early warning system, but such are limited to application at specific sites. They conclude a complete turbine shutdown is not suitable for one very large river they studied. This river, Göta Älv, drains Sweden's largest lake susceptible to flooding and runs through unstable loamy soils sensitive to sudden changes in flow. Besides technical difficulties, there are significant economic losses (less production of energy) for the hydropower company to accept. Instead, the authors recommend trap-and-transport, at least as a short-term solution. The authors conclude that the development of adaptive hydropower management as an efficient mitigating measure will be a challenge.

Jeuthe and Fjälling (2018) evaluated imaging sonars as potential technology for detecting downstream migrating silver eels. This technology is thought to provide an early warning on migrating eels in real time. Results from their study show that the resolution of the DIDSON Long Range was insufficient for indisputable identification of eels at any distance. However, eels could be positively identified at up to 25 metres distance using the ARIS sonar. The standard DIDSON had a somewhat shorter range for positive identification. However, a successful use of imaging sonars requires knowledge of the swimming patterns of eels approaching the given location, and that requires knowledge of the proportion of eels passing through the sonar's field of view relative to those passing the whole cross section of the waterway.

The use of an acoustic cameras for counts of downstream movements of eel has also been reported from Ireland by Lenihan *et al*. (2019).

### 4.1.4 Impact of Pumping stations on eel

A complete overview of the number and distribution of the different types of pumping stations over the eel's distribution area is lacking and compiling this information would require a major data gathering and collation exercise. In general, the presence and distribution of pumping stations is governed by geomorphological characteristics of the basin. Pumps may be very abundant in lowland areas and in some basins or EMUs their impact is considered to be significantly higher than the estimated impact of hydropower. Other significant pumping of water takes place for drinking water abstraction systems and pumped storage hydropower – the latter is often in upland areas and may not be as significant an impact on eel as in low lying systems.

Preliminary (and incomplete) inventories of pumps are available for The Netherlands, England and Wales and the northern part of Belgium. In the Flandrian part of Belgium, 172 pumping devices were counted and categorized (Stevens *et al*., 2011), while in The Netherlands pump counts amounted to 2813 (Van de Wolfshaar *et al*., 2018). In England and Wales, there are 321 pumping stations identified as having the greatest potential to impact on eel, based on the distance from head of tide (shorter distance = greater impact) and the predicted presence of eel (Defra, 2018).

As reported in FAO and ICES (2011), pumping devices can be very different in type, capacity, blade velocity, head, blade diameter, etc. FAO and ICES (2011) concluded that there is sufficient evidence to already provide reasonable estimates for pump station mortality to be used in models and especially where there is information on the characteristics of their pumping stations (type, head, blade velocity, etc.). Table 4.1.3 summarizes the relative distribution of the different types of pumps in The Netherlands and Belgium.

**Table 4.1.3. Relative distribution (%) of different types of pumping devices in The Netherlands and Belgium.**

| | Flanders (Belgium) (%) | The Netherlands (%) |
|---|---|---|
| Water wheel | | 0.2 |
| Archimedes screw | 23 | 26.5 |
| Centrifugal pump | 16 | 14.2 |
| Propeller-centrifugal pump | | 4.6 |
| Propeller pump | 49 | 54.5 |
| Submerged pumps | 12 | |
| Total number of pumps | 172 | 2813 |
| Reference | Stevens *et al*., 2011 | Kunst *et al*., 2008 |

Pumping stations are of particular concern to migrating silver eels as they cause substantial damage to entrained eels, while also influencing the timing and the speed of migration. Delayed migration might influence the chance for successful reproduction. When entrained, silver eels passing through these pumps are particularly vulnerable due to their long body shape, and are easily killed (Bolland *et al*., 2019). Moreover, by affecting river connectivity, pumps significantly decrease habitat available upstream.

As draining of lowland water systems is related to rainfall, the period of pumping activity is significantly higher in Spring and Autumn. In another study, nearly half of the pumping activity coincided with periods of silver eel migration (Stevens *et al*., 2011).

Fish entrained in pumps and turbines can be injured in a variety of ways including after contact with moving blades, grinding between fixed and moving structures, turbulence, or barotrauma through rapid pressure change (Figure 4.1.1). Rates of injury and mortality are highly variable and depend on numerous biological factors such as fish length, mass, flexibility and tissue sensitivity, all of which are dependent on the species and age of the fish (Stanford, 2017). Note this schematic could represent impacts at hydropower turbine facilities as well.

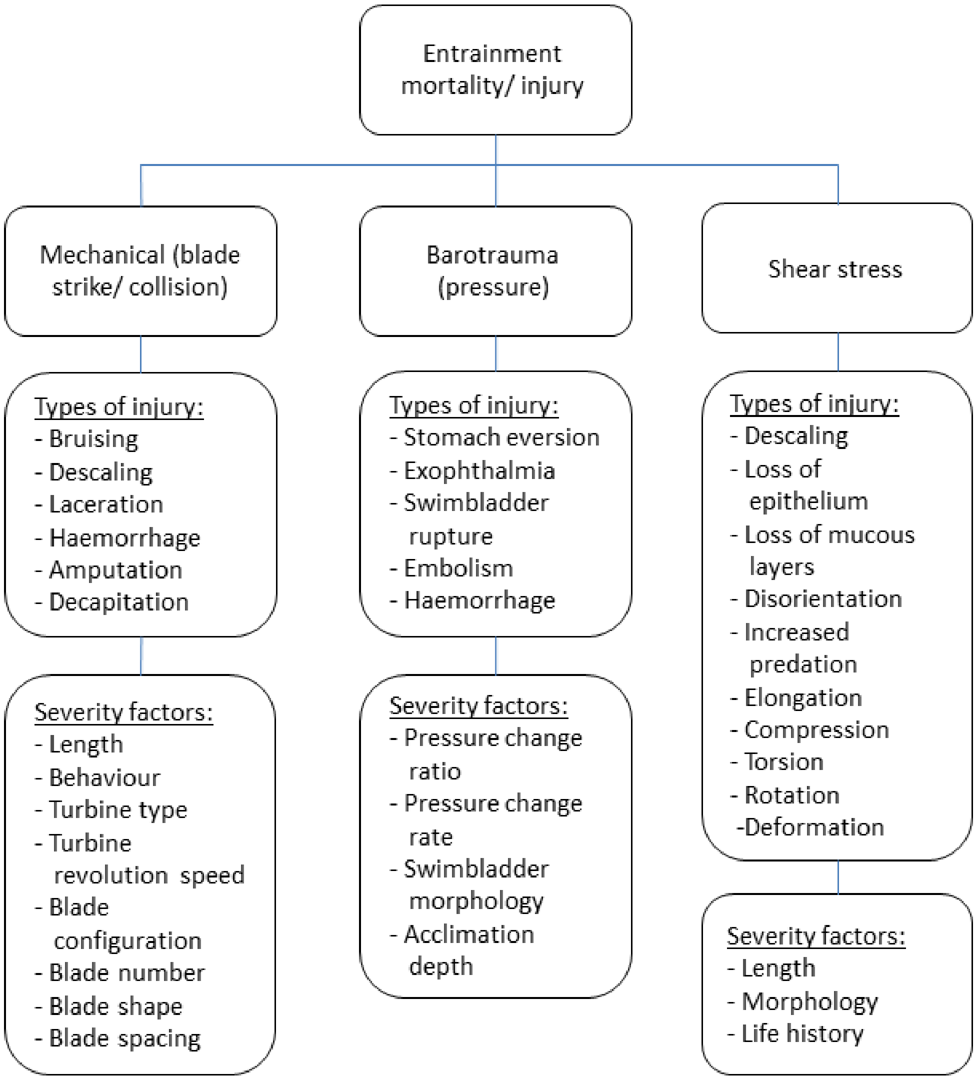


**Figure 4.1.1. Types of injury and factors affecting severity of physical forces contributing to injury and mortality during entrainment, figure by Stanford (2017), adapted from Pracheil *et al*. (2016).**

A table with an overview of impact studies on different types of pumping stations on the survival of eel, was compiled by FAO and ICES (2011). The table specifies mortality estimates at different sites. In general, propeller pumps with axial or axial/radial water flow caused the highest damage, while water wheels and Archimedes screws are relatively "fish-friendly". But, even Archimedes screws are not considered as harmless and can still cause significant mortality. This is supported by recent work by Stanford (2017) demonstrating that pumps considered to have low impact can still affect the long-term survival of an entrained eel. While this study found that the 'fish-friendly' pump had the lowest impact in terms of the rate of injury and average difference in eel condition, it did not have the lowest mortality rate and also had low levels of severe injury and delayed mortality (Stanford, 2017).

Studies available since the 2011 review add datapoints reinforcing the potential damage rates from 10% in the case of the best Archimedes screw pumps to almost 100% in the worst propeller pumps, with other types in between (Buysse *et al*., 2014; Bolland *et al*., 2019; Stanford, 2017; Bierschenk *et al*., 2018). As with turbine injury, delayed (downstream) mortality through internal injury was a major concern.

**Figure 4.1.2. Examples of eel damage, after recapture from pumps during the study from Stanford (2017).**

Two countries reporting to WGEEL incorporated results of modelled mortalities of silver eels. Belgium (Belpaire *et al*., 2018) report 1200 kg silver eel lost in pumps (=17x its hydro losses). The Netherlands Country Report stated 9 to 56% mortality of eels passing pumps.

### 4.1.5 Models to extrapolate mortality estimates to new sites

A major collaborative project in Sweden (programme Krafttag ål,) has produced several reports (in Swedish, hence English summaries given here) on the impact of hydropower on eel and options for mitigation. A number of these present modelling approaches to enable better prediction of areas of interaction between eel and hydropower.

Anderson *et al*. (2017) used computational simulations of fluid dynamics to evaluate the potential for eel migration at a small-scale hydropower plant. A suggestion for a new 'eel-friendly' intake rack was developed and investigated. The general flow in the intake chamber was evaluated and two possible problem areas were identified as the turbine intake and the spillways. In response to flows at spillway gates of 10–85 $m/s^{-1}$, which are too high for eel, alternative designs of spillways were modelled, with a reduction zone to reduce high flow gradients.

Leonardsson (2012) presented a turbine blade strike model for the calculation of turbine passage mortality in silver eel. The study predicted that eel passage losses at 191 hydropower stations in southern Sweden amounted to an average of about 30% per hydropower station. However, discounting regions with the largest rivers and applying an arithmetic mean increased the predicted losses, to between 60 and 70%, as the majority of individual hydropower stations in these rivers are small and expected to cause higher passage losses (over 80–90%). It was calculated that at least 35% of the eels need to pass via spillway or bypasses in order to reach the local biomass escapement objectives set under the EU's Eel Regulation.

Stein *et al*. (2014) conducted studies at five locations in southern Sweden, paying special attention to preferable environmental conditions for migration in statistical modelling. Results indicated that downstream migration triggers can be reliably described using hydrological variables (discharge, precipitation or one of their dynamic derivations), water temperature and lunar phase. Spring and Autumn migrations seemed to be triggered differently. The transferability of models was limited, though transferability among time-series from the same location delivered some reliable results. Success of transferability between locations was limited to sites where eels originated from the same river catchment. Their results clearly show that turbine-induced mortality could be minimized if turbine operation focuses on daytime periods, when water temperature is below 5°C and when the discharge is stable or decreasing.

Jeuthe and Leonardsson (2017) summarized the state of knowledge concerning adaptive hydropower management in connection to eel migration, and evaluated the potential for such mitigating measures to be applied at hydropower facilities in some Swedish eel producing river systems. They considered; adjusted flow, and passage, through the turbines; turbine shutdown (complete or partial) and passage via substantial spill; implementation of temporary intake barriers and passage via moderate spill. An adaptive hydropower management requires a reliable early warning system, but such are limited to application at specific sites. They conclude a complete turbine shutdown is not suitable for one very large river they studied. This river, Göta Älv, drains Sweden's largest lake, is susceptible to flooding and runs through unstable loamy soils sensitive to sudden changes in flow. Besides technical difficulties, there are significant economic losses (less production of energy) for the hydro company to accept. The authors conclude that the development of adaptive hydropower management as an efficient mitigating measure will be a challenge. They recommend trap-and-transport instead, at least as a short-term solution.

There are also French models used to estimate the mortality of eels passing different kinds of hydropower plants (see Baran *et al.*, 2012 and Briand *et al.*, 2015). They will be further developed within the SUDOANG project.

### 4.1.6 Information on Mitigation of Hydropower and pumping impacts

#### 4.1.6.1 Trap and transport

Assuming that the obstacle to downstream migration cannot be removed, the optimal and long-term strategy to increase the survival of downstream migrating silver eels from the primary rearing areas to the sea is to construct mitigating measures aimed at developing guiding devices and facilities that allow as many eels as possible to safely compete downstream migration.

Trap-and-transport (T&T) of silver eels around hazards such as hydropower stations, applied effectively in rivers in many countries, is recognised as being a practical, if short-term solution, when effective diversion of silver eels to bypass channels is not possible. Trap-and-transport programmes substitute one human intervention with another and incur regular running costs whereas bypasses are a more permanent solution. Handling eel should ideally be avoided, and the efficacy of T&T depends on a variety of factors (e.g. river discharge, fishing effort, timing, duration of migration events and total number of silver eels available). Hydropower operators can and do, in several examples, contribute to the T&T programmes, sometimes under terms of water abstraction or power generation licensing.

Trap-and-transport of silver eels from upstream to downstream sites has been implemented in rivers in at least seven countries reporting to the WGEEL. There are also hydropower plants that have been reconstructed to safe downstream migration of silver eels. Emanuelsson *et al.* (2017), considering guiding eel to bypass routes, concluded that the most common way of improving downstream passage conditions at hydropower plants is to use low-sloping racks to guide fish to and through bypasses, to date limited to plants with an intake capacity of <88 $m^3/s$. Reconstruction is not yet common, takes time and resource, and T&T will continue as a measure to decrease eel mortalities due to hydropower exploitation, with the disadvantage that any eels not caught and transported are subject to the mortality rate of the turbines they encounter.

In The Netherlands, since 2011 several (pilot) projects have started at pumping stations to assist the migration of silver eel (programme 'Paling Over De Dijk', PODD). In 2011, 540 kg of silver eel was caught and released again past barriers at four sites. In 2018, about 11 900 kg was caught and released, which is the highest amount since the start of the project.

The mortality rate of silver eel passing the selected barriers in The Netherlands has been assessed at moderate to low (Bierman *et al.*, 2012; Winter *et al.*, 2013a). However, due to eel not always continuing migration, the net amount of eels saved by the trap-and-transport is much lower than the amount caught and released. Barriers for silver eel (rather than yellow) were prioritised in 2013 to improve the selection and efficiency of assisted migration initiatives (Winter *et al.*, 2013). Applying location-specific mortality rates, the net amount of 'saved' eels in 2018 was 3800 kg (Figure 4.1.3). Rates of 50% mortality were used for unknown locations (van de Wolfshaar *et al.*, 2018).

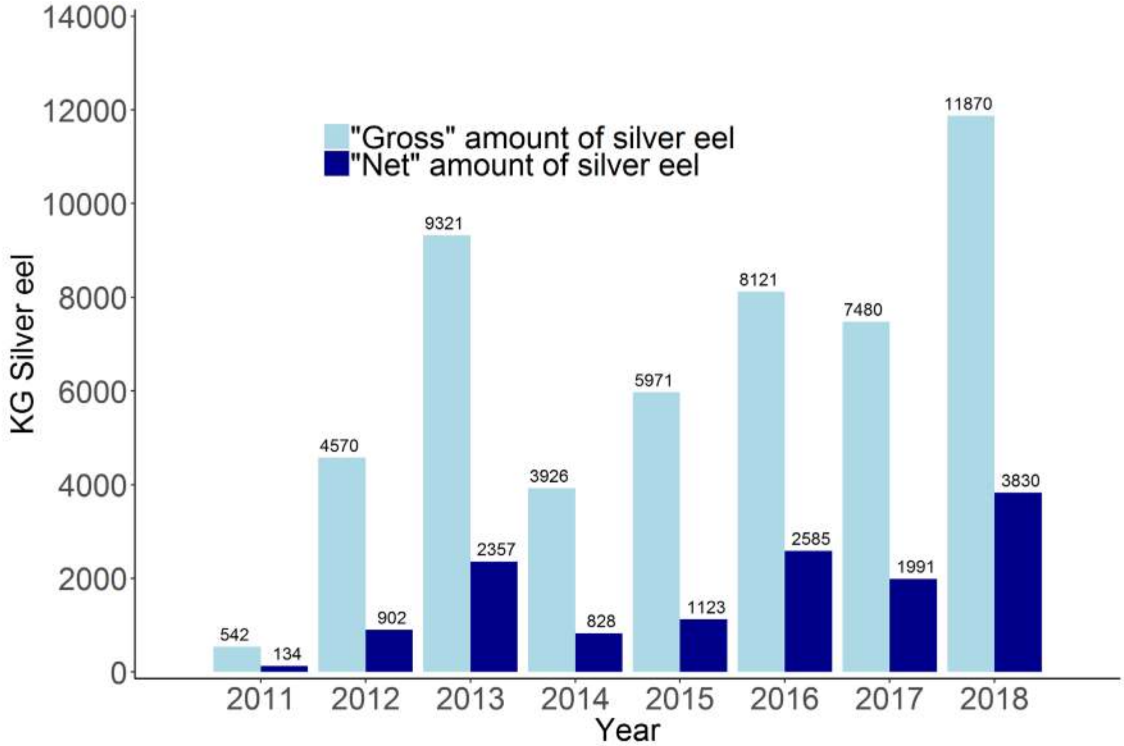


**Figure 4.1.3. Overview of the "gross" and "net" amount of silver eel transported over migration barriers in the Netherlands (2011–2018). "net" accounts for eel not continuing migration.**

### 4.1.6.2 Electric barriers, air bubbles, light and sound

A behavioural distraction utilizing knowledge of what different fish species are attracted to, and repelled by, produces a response from that fish which is then used to divert/deflect the fish species into a bypass around an obstacle such as a hydropower plant (Gosset and Travade, 1999). These behavioural deflectors may consist of bubbles, lights, sounds or electricity (Coutant, 2001) but each deflection method can produce a range of outcomes across the fish species encountered. Often several of these different forms of stimuli are used in combination. A large proportion of the studies that have been published have studied the presence / absence of a species as a result of the operation of the measure, rather than their diversion into, and subsequent passage efficiency, following deflection (Hanel *et al.*, 2019).

Bowen *et al*. (2017) summarized and evaluate studies (primary and grey literature) between 2007 and 2015 for light and its potential for use in deterring and guiding downstream migrating silver eels. It has been known for many decades that migrating silver eels preferred to swim on the dark side of a flowing water, and this behaviour has been used to trial light as a deflection device (Cullen and Mc Carthy, 2000). At the Granö power plant in Mörrumsån (Capacity 60 $m^3/s$) the efficiency was studied for three different behavioural controlled conductors: light barrier, air barrier and electric barrier (Martinell, 1965). When no diversion was present, 37% of the silver eel used the turbine escape route, compared to 84% with a combination of air and light barrier (an illuminated bubble curtain) in place. In an attempt with a stroboscope in the Norrtäljeån river, the corresponding values were 27% bypassing the hydropower turbines without light increasing to 60% with the light activated (Larsson, 1998).

At Hemsjö lower power plant in Mörrumsån (Capacity 20 $m^3/s$), the dissipation efficiency of a combined bubble and sound (bio-acoustic fish fence, BAFF) system was tested (Johlander and Tielman, 1999). BAFF consists of a perforated hose that is placed under the surface and emits sound and compressed air that creates a bubble curtain that fish should avoid passing through (Welton *et al*., 2002).

**Conclusions**

Although there are examples of good deflective effects, the common conclusion is that deflection methods usually have low efficiency at hydropower plants and other types of water intake (Baker, 2008; Gosset and Travade, 1999), since high water velocities can be expected to affect the response that the action produces. In addition, the fish's ability to perceive behavioural controls may decrease or disappear altogether at high flows and / or in turbid waters. These behaviours have been noted in practice when light used as a deflection method often proved ineffective given that the timing of silver eel migration coincides with floodwaters and associated turbid conditions producing diffuse light patterns rather than stronger deflecting beams (Cullen and McCarthy, 2000).

#### 4.1.6.3 Other Technical measures to facilitate downstream movement or bypasses

Examples of physical measures to increase the passage success of silver eels at hydroelectric facilities can be grouped into siphons/pipes and gates/sluices, often in combination with racks. The few studies on siphons and pipes show that these structures allow passage of eels, but at variable or unknown efficiencies (Pedersen *et al*., 2011). Gates and sluices constructed for other purposes are often used to allow passage of downstream moving fish, although often requiring structural modification (Gosset *et al*., 2005; Travade *et al*., 2010; Greenberg *et al*., 2012). In some cases, these bypasses and spill gates have been shown to rehabilitate downstream eel migration (Gosset *et al*., 2005; Travade *et al*., 2010), and in other cases, a low proportion of the eels used the gate (Calles *et al*., 2013).

**Screens**

These are used across a range of hydropower stations globally with varying levels of success dependent upon whether the screening design is based on a collection facility (needing additional removal of caught eel) or leading onto a bypass facility. Different bypass configurations have been tested in France (reviewed by Baran *et al*., 2012). In 2004, a bypass at the water surface was tested with mid-sized eels, small enough to pass through the screen. In 2005, a bottom bypass was tested and, in 2006, a screen with small spaces between the bars was tested with a surface bypass and large eels. In the first two cases, a large percentage (60% and 54% respectively) of the eels went through the turbines. The third configuration, however, limited passages through the turbines to 74%. Observations revealed that when a screen with small spaces was installed, the eels waited just upstream for a flow pulse to pass the obstacle via the spillways.

These observations confirm the effectiveness of screens with small spacing. They also argue in favour of using the surface bypasses for salmon during the downstream-migration period of eels (Baran *et al*., 2012). However, their installation on very large rivers is economically and technically very hard. In France, the use of horizontally or vertically slanted screens was advised, depending on the configuration of the dam. In Germany, the combination of an inclined 10 mm horizontal rake with a shaft-like bypass at the end of the rake is considered as state-of the-art for fish protection at small and intermediate size hydropower installations, which represent about 90% of all existing installations (VDFF, 2018).

**Fish friendly turbines**

These can be installed on low head dams designed to reduce or eliminate the factors injuring the fish, i.e. blade strikes, becoming stuck between the blades and the housing, flow shear. An example is the VLH (Very low head) turbo generator developed by the MJ2 Technologies Company. VLH turbine was tested *in situ* at Frouard on the Moselle River. The percentage of lethal injuries was zero and that of minor, non-lethal injuries within 24 to 48 hours was approximately 2% (Baran *et al*., 2012). However, larger fish friendly turbines are still under development.

**Undershot sluice gate management**

A recent study in a small hydropower station (Egg *et al*., 2017) showed that silver eels approached the opening of an undershot sluice gate and effectively used this corridor during their downstream migration. The opening size of the undershot sluice gate and the resulting higher current velocities in front of this corridor were identified as the most important triggers. Migration occurred primarily at night and peaked with rising discharge. This study suggests that undershot sluice gates can be used as a cost-effective downstream migration pathway and should be operated at night on rising discharge during the peak migration period for eels.

**Turbine closure during flood events or migration peaks**

Peaks in the downstream migration are another possible measure. In this sense, to minimize the economic impact of the closure, it is crucial to be able to predict peaks in migratory activity (Adam, 2000; Bruijs *et al*., 2009). However, this measure seems less effective in hydropower dams located downstream from large river basins than in turbines of small rivers because of the migration dynamics according to the flow, when a longer migration period is expected in large rivers.

Turbine closure has been assessed for eel across a variety of sites in France (Table 4.1.5). However, in France, this measure is recommended only when no other solution (from the range of mitigation measures above) is possible. Moreover, this measure is more effective when the migration period is narrow and the migration peak is well established, and as such the practice is more advanced for small rivers than large rivers where longer migration periods are observed. Ten French rivers with 45 Hydropower schemes (1.5–540 $m^3/s$) were assessed (belonging to four EMUs), including six for which the temporary turbines closures are ongoing, and four in which a permanent solution was found (upgraded to standards or erase). Temporary turbine closure was considered a definitive measure in five of these rivers (see Table 4.1.5).

**Table 4.1.5. Summary of French trials and assessments into temporary closure of turbines during key silver eel migration periods.**

| EMU | River | Definitive solution* | Period of closure | Number of hydropower-plant concerned (Max. turbinated flow) |
|---|---|---|---|---|
| Seine-Normandie (SEN) | Seine | yes | Will start in 2019<br>28 nights/year | 3 HP (248 m³/s, 192 m³/s, and 210 m³/s) |
| | Orne | no | 1 Oct–15 Nov<br>2011–2012<br>2011–onward | <br>5 HP (5 – 43 m³/s)<br>1 HP (3.5 m³/s) |
| | Vire | no | 2010–2014 (different period for each HP) | 7 HP (1.5–10 m³/s) |
| | Sienne | no | 2010–2013 | 2 HP (7-8 m3/s) |
| | Risle | no | 2012<br>2012–2013 | 4 HP (7.5-9 m³/s)<br>2 HP (6.9-12.6 m³/s) |
| | Bresle | no | 2018–onward | 1 HP (3 m³/s) |
| Loire-Côtiers vendéens-Sèvre niortaise (LCVS) | Mayenne | no | 2008–2009: 15 nights<br>2009–2010: 4 nights<br>2010–2011: 16 nights<br>With modalities (only if flow is >10 m³/s over 24h, max. 4 days closure, re-open if flow >70 m³/s) | 18 HP (5.5–24 m³/s) |
| Garonne-Dordogne-Charente-Seudre-Leyre (GDC) | Dordogne | yes | Since 2009, onward<br>-Sept.–Feb. period<br>-121 to 180 nights/year authorized<br>-done: 50 to 121 nights/y<br>6pm–6am with modalities | 1 HP (420 m³/s)<br>(success of the shutdown: escapement at the dam increased from 29 to 75%). |
| | Garonne | yes | Ongoing project: 21 nights (partial : 30% of the flow turbinated) | 1 HP (540 m³/s) |
| Rhin-Meuse (RMS) | Semoy (Meuse tributary) | no | Dec 2018–Jan 2019<br>Oct 2019–Jan 2020 | 1 HP (m³/s) |

When temporary closure of turbines is seen as a future longer term solution, it is feasible that this mitigation measure is trialled and used over the short term. Such an approach would provide the data required to model (and ultimately predict) silver eel downstream migration events. These data would be key in order to target the migration periods and maximize the efficiency of the closures. In addition, such information would indicate the required number of nights of closure and associated energy and financial losses. The French studies (described above) concluded there is a requirement for complex and costly monitoring to develop the model and evaluate its effectiveness (over several years of monitoring by telemetry and/or experimental fishing).

**Improvements in the effectiveness of physical mitigation measures**

In many cases, poor passage efficiency has been attributed to features of poor design of passes, racks and gates covering turbines, as many of these structures were not designed to assist fish bypass (particularly eel) (Coutant, 2001; Hanel *et al*., 2019). Another common problem is a lack of specific expertise as to the biology and migratory behaviour of the eel.

Dutch studies (Buysse *et al*., 2015; Bolland *et al*., 2019) have shown that during several observed downstream migration runs through hydropower plants, catches of downstream migrating eel at the installed fish pass were always low or nil, i.e. the pool and orifice fish pass did not facilitate downstream eel migration. Avoidance behaviour for species being wary of traps has been noted. Further research should reveal whether optimised fish pass design could increase downstream eel passage efficiency. For instance, it is generally assumed that eels are bottom dwellers and as such their migration behaviour may differ to that of pelagic fishes for which most fish passes were originally designed (Haro *et al*., 2000). Better insights into eel behaviour at pumping stations, eel friendliness of pump types, screening and safe upstream and downstream bypass solutions are required, while sharing and compiling best practice knowledge on a regional, national and international scale are necessary. Specific bypasses for eels at hydropower stations must be developed, paying attention to the particular behaviour of migrating silver eels. Expert knowledge on migrating fish (eel) behaviour is essential during the planning, designing and building of fish passes, especially at hydro stations.

To achieve escapement targets set in the Eel Management Plans, fish-friendly pump designs and effective hydro/pumping station bypass solutions are needed (Buysse *et al*., 2015). Some of the evidence presented may be helpful to develop effective remediation measures, such as structural adaptations or operational changes, in order to maximise escapement of eel at pumping stations (Bolland *et al*., 2019).

Eel mortality was studied in a Belgian lowland canal after downstream passage through a large and a small 'de Wit-adapted' Archimedes screw pump over a 12-month period. The hypothesis tested was the minimisation of fish injuries with the de Wit adaptation. Simultaneously, downstream migration through a fishway alongside the pumping station was monitored. Nets were mounted on the outflow of the pumps, and a cage was placed in the fishway. Based on the condition of the fish and injuries sustained, the maximum mortality rates ranged from 19 ± 4% for the large de Wit Archimedes screw pump to 14 ± 8% for the small de Wit Archimedes screw pump. The screw adaptations did not substantially minimise grinding injuries and overall mortality, and the fishway did not mitigate downstream eel migration.

Stanford (2017) assessed five different types of pump in use within the United Kingdom, revealing some of the ways in which these pumps affect entrained European eels. In particular, both the rate of mortality and rate of injury appear to be correlated with pump size and operational speed. Switching to the use of slower and larger pumps could reduce the impacts of entrainment. Furthermore, the use of 'fish-friendly' pumps holds promise for reducing entrainment impacts upon European eels. However, further research is required to better understand the impacts these types of pump can have and whether their efficacy is affected by retro-fitting them into existing pumping stations. It is also worth remembering that even low impact pumps can still have an effect upon the likelihood that an eel will successfully complete its migration and spawn. Therefore, it is important to decide at what level the impact to an eel can be considered acceptable and this will help to inform what mitigation measures should be put in place.

Given that the pump was retrofitted into the existing pumping station, as would be the case if 'fish-friendly' pumps were to be installed at other existing pumping stations as a mitigation measure, further investigation of the site or similar sites is necessary to elucidate whether retrofitting 'fish-friendly' pumps reduces their effectiveness. Furthermore, there is a general need for the independent assessment of 'fish-friendly' pumps in the field as currently the majority of data are the result of lab-based tests carried out by the pump manufacturers (Stanford, 2017).

As a measure to reduce potential damage to fishes, the pumps should run on low revolutions per minute (rpm) as often as possible. This lowers the risk of collision with machine parts and hence mortality rate, as well as the suction effects occurring at high rpm. After long periods in an inactive state, pumps should generally run on low rpm before changing to higher rates (Bierschenk *et al.*, 2018).

Other management options, such as day or night operation, considering the diel behaviour in fish, may further increase the fish friendliness of pumps (Bierschenk *et al.*, 2018).

### 4.1.7 Gaps in Knowledge

As described above, turbine/pumping station mortality assessments often feature the use of hydro-acoustic telemetry to monitor the passage of silver eels through such facilities. However, few studies and reviews collated for this report made any reference to the need to "ground truth" these telemetric assessments (and thus their associated calculated outputs) by the recapture of tagged eels. Recent data have provided two strong arguments for the inclusion of ground truthing in such methods:

- Studies have demonstrated (Havn *et al.*, 2017; Økland *et al.*, 2019) that acoustically tagged silver eels, killed during passage, continue downstream with functioning transmitters emitting their telemetry signal in a similar pattern as a migrating live fish and are thus recorded as such.
- Once inside a turbine/pumping station, 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 (Cada, 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 show 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.

Further data are also available from the industry sources which might, in combination with fisheries data, assist in local and stock-wide estimation of impact and direct targeted mitigation. Hydropower industry sector reports (e.g. Agora Energiewende and Sandbag, 2018) generally focus on industry interests and may not mention fisheries mitigation, but are sources of data such as generation capacity and location. Further work could explore the possibility of a stock-wide parallel estimate of the impact of eel based on hydropower location, capacity and technical details published by the industry, combined with fisheries data compiled from WGEEL or WFD-compliance sources.

To compensate for an upstream impassability of river obstacles, several European countries undertake stocking programs of juvenile eels in upstream regions. In Ireland and Sweden, eels are transported upstream from dams (Dekker *et al.*, 2018) as part of obligations placed upon the power companies. The transportation of eels upstream from river obstacles also corresponds to a large part of the stock in Germany where stocking is one of the main measures in eel management.

There are complex and interlinked problems for eel management, in the relationship between stocking activity, habitat, fisheries and hydropower. There is no doubt that there are large areas of suitable eel habitat upstream of hydropower and in pumped lowland water systems in many parts of the freshwater range of eel. Some are completely inaccessible to upstream migration of eel, some partially so. In some, eel are either stocked from other sources, or given assisted upstream migration within the system through trap-and-transport to utilise the habitat. Some of these activities also support fisheries upstream of hydropower. Considerations as to where and when to stock eel or assist migration for these activities are complex and sometimes conflicting. On the one hand, stocking upstream of hydropower or into fisheries can incur a net loss of eel as opposed to not transferring the eel or stocking the eel elsewhere. On the other hand, not taking action to replace or transfer eel upstream potentially under-utilises very large areas of eel producing habitat – leading to *de facto* write off and acceptance that former eel distributions will never be fully restored. In this context, Net benefit calculations are clearly critical to making choices when translocating eel. There is also a third strand to the issue in that eel have a role in ecological systems as both prey and predator (Hastie *et al.*, 2008; Carss and Marquiis, 1997) and have the potential to dominate natural fish populations in some aquatic habitats, and allowing the loss of eel risks losing much more in terms of wider ecological diversity.

The Iberian Peninsula presents a striking example of areas that have been most affected by large dam construction since the 1950s: Clavero and Hermoso (2015) have estimated that eels have lost more than 80% of their habitat in this region. A map (Figure 4.1.4) of the current and former eel occupied habitat in the Iberian Peninsula shows the level of change due to dam constructions in the area and clearly demonstrates the level of the problem of habitat loss.

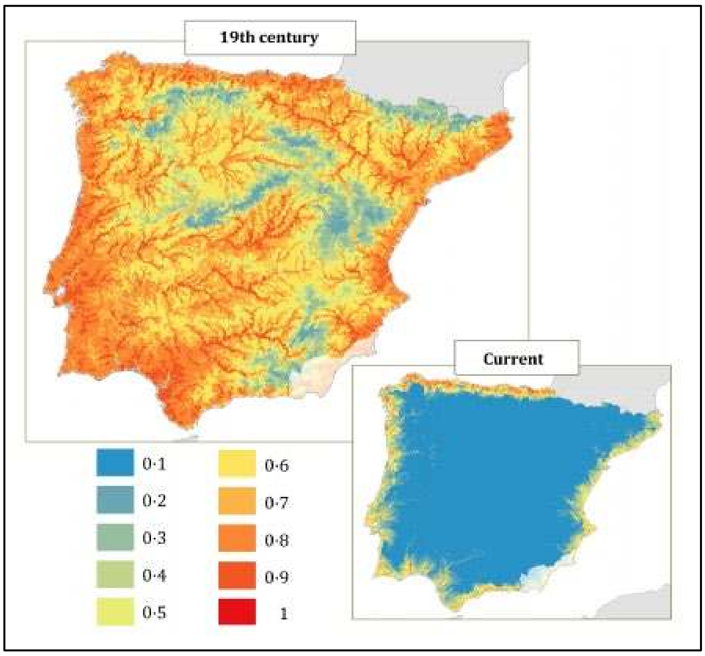


**Figure 4.1.4. Probability of occurrence of the eel in the Iberian Peninsula in the 19th century and the present. Source: Clavero and Hermoso (2015).**

### 4.1.8 Recommendations - Further opportunities for improving measures of hydropower impact on eel and work to carry forward to WGEEL 2020

WGEEL 2019 has considered the impact of hydropower and pumps in the context of reviewing direct mortality of entrained eel and those attempting to migrate past these facilities, and documented methods to mitigate impacts. This exercise has not taken into account the wider issue of habitat loss and related issues due to the hydropower and pumps and particularly the barriers to migration in which they are situated, which is proposed as the theme for a quantitative review by WGEEL in 2020.

The examination of hydropower presented here is a first attempt and identifies options for further and better quantitative estimation of direct loss of eel in hydropower and pumping facilities. In order to achieve this, more detailed and better data will be required on:

- Enumeration, location (mapping), type, water use and capacity of hydropower and pumping facility;
- Improved models enabling extrapolation from locally measured impact to system-, country- or stock-wide estimations of loss;
- Eel population data expressed as geographical information on stock density on a parallel scale to the above hydropower distribution information.

Compiling this information will require a major data gathering and collation exercise. In this context, it is worth noting that several EU-funded projects are underway which aim to compile potentially relevant datasets in parts of the freshwater range of eel, including:

The AMBER project. Adaptive management of Barriers in European Rivers, (compiling barrier data), led by University of Swansea, UK) https://amber.international.

The FIThydro (Horizon 2020, Lead Technical University of Munich, addressing sustainable Hydropower (https://www.fithydro.eu).

The SUDOANG project, (https://sudoang.eu/en/project) led by AZTI, Spain which will help to restore the European eel population and its habitat in the SUDOE area (France, Spain and Portugal), by providing common operating methods. SUDOANG aims to estimate the impact of the turbines on silver eel of the SUDOE area. Currently partners are collecting data regarding obstacles and HPP characteristics. SUDOANG will then establish or consolidate the existing models for estimating the mortality of eels that descend through obstacles with turbines. Finally, partners will calculate mortality from these models, using the silver eel biomass, which will be estimated in SUDOANG through the implementation of the EDA model in the three countries. The results will be displayed on an interactive map that will be available in early 2021.

## 4.2 Risks of data loss due to the implementation of new fishery regulations

Fishery-based data are widely used to assess fish populations. For the European eel, fishery-based data are for example used to assess yearly recruitment (ICES, 2018b), and to estimate current silver eel escapement, $B_{current}$, in some countries (ICES, 2018c). Indeed, fishery-based data such as commercial catch per unit of effort (CPUE) can be used to estimate trends in abundance (Maunder *et al.*, 2006). Amongst the 47 recruitment time-series used by the WGEEL to estimate

'Elsewhere Europe' and 'North Sea' recruitment indices, 17 time-series rely on commercial fishery data, out of which 13 are from Spain, France and Portugal. However, the use of commercial catch time-series generally requires that fishing efficiency is more or less constant through time, and biases in the assessment may arise if this condition is not fulfilled (Rose and Kulka, 1999; Rahikainen and Kuikka, 2002; Kleiber and Maunder, 2008). Implementation of fishery regulations acting on catch, licence or fishing effort, can modify fishing efficiency and consequently bias fishery-based indicators. For example, the implementation of a Total Allowable Catch (TAC) quota system in France in the context of the Eel Management Plan (Ministère de l'Ecologie, de l'Energie, du Developpement durable et de l'Aménagement du Territoire *et al.*, 2010) lead to profound modifications of fishing strategy: fishers restricted their fishing to the most productive nights causing a modification of the relationship between catch and effort. Consequently, none of the French glass eel fishery-based indices have been updated since then. In view of this, and in the context of possible additional fishery regulations, it is worthwhile making an inventory of fishery-based data used to assess European eel populations. This would allow us to explore what the effects of new fishery regulations on those datasets might be, and to check whether it is possible to correct potential biases. To start with, we present a brief summary of the use of fishery-based data, in particular commercial catch and commercial CPUE, as well as the underlying assumptions and the risk of biases.

## 4.2.1 Fishery-based data as abundance indices: assumptions and biases

### 4.2.1.1 CPUE and fishing effort

In stock assessments, an abundance index is a time-series proportional to the considered fish stock, and as such it does not inform on the exact number of fish in a stock, but provides information on variation of the abundance over time. For example, a two-fold decrease of the abundance index during a period should normally indicate a two-fold decrease of the stock abundance during that period. Obviously, this remains true as long as the proportionality factor remains constant.

In some situations, commercial catch fisheries (denoted C(y)) divided by the fishing effort (E(y)), denoted CPUE(y), can be proportional to fish abundance (N(y)):

$$\frac{C(y)}{E(y)} = CPUE(y) = q \cdot N(y) \qquad \text{(Kleiber and Maunder, 2008)}$$

where q is the coefficient factor, sometimes called catchability. In view of this, CPUE are often used as abundance indices.

Fishing effort is a measure of the amount of activity involved in exploiting a stock (Cunningham and Whitmarsh, 1980). It is important to make a distinction between two different types of fishing effort:

- Nominal fishing effort: a straightforward measurable and manageable quantification of resources devoted to fishing (e.g. number of boats, number of days, horsepower of vessels) (Gulland, 1956; McCluskey and Lewison, 2008).
- Effective fishing effort: a measure of the resulting pressure exerted on the stock by the fishery, and directly related to fishing mortality or catch rate (Cunningham and Whitmarsh, 1980; Stocker and Fournier, 1984; Biseau, 1998). Effective fishing effort is difficult to measure and should account for variation in fishing efficiency through time. Some methods have been proposed to convert Nominal fishing effort into Effective fishing effort to account for changes in fishing efficiency due to technical progress, gear modification or other sources of variation (Robins *et al.*, 1998; Rahikainen and Kuikka, 2002; Mahévas *et al.*, 2004; Marchal *et al.*, 2006).

To be an abundance index, the catchability coefficient should remain constant over time. This implies that CPUE is either directly computed using Effective fishing effort, or computed with Nominal fishing effort assuming that fishing efficiency (catchability) has remained constant over time.

#### 4.2.1.2 Source of biases in CPUE

Several factors can lead to modifications of fishing efficiency/catchability (Gascuel, 1995):

- Biological factors: fish availability can change seasonally (in particular during migration periods) leading to higher catchability in some periods. Modifications in spatial distribution can also lead to modifications of catchability. The cod stock in Newfoundland and Labrador is an illustrative example: when the stock started to decline, the remaining cod tended to aggregate in a few patches, generating high fish density. Fishermen targeted those patches meaning that their catch rates decreased more slowly than abundance (Rose and Kulka, 1999).
- Human factors, i.e. related to the human component of fishing efficiency: we mentioned earlier that gear modifications, improved skills of the crew, and increase in boat horsepower are likely to improve fishing efficiency over time. In the context of declining populations, technical progress over time may compensate for the decrease of abundance so that CPUE remains more stable than abundance, a phenomenon called hyperstability (Hilborn and Walters, 1992; Erisman *et al.*, 2011).

It is worthwhile noticing that CPUE can be computed at the individual fisher scale, aggregated on a panel of fishermen, or at the whole fishery scale. While aggregating fishermen reduces the variability of fishing operations, working at the fisherman scale or on a smaller panel of fishermen makes it easier to monitor their activity (spatial and seasonal allocation of effort, technical modifications of ships, etc.) and so makes it easier to depict and quantify changes in fishing efficiency.

Trends in fishing efficiency that hinder the linear relationship between CPUE and abundance are common in all fish stock assessments. In addition to technical progress, several factors may alter the linear relationship between fishing effort and abundance for eels, including:

- Because of the migratory behaviour of the species, the eel fishery is highly seasonal (ICES, 2004). Any modifications in fishing seasonality might lead to modifications of the average fishing efficiency. At an even finer temporal scale, we mentioned that after the implementation of the quota system, French fishers restricted their fishing to the most productive nights leading to an increase in their average efficiency.
- The equation that relates CPUE to abundance indirectly assumes that all units of fishing effort are independent: i.e. the catch made by a unit of fishing effort is not affected by another unit of fishing effort. Is this always true? Collaboration among units of fishing efforts, i.e. collaboration among fishermen, can induce bias: information exchange among fishermen can lead to higher efficiency so that two units of effort have more impact than the sum of two single units of effort. This can lead to catches increasing faster and faster when fishing effort increases, and consequently to hyperstability. Another situation is the competition among units of fishing effort: in the context of intensively harvested fish stocks, competition for fishing grounds and competition to harvest the remaining fish can lead to a decrease in individual fishing efficiency. In this situation, CPUE are not proportional to abundance anymore and therefore CPUE is not a good indicator of abundance. This occurs for eel in many river basins. Because of the high economic value of glass eels, high exploitation rates are common in many river basins and total catch might better reflect glass eel recruitment than CPUE in such instances (Gascuel *et al.*, 1995; Briand *et al.*, 2003).

- Another important phenomenon occurs when fishing effort decreases due to the implementation of new regulations or to the decrease of population abundance. For example, licence buybacks in Quebec, where some fishers ceased their fishery (Cairns *et al*., 2014; Doyon, 2015). In France, the number of commercial fishing licences for glass eel has decreased by 57% since the implementation of the Eel Management Plan (Anon., 2018), and in Sweden, the number of eel fishery licences (note, not glass eel fishery) have decreased by 49% in the last ten years (cf. Swedish Country Report 2019). However, very often the first fishers to leave the fishery are the least efficient fishermen; the ones having low catches and underusing their licences (Holland *et al*., 1999; Martell *et al*., 2009). In such a context, the remaining fishers tend to have a higher efficiency on average, leading to a modification of the average catchability. This has likely occurred in France and probably in other European countries targeting glass eels. Since fishing efficiency increases, this process can lead to hyperstability with CPUE decreasing at a slower rate than abundance.

We mentioned that commercial catches can be used as an abundance index, especially in the context of high exploitation rate. However, commercial catches are biased abundance indices as soon as the exploitation rate varies, and fishery regulations generally precisely aim at decreasing fishing effort and exploitation rate. Where fishing is restricted by quotas restricting total or individual catch, fishing effort can continue at variable levels up to the point when the quota is met. While eels are abundant enough for fishermen to catch the quota there can be a tendency for dataseries recording catch to appear stable, when in reality the effort required to meet the quota varies but remains unrecorded. Fishery output may then fall when stocks decline below a critical level and quotas cannot be met. Rosell *et al*. (2005) describe the Lough Neagh eel fishery in Northern Ireland, UK where CPUE is known to vary, but fishermen simply vary their effort in order to meet individual quotas, potentially masking variable CPUE and levels of stocks.

Those potential sources of bias hinder our ability to correctly interpret fishery-based data, and it might be difficult to validate the origin of inconsistencies between CPUE and total catches.

### 4.2.2 The use of fishery-based data to assess European eel

#### 4.2.2.1 Glass-eel recruitment index

As mentioned earlier, many fishery-based recruitment indices are used by the WGEEL to derive the 'Elsewhere Europe' and 'North-Sea' indices (Figure 4.2.1).

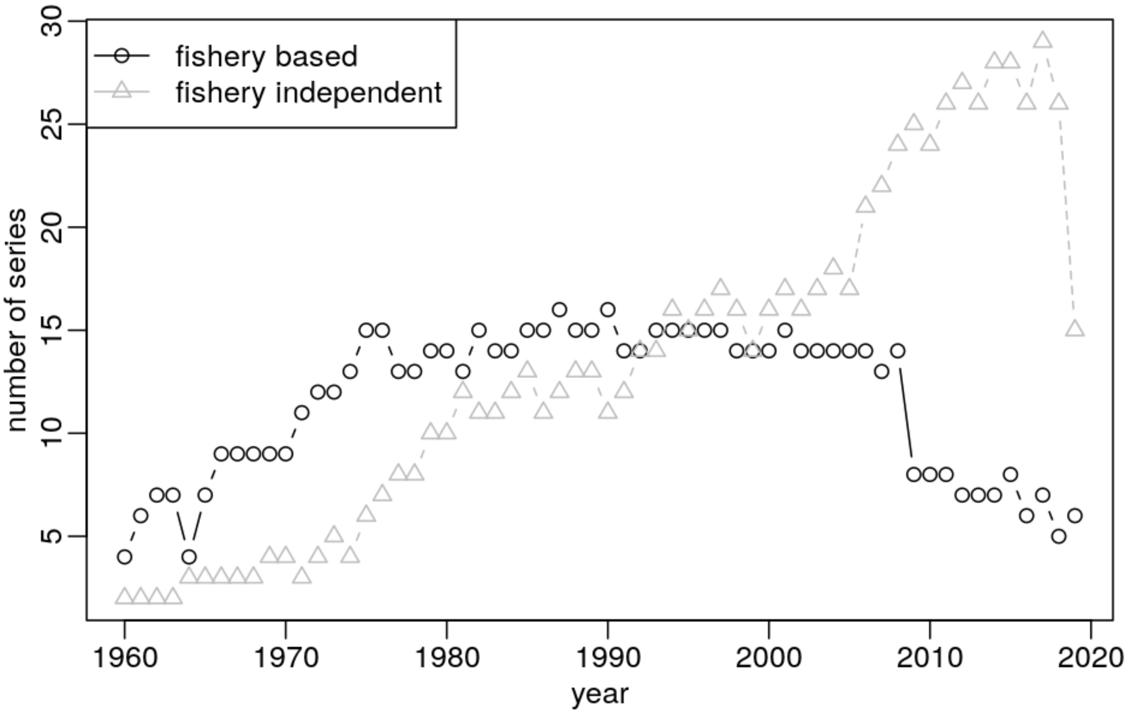


**Figure 4.2.1. Number of available fishery-based (black circles) and fishery-independent (grey triangles) recruitment indices values from 1960 to 2019 used by the WGEEL this year in the GLM analysis.**

Until the early 1990s, fishery-based data accounted for more than half of the available dataseries. This number decreased to about 45% of the dataseries in the 1990s and 2000s. The proportion dropped even further to about 20% since the 2010s due to the end of French dataseries after the implementation of the quota system in this country. On the contrary, the numbers of fishery-independent dataseries have increased during this period, in particular since the 2000s. Many of those series are however shorter, only ten of the 30 series starts before 1980 (around the time of the collapse of recruitment) and eleven start after 2000.

In addition to the temporal coverage, the spatial coverage is not homogeneous. Unsurprisingly, fishery-based time-series are available in countries with important glass eel fisheries, mostly in southwestern Europe (Figure 4.2.2). In France, only one fishery-independent time-series of recruitment is available for the Atlantic Coast (a scientific survey in the Gironde estuary), and all the fishery-based time-series have ceased since the Eel Management Plan in 2010. No fishery-independent time-series are available in Spain or Portugal, while southwestern Europe is thought to receive the largest proportion of the overall recruitment (Dekker, 2000a; Bornarel *et al.*, 2018). In light of this, the implementation of new fishery-independent series in this area, as proposed in the SUDOANG project (Interreg Sudoe), is of major importance.

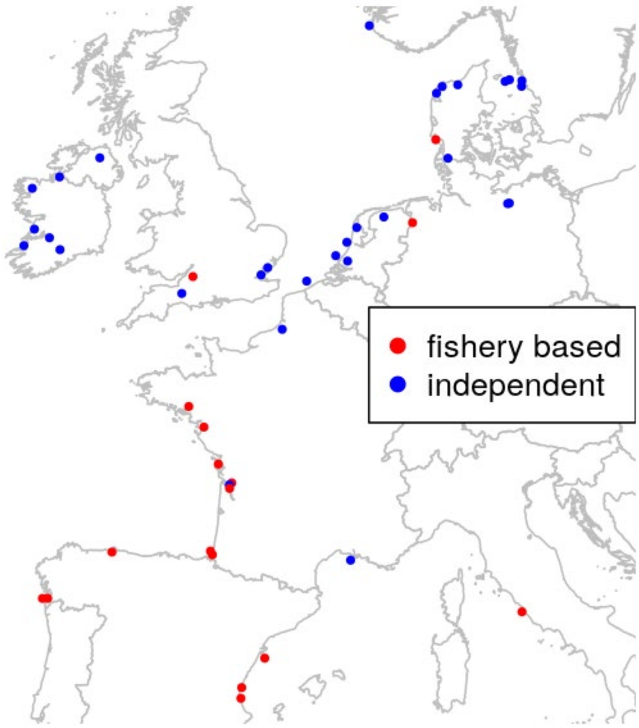


**Figure 4.2.2. Location of glass-eel time-series of recruitment used by the WGEEL (red circles: fishery based, blue circles: fishery-independent)**

#### 4.2.2.2 Effects on estimation of escapement biomass

Commercial catches are also used to estimate $B_{best}$ and $B_{current}$, which are silver eel escapement biomass indicators requested by the Eel Regulation (Council Regulation (EC) No 1100/2007). An overview of the use of silver eel commercial catch data in those estimates has been carried out by collecting information included in the 2018 ICES Data call "ANNEX 5 - Overview" file for each country and single EMU. A description of the methods is also available in the WKEMP report (ICES, 2018a).

Considering all EMUs (n=86), in most cases (68%) estimates of $B_{current}$ are based on fishery data, while the percentage of EMUs where $B_{best}$ calculations are fishery-based is 25%. For Slovenia, Hungary, Latvia, Czechia, Finland and one EMU in Sweden, there is no available information (7%) (Table 4.2.1). Fishery data are not used at all to estimate $B_{current}$ and $B_{best}$ in Belgium, Ireland, some EMUs in Spain, United Kingdom and Estonia, for a total of 17 EMUs. For most EMUs (41), $B_{best}$ estimates are obtained from fishery-independent data (demographic model, literature, electrofishing data, etc.), while fishery data are used to estimate $B_{current}$ by subtracting catches from $B_{best}$. The situation is the opposite in three EMUs (one in each country: Norway, Portugal and Spain), where $B_{best}$ is estimated by adding catches to $B_{current}$, and $B_{current}$ is estimated from fishery-independent data. Finally, in 19 EMUs estimation of both $B_{current}$ and $B_{best}$ are carried out from fishery-based data.

**Table 4.2.1. Use of fishery-based data to estimate biomass stock indicators ($B_{best}$ and $B_{current}$). Numbers in parentheses show the number of EMPs represented by that entry – otherwise the number is 1. Y = included, N = not included, na = not applicable.**

| Country | EMU | $B_{current}$ | $B_{best}$ |
|---|---|---|---|
| Belgium | BE_Meuse | N | N |
| Belgium | BE_Sche | N | N |
| Czechia | CZ_all | na | na |
| Denmark | DK_Inla | Y | Y |
| Estonia | EE_Narv | Y | Y |
| Estonia | EE_West | N | N |
| Finland | FN_all (1) | na | na |
| France | EMU_eda | Y | Y |
| France | EMU_tous | Y | Y |
| Germany | EMU_all (9) | Y | N |
| Great Britain | GB_Scot | na | N |
| Great Britain | GB_Angl | Y | N |
| Great Britain | GB_Dee | Y | N |
| Great Britain | GB_NorE | na | N |
| Great Britain | GB_Neag | Y | Y |
| Great Britain | GB_Humb | Y | N |
| Great Britain | GB_Nort | Y | N |
| Great Britain | GB_NorW | Y | N |
| Great Britain | GB_Seve | Y | N |
| Great Britain | GB_Solw | Y | N |
| Great Britain | GB_SouE | Y | N |
| Great Britain | GB_SouW | Y | N |
| Great Britain | GB_Tham | Y | N |
| Great Britain | GB_Wale | Y | N |
| Greece | GR_NorW | Y | Y |
| Greece | GR_WePe | Y | Y |

| Country | EMU | $B_{current}$ | $B_{best}$ |
|---|---|---|---|
| Greece | GR_EaMT | Y | Y |
| Hungary | HU_all (1) | na | na |
| Ireland | IE_all (6) | N | N |
| Italy | IT_all (20) | Y | Y |
| Latvia | LV_all (1) | na | na |
| Lithuania | LT_all (1) | Y | Y |
| Netherlands | NL_all (1) | Y | Y |
| Norway | NO_all (1) | N | Y |
| Poland | PL_all (2) | Y | Y |
| Portugal | PT_Minho | Y | Y |
| Portugal | PT_Port | N | Y |
| Slovenia | SL_all (1) | na | na |
| Spain | Es_Basq | N | N |
| Spain | ES_Nava | N | N |
| Spain | ES_Cant | N | N |
| Spain | ES_Astu | N | N |
| Spain | Es_Gali | Y | Y |
| Spain | ES_Anda | N | Y |
| Spain | ES_Murc | Y | N |
| Spain | Es_Cast | N | N |
| Spain | ES_Vale | N | N |
| Spain | Es_Cata | N | N |
| Spain | ES_Bale | Y | Y |
| Spain | ES_Inner | N | N |
| Sweden | SE_Inla | Y | Y |

### 4.2.3 What would be the consequences of losing some of the series?

#### 4.2.3.1 Sensitivity of glass eel recruitment indices to the loss of fishery-based series

To build recruitment indices, WGEEL fits a GLM to recruitment dataseries, both fishery-based and fishery-independent, from all over Europe. To assess how the disappearance of fishery-based series might affect the recruitment index, we ran the GLM with three different datasets (Table 4.2.2):

- full: the dataset used by WGEEL composed of 47 recruitment time-series;
- nofishery: the same dataset from which all fishery-based time-series were removed;
- nofishery2010: the full dataset without any fishery-based indices after 2010 (which corresponds to the implementation of the eel regulation).

**Table 4.2.2. Number of fishery-based and fishery-independent time-series per zone available in each dataset.**

| | 'Elsewhere Europe' | | 'North Sea' | |
|---|---|---|---|---|
| dataset | Fishery-based | Fishery-independent | Fishery-based | Fishery-independent |
| full | 15 | 11 | 2 | 19 |
| nofishery | 0 | 11 | 0 | 19 |
| nofishery2010 | 15 | 11 | 2 | 19 |

The explained deviance on recruitment by the different variables and the corresponding p values do not change much when the GLM is fitted with the full, nofishery and nofishery2010 datasets (Table 4.2.3): the area:year interaction explains about 60% of the total deviance whatever the dataset used.

**Table 4.2.3. Deviance table of the GLM to explain recruitment fitted to the three different datasets.**

| Datasets | variable | Explained deviance (%) | p-value |
|---|---|---|---|
| full | site | 0.58 | 0.99 |
| | area:year | 60.7 | <2e-16*** |
| nofishery | site | 0.54 | 0.99 |
| | area:year | 60.0 | <2e-16*** |
| nofishery2010 | site | 0.77 | 0.99 |
| | area:year | 60.1 | <2e-16*** |

Removing fishery-based time-series does not change estimated temporal trends on the recruitment indices (Figure 4.2.3). Full datasets provide a smoother estimate than the nofishery dataset. Two reasons may explain this. First, some fishery-independent time-series are based on scientific surveys with a limited sampling effort compared to commercial fisheries. As such, they can display a greater variability (but on the other hand, they do not suffer from the biases associated with fishery-based indices). More importantly, adding fishery-based indices increases the number of time-series, which can smooth the variability associated with each series, especially in the 'Elsewhere Europe' area where the number of fishery-independent time-series is limited. For the 'North Sea' area, recruitment estimates are slightly higher when removing fishery-based indices since the 1980s (the red line is frequently below blue line; Figure 4.2.3 'North Sea' panel). These differences can be observed in recent years (Table 4.2.4): using all dataseries provides higher recruitment estimates than datasets with only fishery-independent time-series. More importantly, ignoring fishery-based dataseries leads to higher variability in the recruitment indices (6.4, 11.3 and 4.1 in years 2017, 2018 and 2019 respectively). As such, losing fishery-based time-series may lead to higher interannual variability and noise in our assessment caused by the limited number of fishery-independent time-series. Implementing new fishery-independent time-series would mitigate the potential loss of fishery-based time-series and would limit the risk of biases often associated with fishery-based time-series. This is especially important in the 'Elsewhere Europe' series, where proportionally fewer fishery-independent series are found.

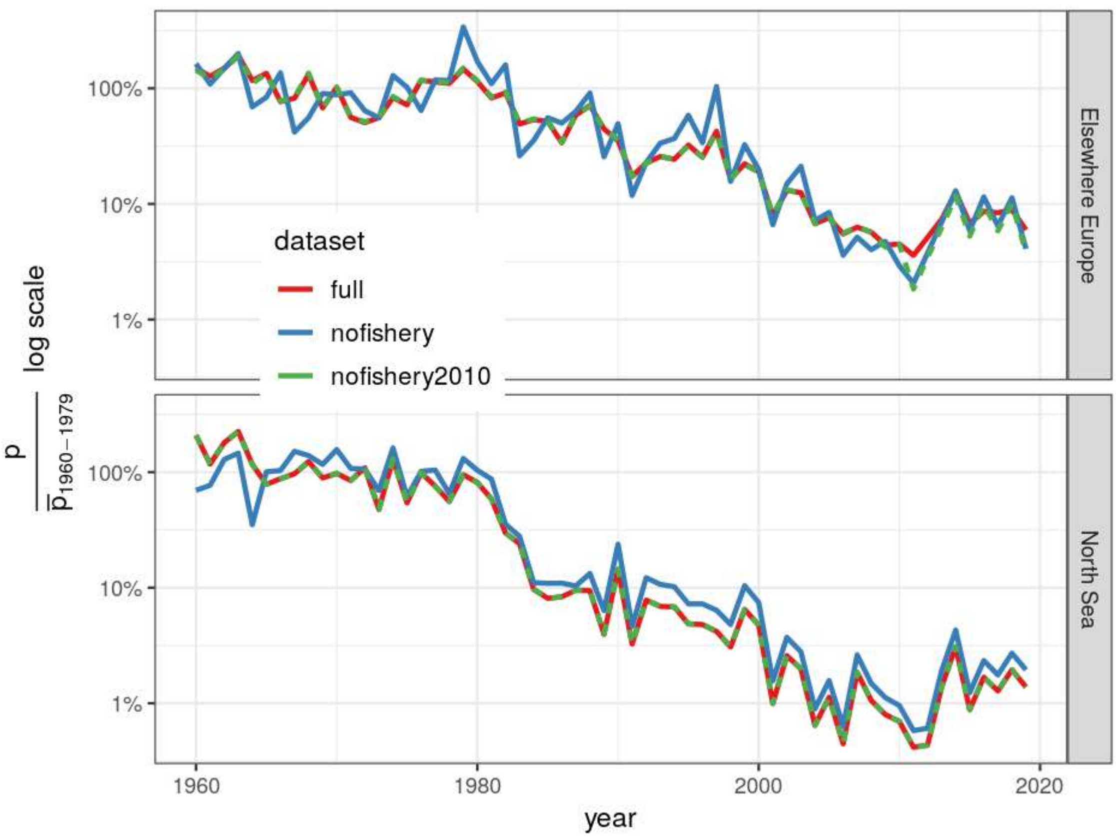


**Figure 4.2.3. Recruitment index: estimated (GLM) glass eel recruitment for the continental 'North Sea' and 'Elsewhere Europe' series following WGEEL usual procedure and using the three different datasets.**

**Table 4.2.4. GLM glass eel ~ year: area + site geometric means of predicted values for 46 dataseries on glass eel recruitment. Values are given as a percentage of the 1960–1979 period.**

| area | dataset | 2017 | 2018 | 2019 |
|---|---|---|---|---|
| 'Elsewhere Europe' | full | 8.4 | 8.9 | 6.0 |
| | nofishery | 6.4 | 11.3 | 4.1 |
| | nofishery2010 | 5.9 | 10.1 | 3.8 |
| 'North Sea' | full | 1.3 | 1.9 | 1.4 |
| | nofishery | 1.8 | 2.7 | 1.9 |
| | nofishery2010 | 1.3 | 1.9 | 1.4 |

### 4.2.3.2 Consequences of the loss of fishery-based series for the estimation of $B_{best}$ and $B_{current}$

The consequences depend on how fishery-based data are used (see previous section) and on the type of fishery regulations. Of course, countries that do not have or use fishery-based data to assess $B_{best}$ and $B_{current}$ would not be affected by new fishery regulations. For other countries, the assessment is frequently based primarily on fishery-independent data (electrofishing data, scientific mark–recapture) to estimate standing biomass from which commercial catches are added or subtracted to estimate $B_{best}$ or $B_{current}$, respectively. In such situations, new fishery regulations should not be problematic for these particular estimates since those methods make no assumptions regarding fishing efficiency. Problems may arise for countries using commercial catches and estimates of corresponding catch rates (for example based on mark-recapture experiments) to estimate $B_{current}$ and $B_{best}$. In such instances, new fishery regulations require that the fishery catch rate estimate is updated in order to estimate $B_{current}$ and $B_{best}$. A total fishery closure might have even more drastic impacts on the assessment, for example on the Swedish West Coast, where such estimations are no longer possible due to a fishery closure in 2012.

## 4.2.4 Do all fishery regulations necessarily result in the loss of fishery-based time-series?

### 4.2.4.1 The influence of fishery seasonality on the efficiency of fishery regulations and consequences for fishery-based time-series

#### Glass-eel fishery

In 2004, ICES (2004) highlighted that glass-, yellow- and silver eel fisheries are highly seasonal and therefore suggested that a seasonal closure might be a relevant conservation measure for eels. Recently, the European Council enforced a three-month closure for all stages in all Union waters of the ICES area, in Union and international waters of the Mediterranean Sea and in brackish waters.

Beaulaton and Briand (2007) estimated the proportion of settled glass eels relative to a non-impacted situation with current (%S/R) or pristine recruitment (%S/R0) under different management scenarios in two French estuaries with contrasting anthropogenic pressures: the Vilaine and the Garonne. In both case studies, licence control and fortnightly or daily closure lead to a smaller increase in %S/R than a seasonal closure scenario. However, depending on the basin and on the month when fishing was closed, a seasonal scenario could be the least effective. Fishing was authorized for some five months per season from 15 November to 15 April. They tested the following open seasons: November 15 to January 31 (early opening); January 01 to March 15 (middle season opening); February 1 to April 15 (late opening). Industrial water intake was also banned during fishing closure. If the closed period was during peak migration (the early opening scenario in both basins), %S/R increased more, whereas closure outside this peak migration period (late opening scenario for the Vilaine estuary, mid-season opening for the Gironde) can lead to less effective management. For that reason, it is important to analyse how glass eel fishery seasonality can influence the efficiency of management measures. To do so, we looked at different case studies:

- In Asturias: glass eel fishery is prohibited from April to October since 2007. To explore the effect of this regulation, we compared the average monthly proportion of catches for the period before (Asturias 1: 1996–2006) and after the implementation of the measures (Asturias 2: 2007–2019).
- In Basque Country: glass eel fishery is closed in October, partly in November (1–15) and in February and March since 2010. To explore the effect of this regulation, we compared the average monthly proportion of catches for the period before (Basque Country 1: 2004–2009) and after the implementation of the measures (Basque Country 2: 2010–2019).
- In Gironde estuary: a quota system was implemented in 2009. Although this is not a seasonal closure, it might affect fishing seasonality, therefore we compared the average monthly proportion of catches for the period before (Gironde 1: 1997–2009) and after the implementation of the measures (Gironde 2: 2010–2015).

Glass eel fisheries around Europe show a temporal distribution from October to May with a south to north gradient (ICES, 2004). Here, southwestern Europe glass eel catches have been analysed. The seasonality of the glass eel fishery in these case studies is evident (Figure 4.2.4), and is consistent with results from ICES (2004), concluding that the fisheries in southwestern Europe begin in November and end in March/April. In Asturias, the implementation of a closure in October had limited consequences for the total catches since catches for this month used to be very low (only 1.4% of yearly catches). On the other hand, the implementation of a closure in October, February and March in the Basque Country had more evident consequences on total catches. As such, corresponding fishery-based indices should take this modification into account. Interestingly, the fishery seasonality was also modified by the implementation of a quota system in the Gironde estuary due to changes in the behaviour of the fishermen, who tend to start fishing earlier, leading to higher proportions in November. Conversely, catches are more limited in February when the quota is nearly filled. These modifications of fishery seasonality induced by regulations can lead to the exclusion of a fishery-based recruitment time-series, and the Gironde modification of seasonality, among other modifications, typically illustrates why French dataseries that are no longer used for the calculation of the WGEEL recruitment index.

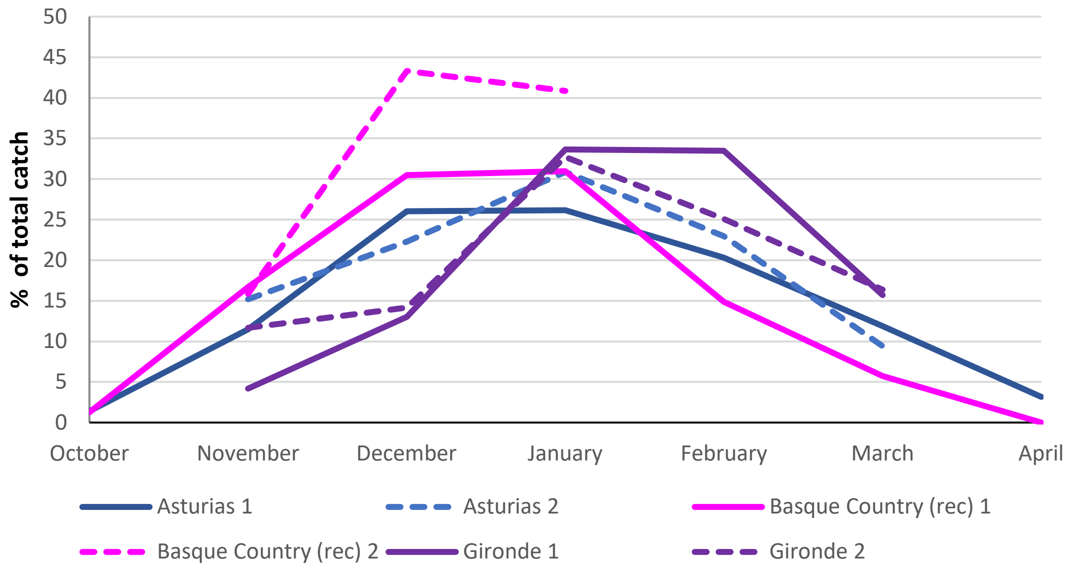


**Figure 4.2.4. Average monthly proportions of glass eel catch in the datasets: Asturias 1 (1996–2006), Asturias 2 (2007–2019), Basque Country 1 (2004–2009), Basque Country 2 (2010–2019), in Spain, and Gironde 1 (1997–2009), and Gironde 2 (2010–2015) in France.**

To illustrate the potential impact of a three-month closure on total catch, we calculated the average percentage of catches that would be affected by a closure (depending on which months that will be closed for the range August–April, as proposed by the EC) in Asturias, Basque Country and La Gironde. The analysis clearly shows that the effect will range from null (closures starting in August) to drastic (closures starting in November, December) depending on the selected months (Figure 4.2.5). It should be noted that in the Basque Country, the fishery is already closed in October, February and March, hence a November–December–January closing would result in a total ban of the fishery. To be efficient, management measures should be adapted to the local fishery seasonality. If only months associated with small proportions of catches are closed, corresponding fishery-based time-series will not be impacted and the fishing pressure will be hardly reduced. However, as soon as the fishery regulation impacts, the fishery and modifies the seasonality, it might be necessary to adapt fishery-based time-series to account for the modification (see following section).

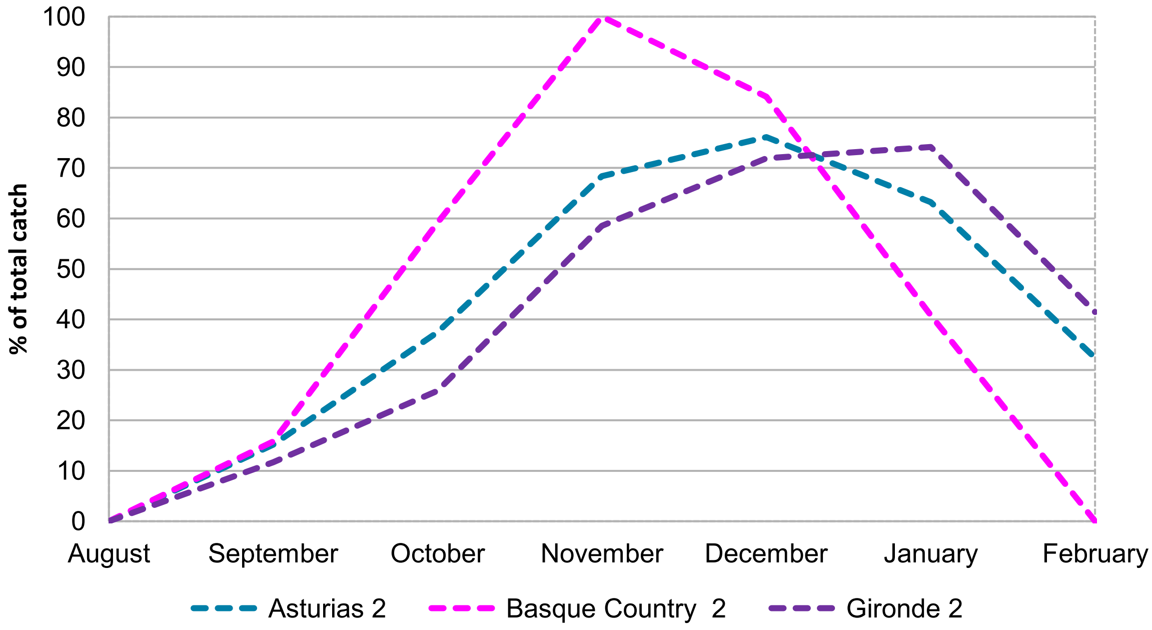


**Figure 4.2.5. Average percentage of catches that would be lost depending on the selected months for the three-month closure (the month indicated on the x-axis represents the beginning of the closure) in Asturias 2 (2007–2019), Basque Country 2 (2010–2019) in Spain, and Gironde 2 (2010–2015) in France.**

## Silver-eel fishery

A similar analysis was conducted for silver eels based on data from Sweden and Italy. In Sweden, the fishery for eels along the West Coast in the North Sea (FAO Subdivision SD 20 and the main part of SD 21, north of Torekov), was closed in Spring 2012. In addition, the eel fishing in the Kattegat (West Coast, south part of SD 21, south of Torekov), in Öresund (SD 23), and in the Baltic Sea (SD 24–31) has been limited to a period between May 1st to September 14th, or an individually determined period of 90 consecutive days. In one part of the Kattegat, just north of Öresund (part of SD 23), this determined fishing period is restricted to 60 days. To illustrate the effect of these regulations, we compared average monthly proportion of catches before the regulations were implemented (1999–2011) to after they were implemented (2012–2017) for the subdivisions 23–25, and 27 (Figure 4.2.6).

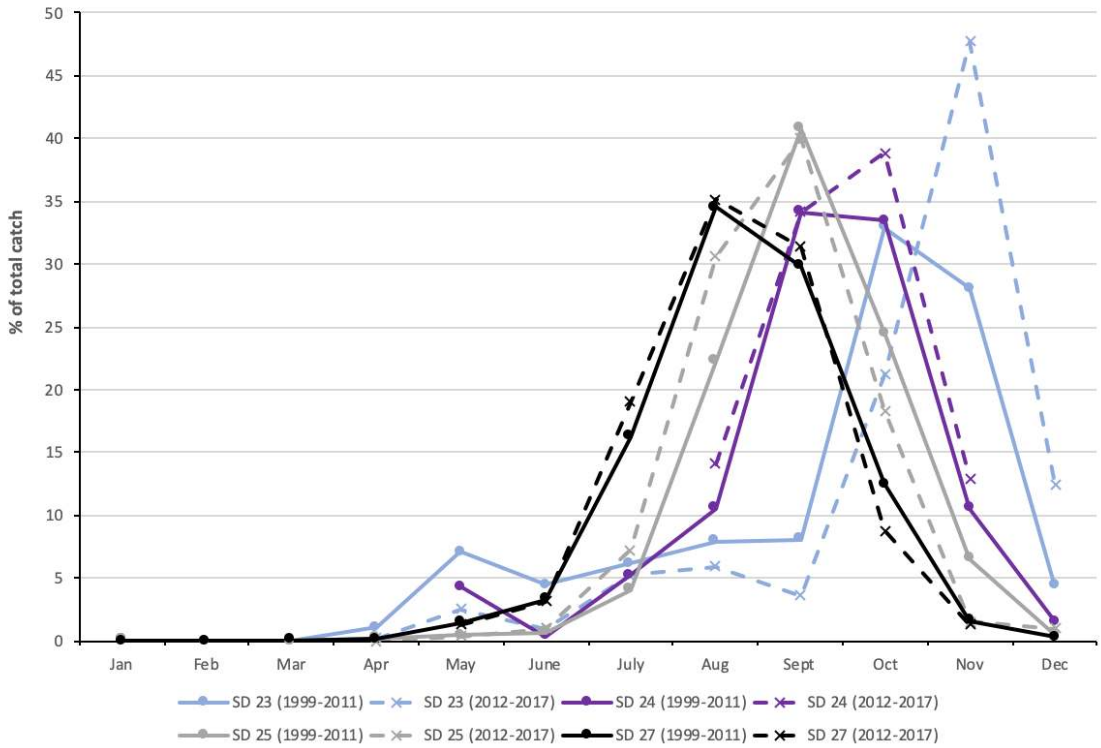


**Figure 4.2.6. Average monthly proportion of total catch before fishing limitations were implemented (1999–2011, solid lines and closed circles) compared to after (2012–2017, dashed lines and crosses) for subdivisions SD 23–25 and SD 27 in Sweden.**

For most subdivisions, the effects were small, most likely due to the flexibility of the closure (i.e. the possibility to utilise an individually determined 90-day fishing period), allowing fishermen to exclude periods when the fishing was already limited. In SD 23, the individually determined fishing period was restricted to 60 consecutive days, resulting in a more visible impact. This illustrates that depending on the way fishery regulations are implemented with respect to the fishery seasonality, it may or may not have an impact on the fishery, and consequently on related fishery-based time-series.

At the EU Ministerial Council in December 11–13, 2017, a decision was taken on a moratorium for commercial fisheries on eels longer than 12 cm in all EU marine waters in the Northeast Atlantic, including the Baltic Sea. In Sweden, this three-month closure has been implemented in November to January (for 2018–2019 and 2019–2020), which is a time period with limited fishing, except for November (Figure 4.2.7). This means that the closure will only bias fishery-based data based on lost data from one month. In 2018, the GFCM adopted Recommendation GFCM/42/2018/1 establishing management measures for European eel (*Anguilla anguilla* L.) in the Mediterranean Sea. Among other measures, GFCM included a three-month closure for eel fishery in the area. Then, the EU generalised the three-month closure all over Europe for marine and transitional waters (Reg (EU) 2019/124). The three contiguous months should be within a seven-month period (from 1 August 2019 to 29 February 2020) in the Atlantic area, whereas there are no time restrictions in Mediterranean area. In view of this and contrary to Sweden, Italy enforced the three-month closure during a period when fishing effort might be rather high (January–March, starting from the fishing season 2020). As an example, in two non-tidal coastal lagoons (Fogliano and Caprolace within the Circeo National Park on the central Tyrrhenian coast) the fishing season previously lasted throughout the year (until 2007 when commercial fishing was banned in these specific lagoons, Figure 4.2.8). Postulating that seasonality is similar across the coastal lagoons (where fishing has not been banned), which is likely, the three-month closure would imply a ~20% decrease of the total catch. In order to overcome possible biases in fishery-based data and consequently in further stock assessment, such effort reduction should not be ignored but rather considered appropriately at each site for all EMUs.

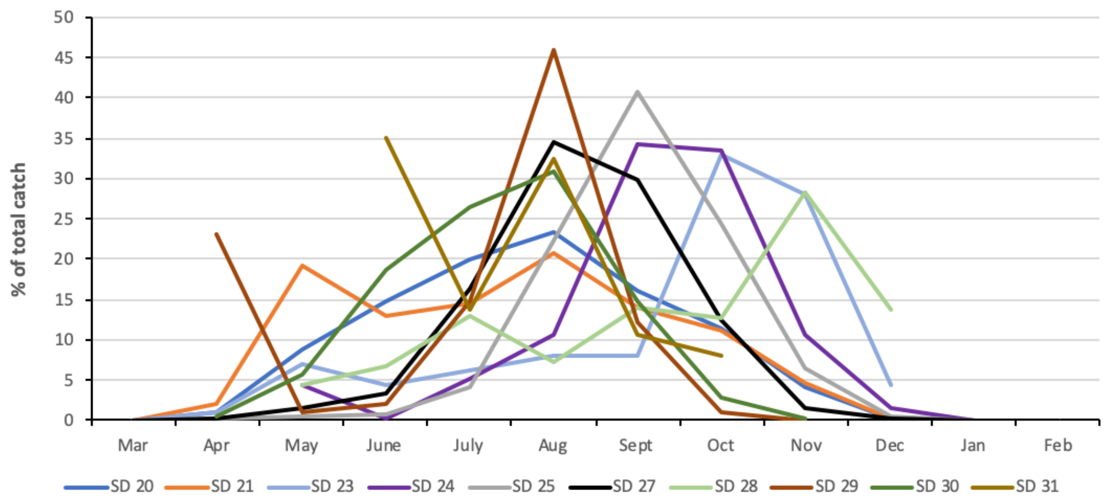


**Figure 4.2.7. Average monthly proportion of total catch for subdivisions SD 20–31 in Sweden (1999–2011, before fishing limitations were implemented). The three-month closure has been placed in November–January (for the period 2018–2019 and 2019–2020).**

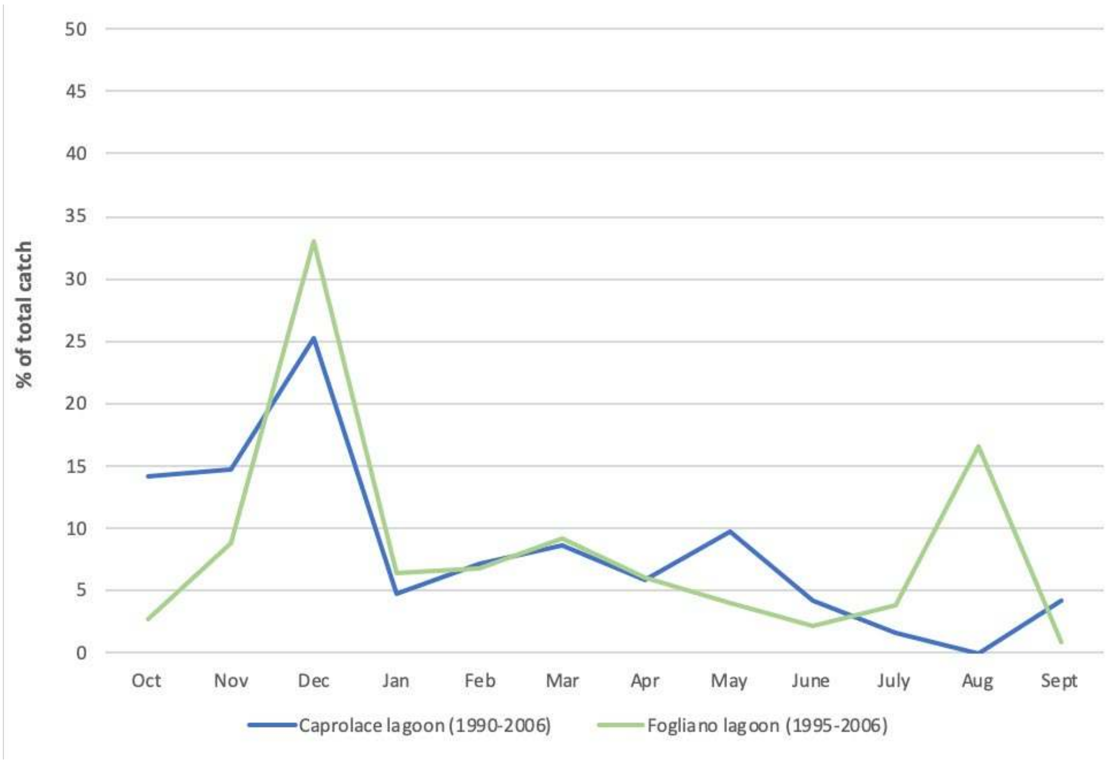


**Figure 4.2.8. Average monthly proportion of total catch for Caprolace (1990–2006) and Fogliano (1995–2006) in Italy (before fishing limitations were implemented). The three-month closure has been placed in January-March and will commence in 2020).**

### 4.2.4.2 Type of regulations and consequences for related fishery-based time-series

Of course, the consequences of a new fishery regulation depend on the type of regulation. As mentioned earlier the implementation of a new quota system has totally changed the fishing strategy of French fishermen. It led to profound changes in total catches and fishing efficiency and therefore, CPUE or commercial catches are no longer comparable. By definition, a fishery ban implies the end of that corresponding dataseries. A seasonal closure might have a more limited impact, as seen in previous sections, and it might be possible to correct fishery-based indices to address the problem and maintain the time-series (see following section).

More generally, fishery-based indices are often biased due to variations in fishing efficiency through time. Many fishery regulations can lead to such variations of fishing efficiency and bias both total catches and CPUE. Strong variation in nominal effort (number of licences, number of fishing days, number of nets, etc.) is often accompanied with important modifications in the fishery and, in this situation, a cautious analysis is required to check whether the assumptions of fishing efficiency is still valid. In other words, unfortunately, the more impact a measure has, and therefore in a sense, the more effective it is, the more likely it is to bias the fishery-based indices.

### 4.2.5 The specific case of the 3-month closure: can we correct time-series of glass-eel recruitment to account for the regulation?

In order to determine the effect a closure might have on the continuity of eel dataseries, the possibility to relate total annual catch with a closure to total annual catch without closure was analysed by eliminating certain months. The effect of closing months either at the beginning and end of the season as well as months in the middle of the season was tested. A linear regression was used to investigate whether there is a relationship between catches with certain months excluded and total catches. If a significant relationship was shown, it could be used to correct dataseries with closed months in the future.

Two sets of data from Spain (Asturias) and France (La Gironde) were used to carry out this analysis. Data prior to the implementation of management plans were used, i.e. before reduction of fishing seasons and the quota system were implemented.

For both datasets, a significant linear regression was found when captures of the peripheral months were eliminated (Figures 4.2.9 and 4.2.10). However, regressions were less significant when the central months were eliminated (Figures 4.2.9 and 4.2.10). Therefore, in the event that the fishing season is shortened in the initial or final months (the most likely case), the series could be corrected and a simple regression equation can be used to extrapolate catches to the missing months.

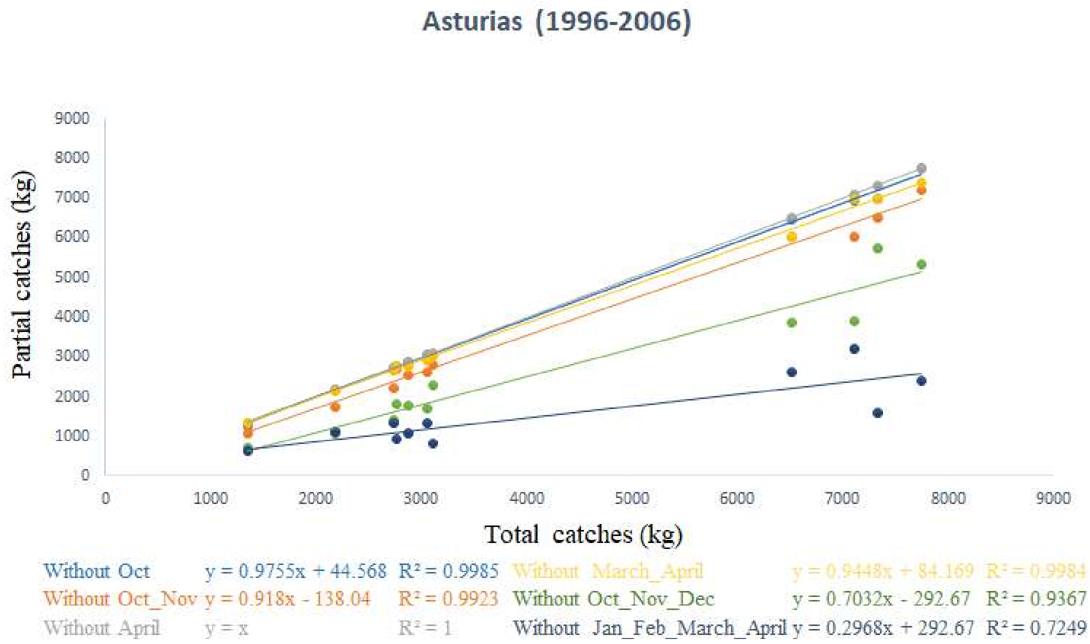


**Figure 4.2.9. The relationship between catches excluding certain months (x-axis) and partial catches (y-axis) for the period 1996–2006 in Asturias, Spain, before fishery restrictions were applied.**

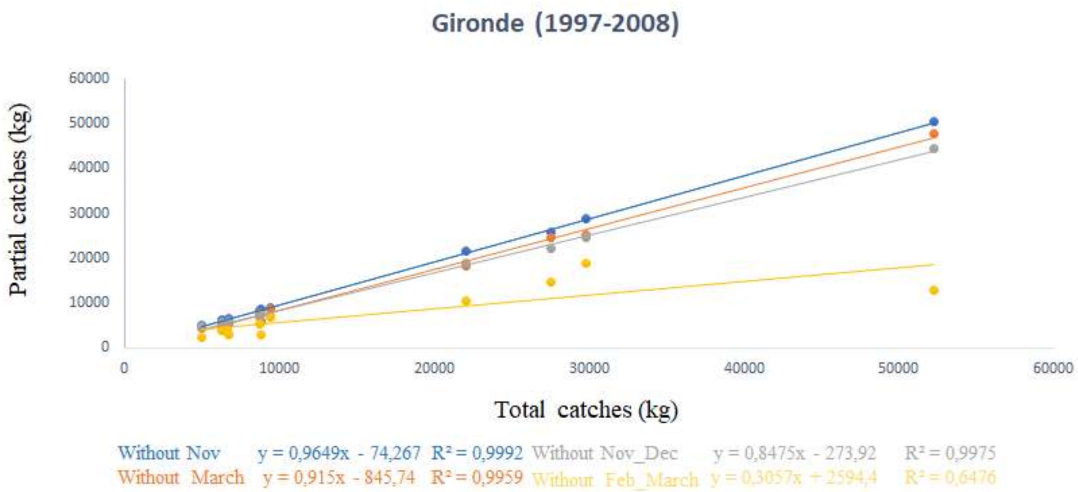


**Figure 4.2.10. The relationship between catches excluding certain months (x-axis) and partial catches (y-axis) for the period 1997–2008 in La Gironde, France.**

For example, in Asturias in 2007, the season was reduced by excluding the months of October and March. Thus, applying the equation obtained by relating the total catches with those produced excluding these two months for the 1996–2006 period (catches without October and April = 0.9203, total catches + 128.74; $R^2 = 0.9974$, Figure 4.2.9), the catches that would have been obtained if fishing in October–March had still occurred could be estimated. The catches that would have taken place in the 2007–2019 period would only have been slightly higher if the reduction had not taken place (Figure 4.2.11). However, it should be noted that this is only one of the many measures applied in Asturias that have reduced fishing effort (other restrictions include rest days in the fishing months and restriction of the number of licences).

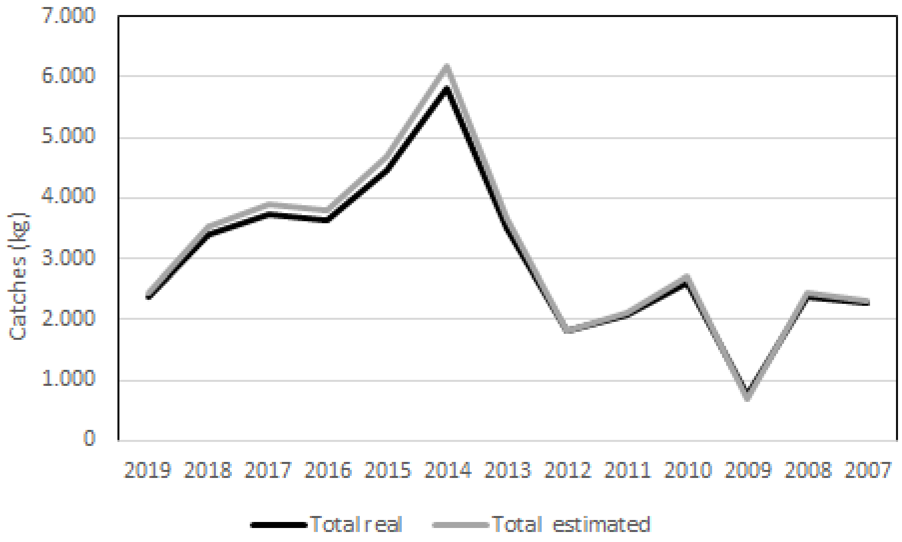


**Figure 4.2.11. Annual trends of total real catch (when fishing season was shortened to November–February) and estimated total catches that would have been obtained if they had fished in the October–March period, in Asturias, Spain.**

### 4.2.6 Conclusions and recommendations

Many fishery-based time-series are used to assess eel population status, in particular recruitment. Losing such data would increase the uncertainty in the assessment and would lead to a poor spatial coverage in southwestern Europe. However, new fishery regulations are not necessarily synonymous with losing fishery-based dataseries and, as shown in this chapter, some solutions exist to correct the data. Whether corrections can be done or not, depends on the nature of the implemented fishery regulation, and how the fishery-based data are used in the assessment. It is clear though that the more a management measure impacts the fishery, the more likely it is that fishing practices will be altered (e.g. changes in fishing effort, fishing strategy, fishing seasonality) and consequently bias corresponding fishery-based indices. More generally, fishery-based indices should be analysed with great caution when important changes in fishery have occurred, whichever the reason, since it may lead to violations of underlying assumptions. For example, eel fishing effort has decreased in many countries as a response to dwindling abundances. Such reduction of fishing effort, if not considered, may lead to biases on fishery-based indices.

Possible effects that a temporary reduction could have on catches were also explored. For the analyses, the assumption was made that effort during months outside of the closure was maintained (i.e., effort in for example December would be the same before and after implementation of the closure). However, it is possible that a temporary fishing closure, if not accompanied by effort limitations (e.g. limitations in number of gears, fishing hours, etc.) could lead to increased effort during the open months. This needs to be considered when performing correction of time-series and/or analyses on the effect of closure measures.

In view of this, there is an urgent need to implement new fishery-independent monitoring systems, in particular in the south of Europe where fewer fishery-independent series exist. Initiatives such as the coordinated monitoring network implemented by the SUDOANG project in southwestern Europe are very valuable. Ideally, new monitoring series should commence before a new fishery regulation is implemented to allow intercalibration of the new series with the pre-existing fishery-based dataseries. It should be noted that fishery-independent time-series may also display biases. The study group SGIPEE (ICES, 2010) pointed out that some fisheries-independent glass-eel abundance indices (based on ladder and trap) used by the WGEEL may have been altered due to ladder/trap modifications, and changes in effort due to cessations in fishing, floods and access issues, etc. This is similar to altered fishing efficiency and requires modifications to the estimations.

## 4.3 New and emerging threats and opportunities

### 4.3.1 Threats and opportunities raised in previous WGEEL reports

WGEEL have reported on emerging threats and opportunities in each of the previous three years (ICES, 2015b; 2016a; 2017). The general threat types highlighted in the each of the years remain the same within this 2019 report (summarised in Table 4.3, ICES, 2018).

As before, while some of these reported threats are newly emerging (e.g. a newly identified eel virus), there is the danger of overlooking the fact that these previous summaries refer to threats that, once identified, should be regarded as current and ongoing. In many cases, these areas of threats have a relatively long history (decades) yet the mitigation measures that have been implemented have tended to be minor and incremental rather than decisive, and thus scope for action may remain, or analyses are yet to be complete. As such, it is recommended that this section is not seen in isolation but as part of a continuum from previous WGEEL reports.

### 4.3.2 New and emerging threats

Country Reports and expert comments provided the information to highlight new or emerging threats:

*Germany, Disease transfer via restocking*: WGEEL has previously highlighted the risk of spreading diseases via restocking of glass eel outwith their catchment of origin. To date, studies on eel viruses mostly focus on the anguillid herpesvirus 1 (AngHV-1; HVA), the birnavirus European Eel Virus (EVE; IPNV) and the rhabdovirus Eel Virus European X (EVEX). Furthermore, in countries with health inspection procedures of restocked eels these are restricted to the detection of HVA and/or EVEX infections. Besides HVA, EVE and EVEX, other viruses have been isolated from eels. For instance, the eel picornavirus (EPV-1) was detected in organs from a diseased yellow eel in Lake Constance in Germany (Fichtner *et al*., 2013). In the study by Fichtner *et al*. a mortality rate of 43% of 16 artificially infected glass eels was calculated. In the past, picorna-like viruses have been found in eels from the Netherlands (Van Ginneken *et al*., 2004). But, to date publications about EPV-1 infections and the impact of this virus on health and escapement are missing. Within an ongoing study, EPV-1 has been detected in yellow eels in North Rhine Westphalian rivers (Germany). The lack of any progress toward effective quality assessment, which comprised a veterinary health inspection that includes viral assessment of eels used for restocking, remains an important risk for disease transfer. To ensure that the viruses do not spread any further, quarantine and/or fish health inspection procedures prior to restocking should be implemented, at least for HVA and EVEX, which seem to have a negative impact on the stock (Haenen *et al*., 2002; Van Ginneken *et al*., 2005). In addition, research on other eel viruses, for instance EPV-1, is necessary to define their impact on the eel stock and their role in the virus transfer via restocking.

# 5 ToR D: Consider the consequences of the Precautionary Approach on advice for European eel

This chapter addresses ToR d - "Consider the consequences of the Precautionary Approach on advice for European eel." The findings below are based on earlier reports of WGEEL and related workshops, a working paper made available at the start of the meeting (Annex 10), and discussions during the meeting. To address the Terms of Reference, relevant documents for the Precautionary Approach were analysed, and findings contrasted with the Eel Regulation, our knowledge about eel biology and management, and the official ICES Advice (ICES 2018c,d). In this chapter, the focus is on the design of a framework for the development of scientific advice on eel stock management.

## 5.1 Introduction

In the light of the growing evidence on the long-term decline of the eel stock across Europe, ICES (2000 through to 2007) recommended, "that a recovery plan should be implemented for the eel stock". As a long-term goal for recovery, ICES (2002) suggested rebuilding recruitment to levels "similar to those of the 1980s" (though we assume it meant pre-1980 given the recruitment decline in the early 1980s). Although "the ecology of the eel makes it difficult to demonstrate a stock-recruitment relationship, […] the precautionary approach requires that such a relationship should be assumed to exist for the eel until demonstrated otherwise" (ICES 2002). A spawning–stock biomass of "30% of the virgin (F=0) [state] is generally considered to be a reasonable provisional reference target. However, for eel a preliminary value should be 50%" (ICES, 2002 through to 2007).

In 2007, the European Union adopted Council Regulation (EC) No. 1100/2007 establishing measures for the recovery of the stock of European eel, with the objective "to reduce anthropogenic mortalities so as to permit […] the escapement […] of at least 40% of the silver eel biomass [relative to the notional pristine biomass]". The Eel Regulation aims to achieve this reduction in anthropogenic mortalities through the implementation of national or river basin specific Eel Management Plans. Subsequently, the European Commission requested from ICES a review service to pre-evaluate these national Eel Management Plans (ICES, 2009), and (amongst others) requested a review of progress reports of those EMPs (as reported in ICES, 2018a). Although ICES responded to these requests, ICES did not evaluate the Eel Regulation itself, and its annual advice (ICES, 2008 through to 2018c) did not relate to the ongoing implementation of Eel Management Plans in EU Member States. ICES provided precautionary advice, based on a single whole-stock indicator time-series (recruitment) only. As that advice addressed the whole stock (all of Europe and the Mediterranean), while the stock is actually managed and protected in national (or lower level) Eel Management Plans, there was a mismatch between the management needs and the scientific advice provided. This mismatch has been paralysing progress in the implementation of the international eel recovery plan (Dekker, 2016).

## 5.2 Precautionary Approach

ICES provides advice on fisheries management, in the context of several international agreements and policies (ICES, 2018d). These include the United Nations Straddling Fish Stocks Agreement (UN, 1995), and the FAO Code of Conduct for Responsible Fisheries (FAO, 1995). The FAO Code "calls on … all those involved in fisheries to collaborate in the fulfilment and implementation of the objectives and principles contained in this Code." The other policies and agreements listed by ICES (2018d) do apply in coastal waters and at high seas - but have no competence in inland waters, where most anthropogenic impacts on eel occur. The Code of Conduct specifies that "States should apply the precautionary approach widely to conservation, management and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment" (Art. 7.5.1). ICES (2000a) and Russell and Potter (2003) have discussed the implications of the precautionary approach for the management of the European eel before. Major elements relevant to the current discussion are (bold formatting added):

a) The adoption of "measures for the **long-term conservation and sustainable use** of fisheries resources" (FAO, 1995, Art. 7.1.1),
b) "Conservation and management measures, whether at local, national, subregional or regional levels, should be based on **the best scientific evidence**" (FAO, 1995, Art. 7.1.1),
c) "**Depleted stocks [should be] allowed to recover** or, where appropriate, are actively restored" (FAO, 1995, Art. 7.2.2.e),
d) "To be effective, fisheries management should be concerned with the **whole stock unit over its entire area of distribution** … and other biological characteristics of the stock" (FAO, 1995, Art. 7.3.1),
e) "In order to conserve and manage… highly migratory fish stocks … throughout their range, conservation and management measures [should be] established for such stocks **in accordance with the respective competences of relevant States**" (FAO, 1995, Art. 7.3.2),
f) "Long-term management **objectives should be translated into management actions**, formulated as a fishery management plan or other management framework" (FAO, 1995, Art. 7.3.3),
g) "The **absence of adequate scientific information** should not be used as a reason for postponing or failing to take conservation and management measures" (FAO, 1995, Art. 7.5.1),
h) "**Two types of precautionary reference points** should be used: conservation, or limit, reference points and management, or target, reference points" (UN, 1995, Annex II, point 2),
i) "Precautionary **reference points should be stock-specific** to account, inter alia, for the **reproductive capacity, the resilience** of each stock and the characteristics of fisheries exploiting the stock, as well as **other sources of mortality** and **major sources of uncertainty**" (UN, 1995, Annex II, point 3),
j) "When information for determining reference points for a fishery is poor or absent, **provisional reference points** shall be set" (UN, 1995, Annex II, point 6),
k) "**Prior identification of undesirable outcomes and of measures** that will avoid them or correct them promptly" (FAO, 1996, point 6.b),
l) "Where the likely impact of resource use is uncertain, **priority should be given to conserving** the productive capacity of the resource" (FAO, 1996, point 6.d),
m) "A precautionary approach requires that the feasibility and reliability of the management options be evaluated. … The evaluation should attempt to determine if the management plan is **robust to both statistical uncertainty and to incomplete knowledge** …" (FAO, 1996, point 35),
n) "Establish a recovery plan that will **rebuild the stock over a specific time period** with reasonable certainty" (FAO, 1996, point 48.b),
o) "**Do not use artificial propagation as a substitute** for the precautionary measures …" (FAO, 1996, point 48.g).

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

A recovery plan (or an initial recovery phase within a long-term management plan) cannot be judged using the same criteria for precautionarity as a management plan. It seems more logical to judge a recovery plan according to its ability to deliver spawning biomass recovery within a certain time frame that is appropriate to 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 a recovery plan as precautionary would be that the probability of spawning biomass to be above $B_{lim}$ in a prespecified 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. (The EU Science, Technical and Economic Committee for Fisheries (STECF) recommended three generations; the EC Eel Regulation states "in the long term");
- The probability of achieving the target is undefined.

In the event of an absence of data, or the ability to derive a reference point or an outcome, a provisional reference point should be put in place, and this should be subject to periodic review at an appropriate time frame.

While ICES welcomed the adoption of the EC Regulation as a significant step toward the recovery of the eel population and supported the approach taken in the EC Regulation to develop management plans based on Eel River Basin Districts (ICES, 2007), a system of post-evaluation and feedback 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 an irreversible collapse of the stock.

The adoption of a mortality target at the EMU level, derived from the stock-wide biomass target would facilitate a real-time assessment of contribution to the recovery of the stock and a feedback mechanism to the managers. A mortality-based reference point $\Sigma A=0.92$ has been proposed (Dekker, 2010; ICES, 2010) that results in 40% of the pristine stock numbers; i.e. the sum of all anthropogenic impacts, summed over the entire continental lifespan, should not exceed a fixed value of 0.92.

For long-lived stocks with population size estimates, ICES bases its advice on attaining an anthropogenic mortality rate at or below the mortality that corresponds to long-term biomass targets. However, in the ICES form of advice, $B_{trigger}$ is a biomass level triggering a more cautious response. Below $B_{trigger}$, the anthropogenic mortality advised is reduced, to reinforce the tendency for stocks to rebuild. Below $B_{trigger}$, ICES conventionally suggests to use a proportional reduction in mortality reference values (i.e. a linear relation between the mortality rate advised and biomass). In the case of eel, however, a proportional reduction below the management reference point $B_{mgt}$ is proposed, the slope of which is determined by the generational time frame proposed for the attainment of $B_{mgt}$.

For fish stocks in general, the 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 in particular, however, current stock and recruitment are historically low, and indications are that the conventionally assumed mechanisms (e.g. a compensatory stock–recruitment relation) 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 fishing products has kept other fisheries going.

For the eel management units in the EU Member States, the Eel Regulation sets a minimum limit for the escapement of silver eel biomass ($B_{mgt}$) 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". In this, it is assumed that at that biomass level, recruitment would not have been impaired. This management limit was based on scientific advice by ICES (2002), based on a meta-analysis of stock–recruitment relations across unrelated fish stocks, in other words, it is above the standard $B_{lim}$ of 30%. It is proposed to adopt this management reference point for the whole distribution area of European eel. First, it would be a science-based reference point for those areas too, and secondly, it would align the objectives of the different regions facilitating the stock-wide orchestration.

The anthropogenic mortality rate for the eel lifespan (say $\Sigma A_{mgt}$) corresponding to $B_{mgt}$ is $\Sigma A=0.92$ for each eel management unit, considering a similar contribution of each unit to the reproduction success and without any consideration of possible density-dependence mechanisms (ICES, 2010). Note that a biomass-reference point applies to the long term, and that mortality-reference points are manageable in the short term.

Below $B_{mgt}$, it is recommended to reinforce the mortality limit in order to allow the stock to recover. The magnitude of the reduction is under political decision and reflects the ambition level to restore the stock (Figure 5.1), i.e. the time frame set to achieve a recovery. Clearly, the lower the mortality level achieved, the faster recovery of the stock can be expected and the lower the risk of further deterioration (Figure 5.1), though multiple generation times might be required to achieve full recovery (Åström and Dekker, 2007; FAO and ICES, 2011). Notice that the reduction in mortality target proportional to the reduction of spawning biomass corresponds to the harvest control rule advised by ICES protocol.

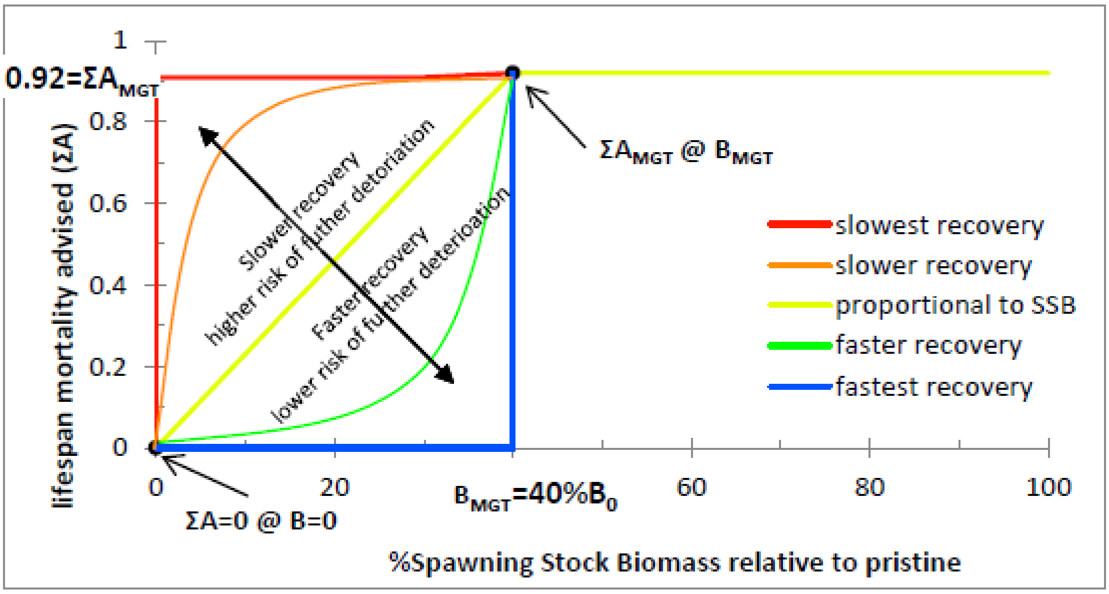


**Figure 5.1. Schematic overview of different control rules. $B_{mgt}$ is the escapement biomass management target fixed at 40% of the escapement to the sea of the silver eel biomass relative to the best estimate of escapement in pristine conditions. $\Sigma A_{mgt}$ is the corresponding lifespan mortality rate. Below $B_{mgt}$ different control rules are possible that lead to more or less fast recovery speed with more or less risk of further deterioration. (Source: ICES, 2016a).**

## 5.3 European Eel

A comprehensive overview of eel biology, stock status, human impacts, management frameworks, and scientific advice on eel is presented in ICES (2016c) and updates of the major time-series in ICES (2018a) including the 3rd round of reporting of Indicators to the EU. For the current discussion, the following issues are relevant:

1. **Spatial distribution and life cycle**. The eel occurs in inland and coastal waters, all over Europe and the Mediterranean (Dekker, 2003b). The stock is scattered over a multitude of smaller habitats, with little or no connection between sub-stocks in different river systems during their continental life (Dekker, 2000b). The whole stock is generally considered to constitute a single, panmictic stock (Palm *et al*., 2009), but there is no full and final evidence (e.g. Baltazar-Soares *et al*., 2014). It is not known which part (or all) of the continental distribution actually contributes to the oceanic spawning stock (Dekker, 1999; 2016).

   Reproduction takes place in the ocean, not in continental waters. All life stages in continental waters, in waters under national or EU jurisdiction, in waters where protective measures can be taken, are immature. Stock assessments and management measures, while often applied at earlier life-history stages, are therefore focused on increasing the amount of the (maturing) silver eel stage, escaping towards the ocean. Where international agreements and protocols write "spawning stock", we read that as "silver eel escapement".

2. **Landings trend**. Commercial landings data are incomplete and not reliable. Trend analysis indicates that reported landings have diminished since the 1960s, declining by about 5% per year to below 10% of the quantity caught half a century ago (Dekker, 2003a). There is circumstantial evidence of a much longer (mid-1800s) downward trend; partly masked by expansion of fisheries to new, larger-scaled habitats (larger lakes, major rivers) and other countries (Dekker, 2019). For recreational fisheries, far less information is available but these may be in the same order as commercial landings (ICES, 2018b).

3. **Recruitment trend**. Monitoring of the immigration from the ocean has taken place for many decades, at many places (mostly on the Atlantic coast), in fisheries-dependent and independent settings. Results show a strong coherence among sites, over the years. See chapter 3, for details and latest results.
4. **Non-fishing impacts**. In addition to fisheries, many other anthropogenic activities have an impact on the stock, including land reclamation, water management, water pollution, hydropower generation, and many more. Their impacts vary from country to country, as well as with different habitat types. Recent assessments (ICES, 2016a) indicate that fishing and non-fishing mortalities often have a comparable impact (Dekker, 2016; ICES, 2018b).
5. **Restocking**. Since 1840, immigrating young eel have been redistributed, from areas of highest abundance in river mouths (especially in countries around the Bay of Biscay), to other countries (mostly DE, PO and NL, UK N. Ireland; foremost after 1950) and further inland. The aim of this restocking was to support dwindling fisheries, or even to enable new fisheries (Dekker and Beaulaton, 2016a). The restocking-based production was small in comparison to the total reported landings, until the landings declined considerably in the 1990s (Dekker and Beaulaton, 2016a). After 2010, restocking has increased, in the context of the implementation of national Eel Management Plans.

## 5.4 Population, stock and management unit

"To be effective, fisheries management should be concerned with the whole stock unit over its entire area of distribution" (FAO, 1995). While there is little doubt, that the European eel species consists of a single, panmictic population (Als *et al*., 2011; Palm *et al*., 2009), the identification of unit stock(s) and management unit(s) is less straightforward. While there is commonly no doubt on the single spawning stock, the geographical origin of the spawners from continental waters is not known. Not knowing which areas effectively contribute to the spawning stock, the prudent approach is to manage each and all areas to the same sustainability standards. Additionally, in the case that the stock would not be panmictic (e.g. Baltazar-Soares *et al*., 2014), the same approach (manage each and all areas to the same sustainability standards) would apply. That is: application of uniform sustainability standards is the most risk-averse strategy.

The European Union adopted the Eel Regulation, following the suggestion of Dekker (2004) to implement a distributed control system (Dekker, 2016). The Regulation adopted common objectives, uniform reference points and an international evaluation process for the Union as a whole, but delegated design and implementation of protective measures, as well as monitoring and assessment to its Member States (Dekker, 2016). While the objective is set at the central level, the means to implement were found at the decentralised level.

Stock identification should consider the genetic structure of the population, the existence of spatially isolated subunits (potentially with different phenotypes, or dissimilar human impacts), and the needs and competences of fisheries managers (Begg *et al*., 1999). These requirements are reflected in the FAO Code of Conduct, in "the whole stock unit over its entire area of distribution" (Art. 7.3.1), "in accordance with the respective competences of relevant States" (Art. 7.3.2), and "objectives should be translated into management actions" (Art. 7.3.3). For the European Eel: while the genetic homogeneity of the population across the whole distribution area pleads to consider the whole population as a single stock, the (phenotypic) variation in life-history characteristics, the geographic diversity in human impacts, and the precedence of national competences over centralised management (subsidiarity) favour much smaller geographical entities. With the lack of knowledge in the case of eel for any population sub-structuring, the prudent approach is to manage each and all areas to the same standards (Dekker, 1999).

"Conservation and management measures, whether at local, national, subregional or regional levels, should be based on the best scientific evidence" (FAO, 1995, Art. 7.1.1). Latest scientific advice (ICES, 2018c) indicated that available information (on catches, and other anthropogenic mortalities) is inadequate to derive a full assessment, and therefore advised - on precautionary grounds - to minimise all impacts across the whole stock. However, for individual management areas (especially in the EU), the required information is available, and assessments of the impacts have been made (ICES, 2018a,b), but these have not, to date, been included in the advice on eel. Hence, the absence of fully adequate scientific information in many areas leads to putting aside the available information in other, better documented areas and hence, not "all the available information [is] used" (ICES, 2018d). While the available information is currently insufficient for an assessment of the whole stock, this information is unlikely to be completed in the near future or ever (Dekker, 2016).

In conclusion, a differentiation of the scientific advice is worth considering. For setting the long-term objective, and for assessing the overall status of the stock, stock-wide indicators need to be considered. For assessing the protection status, only a regionalised assessment of human impacts will make use of the best scientific evidence, and only a regionalised assessment can be translated into management actions. The long-term objectives are necessarily central, the means to protect are only found at the decentralised level.

## 5.5 Information poor, provisional advice

The FAO Code of Conduct (FAO, 1995) calls upon parties to use "best scientific evidence", to derive "stock-specific" reference points, to translate "objectives […] into management actions". "When information for determining reference points for a fishery is poor or absent, provisional reference points shall be set."

For the eel, the decline of the stock in inland waters had been noted for more than a century (Dekker and Beaulaton, 2016b), but it is only in most recent decades, that the decline in glass eel recruitment (since 1980) attracted considerable attention. ICES (2002) noted that recruitment, abundance and landings had been in decline for several decades, but "current scientific knowledge is inadequate to provide management reference points for eel".

For the glass eel recruitment, Dekker (2000b) analysed the coherence among dataseries across the continent, finding no spatial differentiation in the declining trends in glass eel recruitment since 1980. Subsequently, re-analysis of longer time-series in 2010 (ICES 2010) confirmed this outcome. Testing fixed geographical areas (ICES eco-regions), ICES (2010) found that the 'North Sea' series declined faster than 'Elsewhere Europe', although this did not hold for all series within the North Sea. Most of this discrepancy between 'North Sea' and 'Elsewhere Europe' occurred in the mid-1980s; the downward trends thereafter run in parallel. Overall, the available recruitment dataseries are considered to provide reliable indices of recruitment, representative for the major part of the distribution in the Atlantic area; for the Mediterranean, too little information is available to compile a reliable index for this whole area. All evidence points at a stock-wide major reduction in glass eel recruitment, between 1980 and 2010.

For the spawner-escapement from the continent, few long-running dataseries are available from unexploited river systems (Burrishoole, Ireland; Imsa, Norway (Sandlund *et al*., 2017; Poole *et al*., 1990; 2018)), or Norwegian coastal waters (Durif *et al*., 2010). Dekker (2003a; 2004) tentatively assumed that silver eel escapement from the continent is approximately proportional to the catches made from the continental stock, and analysed the relation between the trends in landings and subsequent recruitment, as a substitute for the stock–recruitment relation. This analysis suggested a strongly depensatory relation: recruitment fell more rapidly (-15% per year) than the spawning stock, that is: than the landings (-5% per year). Since the implementation of substantial fishing restrictions, in the context of the Eel Regulation, the relation between spawner escapement and landings will certainly have been lost.

In summary, the dynamics of the whole stock are poorly understood, barely quantified; and thus, there is hardly a basis for stock-specific reference points. ICES (2002) therefore advised to adopt provisional reference points: a spawner escapement of 30% of the virgin escapement "is generally considered to be … a reasonable provisional reference target", and - adding an uncertainty margin to deal with the incompleteness of knowledge - a spawner escapement of 50% was advised. The alternative - advice based on the tentative, strongly depensatory stock-recruitment-relation - would have urged for far more stringent, and far more urgent reduction of all anthropogenic mortalities. Subsequently, the EU Eel Regulation indeed adopted a provisional reference point, setting the limit at 40% of the pristine escapement. This provisional reference point of 40% is higher than the universal value of 30%, to accommodate for the incomplete knowledge; it does not contain a precautionary safety margin for statistical uncertainty, and indeed, a provisional, not species-specific, stock–recruitment relation does not allow for the derivation of such.

## 5.6 Maximum Sustainable Yield of eel, fisheries and non-fisheries impacts

"An important part of ICES advice regards *the management of the exploitation of living marine resources*. To this end, ICES considers *ecosystem-based management* (EBM) as the primary way of managing human activities. ICES has developed a comprehensive framework including a set of advice rules to be applied when addressing requests for advice on fishing opportunities" (ICES, 2018d). "To address requests for advice on other topics than fishing opportunities, ICES is dependent on the clients having clearly defined the question(s) to be addressed along with the objectives and criteria to be considered so that the advice is appropriately developed" (ICES, 2018d).

The Eel Regulation "establishes a framework for the protection and sustainable use of the stock of European eel", with the objective "to reduce anthropogenic mortalities so as to permit […] the escapement […] of at least 40% of the silver eel biomass [relative to the notional pristine biomass]." Among the list of potential management measures (Art. 8), actions related to commercial and recreational fisheries, as well as a range of non-fishery-related actions have been included. The Eel Regulation aims for a comprehensive policy, addressing both fisheries and non-fisheries issues without precedence.

For the past and current eel fisheries across Europe, the value of the eel catch far outweighs the production of biomass for food (Dekker, see Annex 9). Fishery development throughout the 20th century had been driven by rising prices and developments in processing and markets (Dekker, 2019). That is: maximising yield (in kg) has never been the objective.

For an unrestricted eel fishery, maximisation of the yield per recruit can be achieved, by minimising the glass eel and yellow eel fisheries, and maximising the silver eel fisheries (Pohlman *et al.*, 2016, Figure 3b). In practise, however, silver eel fisheries dominate only in areas of low abundance, as an adaptation of the fisheries to low stock densities (Dekker, 2003b). Until the adoption of the Eel Regulation, governance was primarily aimed at local conflict resolution, opportunistically supported by arguments concerning yield maximisation, or even stock protection (Dekker, 2008). Current fisheries too appear to be dominated by maximising profit, not by maximising the production of staple food (Dekker, see Annex 10). For instance, glass eel fisheries effectively catch a minimum of biomass (yield) per recruit, against a maximum profit (Dekker, see Annex 10). The objective of eel fisheries management rarely (if ever) is or has been Maximum Sustainable Yield (MSY) and for the major part of the fisheries, the current state is very far from MSY.

The ICES approach to advice on fishing opportunities integrates ecosystem-based management with the objective of achieving 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 ecosystems. Populations need to be maintained within safe biological limits to make MSY possible, but a precautionary approach is generally not a sufficient condition for MSY; to achieve MSY, more stringent conditions should be set.

Apart from fisheries, many other anthropogenic activities have an impact on the eel stock. Recent assessments (ICES, 2016a; 2018b) indicate that fishing and non-fishing mortalities often have a comparable impact (Dekker, 2016). Fishing and non-fishing activities, jointly or separately, have an impact exceeding minimal sustainable bounds in many areas, and hence, reductions in both fishing and non-fishing impacts need to be considered. Fisheries constitute a deliberate impact on the stock (making a profit), while non-fisheries impacts are an unintentional side effect of human actions aimed at other benefits. If eel fisheries would be managed on the MSY-criterion (optimising yield or even profit), while other impacts are not (setting only maximum allowable limits on side effects), that would lead to incongruous results. When minimal sustainable limits would have been achieved, more stringent restrictions would be required to bring the fishery to MSY, while for the non-fishing impacts, no further restrictions would be required. If the management succeeded in achieving MSY, restrictions on non-fishing impacts could be relaxed. In the long run, this would favour the replacement of fishing impacts by non-fishing impacts, which would move the stock away from the MSY-target. Managing towards MSY, increasing non-fishing impacts would bring the stock away from MSY.

While the MSY-concept is at the heart of fishery-policies related to the precautionary approach, the current eel fisheries are far from MSY, aiming at maximising profit rather than yield; non-fishing impacts make a major impact, thwarting the achievement of MSY; and the Eel Regulation aims at a broad and comprehensive protection, including sustainable management of non-fishing impacts. Therefore, the MSY-concept provides no basis for the development of precautionary advice on eel.

## 5.7 Towards a framework for advice on eel

The current goal of the European eel management, set by the Eel Regulation (Council Regulation 1100/2007), is to reduce mortality to a level that allows a silver eel escapement from all EMUs of at least 40% of pristine values. 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). Mortality-based indicators and reference points routinely refer to mortality levels assessed in (the most) recent years. ICES (2011a) noted that the actual spawner escapement would lag behind, because cohorts contributing to current spawner escapement have experienced different mortality levels earlier in their life. Consequently, stock indicators based on assessed mortalities do not match with those based on measured spawner escapement. The time-lag does not apply to mortality-based indicators as well as to %SPR-based indicators. It will be in line with the conventional ICES procedures and the standard Precautionary Diagram to focus on immediate effects ($\Sigma A$), ignoring the inherent time-lag in spawner production. This will show the full effect of management measures taken (on the vertical mortality axis) although the effect on biomass (horizontal) has not yet fully occurred.

While the long-term objectives are central and should be managed on the whole stock level, the means to protect the European eel stock are often found at the decentralised level, due to the diversity of habitats and threats throughout the distribution area and the variability of biological parameters between areas (e.g. growth, age at silvering, sex ratio). In addition, a regionalised assessment may be more easily translated into management actions than a whole stock assessment. It is therefore worth considering, whether eel management could benefit from a differentiation of the scientific advice into an EMU-wise mortality-focused part and a whole stock biomass-focused part.

In such a case EMUs would be managed with individual mortality targets necessary to increase the stock above $B_{mgt}$ (40%) within a defined time period, whereas the extent of ΣA–reduction depends on the chosen time period (number of generations) until recovery. As long as the stock is below $B_{mgt}$, a reduction in ΣA is advised, in order to allow the stock to rebuild (shrinking of $\Sigma A_{mgt}$). Eel Management Units without an Eel Management Plan should reduce mortality to zero until they have compiled and implemented an effective, peer-reviewed management plan.

The FAO Code of Conduct (FAO, 1995) notes that artificial propagation should not be used "as a substitute for the precautionary measures" to protect a stock. In line with this condition, restocking should not be used as an alternative to reducing mortality.

There are a number of potential consequences that need to be considered:

- For some areas, the currently estimated mortality might already be below the above suggestions for mortality limits. One may consider capping those mortalities at their current value, i.e. not to allow increases in mortality above the current level in any management unit, for as long as the whole stock is outside safe biological limits. In the absence of full insight in the dynamics of the stock, the effect of capping or not capping mortality cannot be quantified.
- ICES provided advice on the conditions for the consideration of a CITES Non-Detriment Finding for trade (ICES, 2015a). The framework worked out above (an international stock status assessment, complemented by national or lower level mortality-assessments) is in agreement with the advice relating to the CITES Non-Detriment Finding, but does not advise a reduction in mortality below $B_{mgt}$, and does not advise setting an appropriate time frame (which determines the rate of reduction in mortality below $B_{mgt}$); ICES 2015 advice on CITES-NDF did not suggest a safety margin, for the recovery of the stock. It would be in line with the Precautionary Approach, to include such a recovery-margin, and to advise to reduce mortality below $\Sigma A_{mgt}$; in the setting of CITES-NDFs too. An NDF assessment on a finer spatial scale than the total area of distribution or only on part of the life stages from glass eel to silver eel requires that information on the contribution of the eel from the subarea/life stage to the spawning stock is available and sufficient to assess the eel subpopulation in question applying the advised criteria. Until such information is available, ICES advised that the scale to be used to make an NDF assessment should cover the entire stock of the European eel (ICES, 2015a).
- Related management structures, with wider/complementary geographical coverage to the Eel Regulation, such as the CMS and GFCM. For these too, a framework of reference points, assessments and scientific advice is required. Realising that the currently proposed framework could be applied within those organisations too, it is noted that a geographically differentiated approach, as proposed here, inevitably applies among these organisations.

In line with the Eel Regulation and the Joint Declaration (Anon, 2017), the progress in EMUs should be evaluated every three years (next in 2021). ICES (2018b) noted that due to the recent decline in recruitment, spawner production is expected to decline further in the near future (Åström and Dekker, 2007) and therefore further reductions in mortality may be required. Reported indicators, as provided by EU Member States in response to the Data call 2018, indicate that the stock in many reporting countries/areas was below the biomass limits of the Eel Regulation and in most management units, anthropogenic mortality is above a level that can be expected to lead to recovery, in many cases even exceeding the level that would sustain a healthy stock.

For assessing the overall status of the stock, stock-wide indicators need to be considered (spawner–stock biomass and recruitment trends). Considering the long generation time, the status of the whole stock should be evaluated every so many years in a Benchmark (https://www.ices.dk/community/advisory-process/Pages/Benchmarks.aspx). A tentative interval of nine years (i.e. every third progress report to the European Commission) can be suggested. During the Benchmarks, national assessments should be re-evaluated and adjusted (QA), stock-wide abundance indicators (B) and reference points should be analysed for appropriateness and recruitment trends should be analysed. The effect of restocking on reference points and the contribution of restocking to reported stock indicators should be assessed on EMU-level and where appropriate reductions in ΣF and ΣH might be assessed separately to compare their contribution to the achieved protection.

## 5.8 Proposals on the consequences of the Precautionary Approach on advice for European eel

ICES (2016c) classified the European eel as a "category 3" stock, "for which survey-based assessments indicate trends". This category "includes stocks for which survey or other indices are available that provide reliable indications of trends in stock metrics, such as total mortality, recruitment, and biomass". For eel, the only stock-wide data available are the recruitment trends while no stock-wide trends for mortality, landings or biomass exist. Therefore, this categorisation does not fully make use of "the best scientific evidence" (on abundance, mortalities, protective actions), does not allow the derivation of "precautionary reference points" and ignores the need to provide advice on the status of the recovery of the stock. Based on these considerations, and checking against the requirements of the FAO Code of Conduct, the ICES form of advice, and the adopted EU Eel Regulation, an eel-specific framework for advice has been developed, above.

We note that this proposal for a framework for advice may be unusual for ICES and therefore suggest that a follow-up workshop convened by ACOM might be appropriate. This workshop should discuss and evaluate the proposed framework and consider any now unforeseen or unintentional consequences, and propose a timetable, criteria for a QA assessments and benchmarks for ACOM's consideration.

Based on the above discussions, the following conclusions can be derived:

1. ICES (2002) has advised to set $B_{lim}$ at 30% of the pristine spawning–stock biomass and $B_{pa}$ at 50%, provisionally. The EU has adopted a long-term objective of 40%. It would be in line with the ICES form of advice (ICES, 2018d), if ICES adopted $B_{mgt}$ = 40% as a provisional management reference point for biomass, and used that as the basis for providing advice.
2. a) The EU Eel Regulation sets an objective for (national or lower level) Eel Management Plans "to reduce anthropogenic mortalities so as to permit escapement of at least [$B_{mgt}$]." For eel, both fishing and non-fishing mortalities make a considerable impact on the stock, and the relevant mortality indicator is the lifetime sum of both, $\Sigma A$. It would be in line with the ICES form of advice, to adopt a mortality limit corresponding to $B_{mgt}$, say $\Sigma A_{mgt}$, and set $\Sigma A_{mgt}$=0.92 (i.e. %SPR=40%, 40% lifetime survival).
   b) For areas without a management plan for eel, a mortality limit of $\Sigma A_{mgt}$ =0 should be advised, until an effective, peer-reviewed management plan has been compiled and implemented.
3. Because the stock abundance is considerably below the management target $B_{mgt}$, it will be appropriate to reduce anthropogenic mortality to below $\Sigma A_{mgt}$, allowing a recovery of the stock. Aligning with the ICES form of advice, it is suggested to adopt $B_{trigger}$=$B_{mgt}$.
4. Restocking is the practice of moving young eels from areas of high, to areas of low abundance, often across the continent. ICES has previously advised on restocking (FAO and ICES, 2011b; ICES, 2016b). It is in line with the precautionary approach not to consider restocking as an alternative to reducing mortality.
5. Neither the Eel Regulation, nor current ICES advice, indicate a time frame for the recovery of the stock. It will be in line with the precautionary approach, to set an explicit time frame. Noting that the dynamics of the eel stock are not well understood, only a provisional time frame can be advised. On theoretical grounds, a provisional time frame can be formulated in number of generations, but lacking full insight in stock dynamics, it is hard to translate that into a real number of years. A specified number of generations translates directly into a corresponding reduction in mortality, where a fixed number of years would not. It is therefore suggested to set a time frame for the recovery of the stock,

formulated in number of generations, for the stock as a whole. This determines the reduction in mortality required for the recovery of the stock, which in turn can be related to management actions (not to a time-line for implementation of protective actions in each Eel Management Unit). WGEEL has earlier discussed a period of three generations, but any value between the most rapid recovery (minimise mortality) and a high number of generations ($\Sigma A_{mgt}$ close to 0.92) might be considered. Obviously, the more generations, the higher the risk of not achieving recovery.

6. Current ICES advice is focused on the whole stock, for which insufficient information is available to give more than a basic precautionary advice to minimize all impacts. It would be in line with the precautionary approach, to provide mortality-focused advice that can be related to management actions. Noting that management actions are differentiated by management areas (Eel Management Units), this boils down to mortality-focused advice per management unit.
   This mortality-focused advice should not replace stock-wide advice, on trends in recruitment (and abundance), but complement that.
7. Assessments of anthropogenic mortality on the eel are available per eel management unit in some EU Member States, based on assessments made under national responsibility. It will be appropriate to consider an international Quality Assurance procedure for these national assessments; preferably initiated in a start-up workshop urgently (noting the next round of EMP progress reporting is 2021) and applied in a full QA soon thereafter; then repeated at an appropriate time interval.
8. The Eel Regulation and the Joint Declaration (Anon, 2017) oblige the EU Member States to report in a triannual cycle; these reports have been the basis of the mortality estimates considered by ICES. Noting that mortality levels show restricted year-to-year variation, it is suggested to adopt a three-year cycle for advice on anthropogenic mortalities per management unit.
9. For the stock as a whole, recruitment indicators show a slow (multidecadal) trend, with large year-to-year fluctuation superimposed. Most of that short-term variation might be due to statistical uncertainty, and short-term fluctuation in environmental factors. There seems to be little point in updating stock-wide advice in a short time cycle, unless unforeseen developments occur. It is therefore suggested to provide stock-wide advice at lower frequency (in line with the ICES form of advice), based on a regular benchmark assessment, phased at every third regular assessment, i.e. every nine years (potentially starting in 2022). The benchmark ToRs may include: stock-wide abundance indicators (B), recruitment, other indicators, appropriateness of the reference points, restocking (relation to reference points, contribution to reported stock indicators), and more.
10. For some areas, the above suggestions for mortality limits might result in a limit above the current estimate of mortality. It might be prudent to cap mortalities at their current value, i.e. not to allow increases in mortality above the current level in any management unit, for as long as the whole stock is outside safe biological limits. In the absence of full insight in the dynamics of the stock, the effect of capping or not capping mortality cannot be quantified.
11. ICES provided its first advice on the European eel in 1999; the Eel Regulation was adopted in 2007; three triannual progress reports have been produced by EU member states, which included an assessment of the national stocks. WGEEL considers that the establishment of an appropriate and effective framework for the advice under the principles of the precautionary approach is a matter of urgency, and notes that the timing of the next triannual assessments in 2021 urges swift action.

# 6 ToR E: Address the task of quantifying the effort that is undertaken in the commercial eel fisheries around Europe

## 6.1 Background

In response to a request from the Chair for input into the 2019 Terms of Reference for the WGEEL, EIFAAC requested that the group address the task of quantifying the effort that is undertaken in the commercial eel fisheries around Europe. The group should compile quantitative and/or qualitative descriptions of eel fishery effort reflecting the local situation and any reductions imposed under the Eel Regulation (EC 1100/2007: European Council 2007).

To fulfil this ToR, a questionnaire and data table were added to the 2019 WGEEL Data call. The objective of the effort questionnaire was to capture the summary description of the eel fisheries present in every country. The fishing effort data table aimed to capture the actual effort data by country/region by licence category by year. This request was the first step towards describing the diversity in fishing methods and developing the most appropriate and efficient metrics.

## 6.2 Introduction

According to FAO, fishing effort is the amount of fishing gear of a specific type used on the fishing grounds over a given unit of time e.g. hours trawled per day, number of hooks set per day or number of hauls of a beach seine per day (FAO, 1997). The impact of a unit of effort on the fish populations and the ecosystem in general differs between waterbodies. In marine and estuarine waters, effort statistics need to take into account vessel type, size and motor power. In freshwater, the number of nets set and number of nights per fisherman can impact on the overall catch. When two or more kinds of gear are used by the same vessel or fisher this must be recorded with the accompanying catch and effort data. Recording capacity and effort in freshwater systems is more complicated due to the variety of fishing methods undertaken across the range states.

In the EU marine waters, the Electronic recording and reporting system (ERS) is used to record, report, process, store and send fisheries data (catch, landing, sales and transhipment). In the electronic logbook the master of a fishing vessel >10/12 m (limit length dependent on region) keeps a record of fishing operations. The record is then sent to the national authorities, which store the information in a secure database. For vessels between 10–12 m (8–10 m in Baltic), it is required to fill out a paper logbook and for vessels less than 10 m there is no obligation to report catches. The European Commission has put forward a proposal to revise the control system, with an aim to modernise, strengthen and simplify the EU fisheries control system and to level the playing field in fisheries controls. Reporting requirements are currently set out in various pieces of EU legislation, Council Regulations 1224/2009 and 2017/2403 and Commission Regulations 404/2011.

In inland waters, there is a great heterogeneity of fishing methods and gear constructions. National inland waters are not managed within the framework of the European Common Fishery Policy so collection of catch data is based on the country-specific regulations. There are no standards set for reporting freshwater commercial fishery data. For recreational fisheries, FAO recommends as a minimum standard mandatory self-reporting of effort, catch, harvest and size of each species caught (FAO, 2012). See section 4.2.1 in 'Fishery based data as abundance indices: assumptions and biases' in this report for further information on the importance of effort data.

According to the latest ICES advice (ICES 2018c), total landings and effort data are incomplete but vary according to country. In addition, there is great heterogeneity among the time-series of landings due to inconsistencies in reporting by, and between, countries. Changes in management practices have also affected the reporting of commercial and non-commercial/recreational fisheries. Therefore, ICES does not have the information needed to provide a reliable estimate of the total catches of eel. Furthermore, the understanding of the stock dynamic relationship is not sufficient to determine/estimate the level of impact that fisheries (at the glass, yellow, or silver eel stage) have on the reproductive capacity of the stock. Information on fishing effort and the capacity of the fisheries is lacking, but is necessary to fully interpret the changes to the landings data over the years. However, the wide variety of fisheries and gear types makes this challenging.

Article 10 of the Eel Regulation (EC 1100/2007) relates to control and enforcement. It is stated that 'Member States shall establish a control and catch monitoring system adapted to the circumstances and to the legal framework already applicable to their inland fisheries, which shall be consistent with the relevant provisions set out in Regulation (EEC) No 2847/93' [note this regulation has since been repealed]. The EU data collection regulation (Regulation 2017/1004) also requires Member States to make available the data needed for scientific analysis, which should include the effort data related to commercial and recreational fisheries. Member States shall also establish on a regular basis an estimate of the number of recreational fishermen and their catches of eels (Article 11 EC 1100/2007).

## 6.3 Results

### 6.3.1 Qualitative Description

Of the 21 countries considered, eleven have an eel-specific licence for commercial fisheries; this means that ten countries only have multispecies licences for commercial gear that captures eels (Table 6.1). In addition to the seven with only multispecies licence, four countries have both eel-specific and multispecies licences. In some cases, this varies by eel management unit.

**Table 6.1. Summary of effort questionnaire for commercial fisheries (y= yes, n = no, np = not pertinent).**

| Country | Eel specific licence | Multispecies licence | Métier type licence | Life stage licence | Season licence | Licences type: other |
|---|---|---|---|---|---|---|
| NO | y | n | n | n | y | n |
| SE | y | n | n | y | n | n |
| FI | np | np | n | n | n | n |
| EE | n | y | y | n | n | n |
| LV | n | y | y | n | n | n |
| LT | y | y | n | n | n | y |
| PL | n | y | y | n | n | n |
| DE | y | y | y | n | y | y |
| DK | y | n | y | n | n | n |
| NL | n | y | y | n | n | n |
| IE | np | np | np | np | np | np |
| FR | y | n | n | y | n | n |
| ES | y | n | y | y | y | y |
| PT | y | y | y | n | y | y |
| IT | n | y | n | y | n | y |
| HR | n | y | y | n | n | n |
| GR | y | y | y | n | y | y |
| UK | y | n | y | n | n | n |
| TN | y | n | y | n | n | n |

An overview showing the different fishing methods by country and waterbody type (Figures 6.1–6.3) highlights the difficulties in quantifying the effort in landings data with many countries involved in different methods and gears to catch eels. Many countries have fisheries that capture eel in all three waterbody types; freshwater, transitional water and marine water, with different legislation and authorities responsible for managing fish stocks across these environments. Figures 6.4 and 6.5 show images of the different types of fishing gear (active and passive methods) from around Europe. For further details on the eel fishing gear and techniques, see EIFAC consultation on eel fishing gear and techniques (EIFAC, 1971).

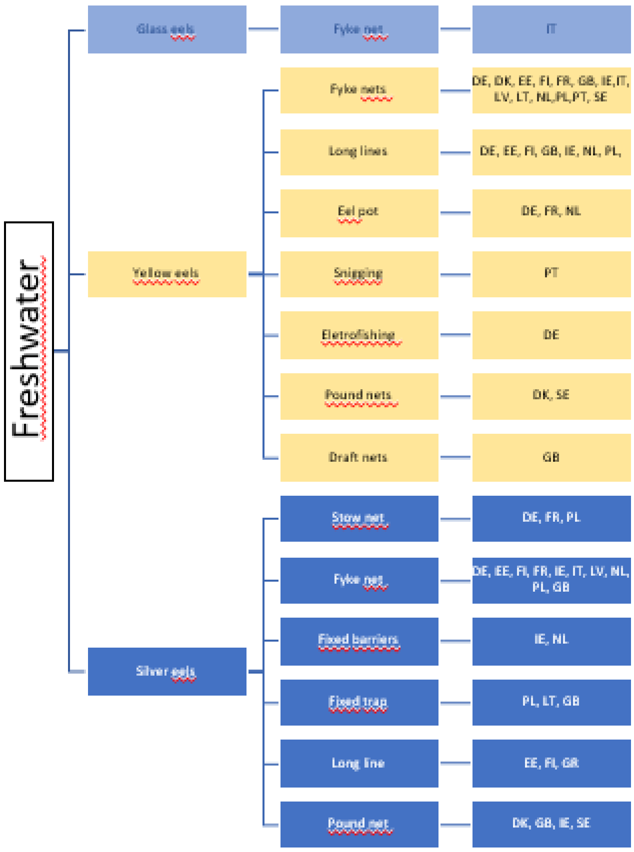


**Figure 6.1. Overview of the main fishing methods for eel in freshwater.**

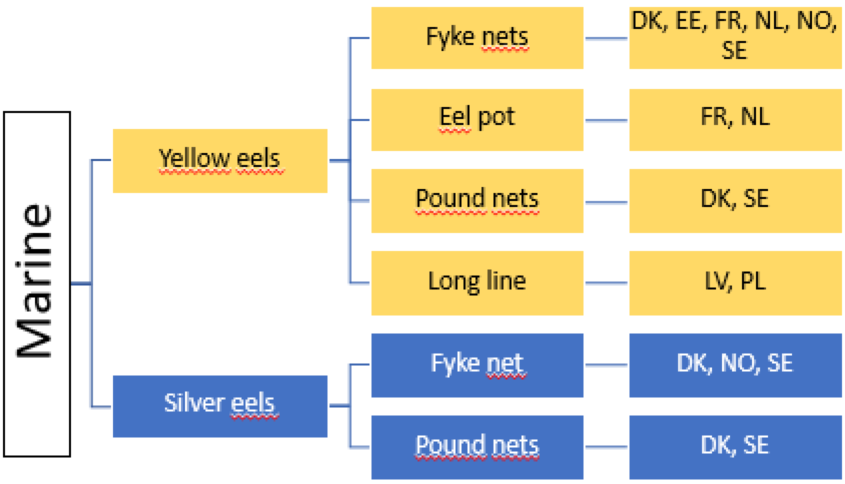


**Figure 6.2. Overview of the main fishing methods for eel in marine waters.**

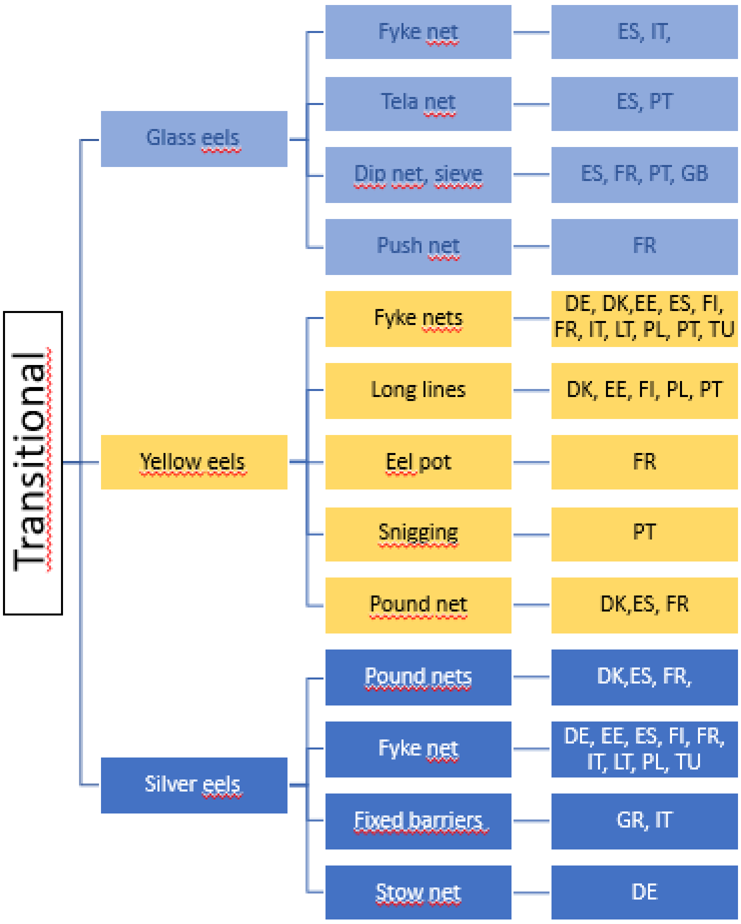


**Figure 6.3. Overview of the main fishing methods for eel in transitional waters.**


**Figure 6.4. Types of fishing gears used to catch eels (glass eel, yellow and silver eel). Fixed barrier (A, B and C) and Shore lift net (N). Passive fishing gears: pots (D) fykenets (E, F and G).**

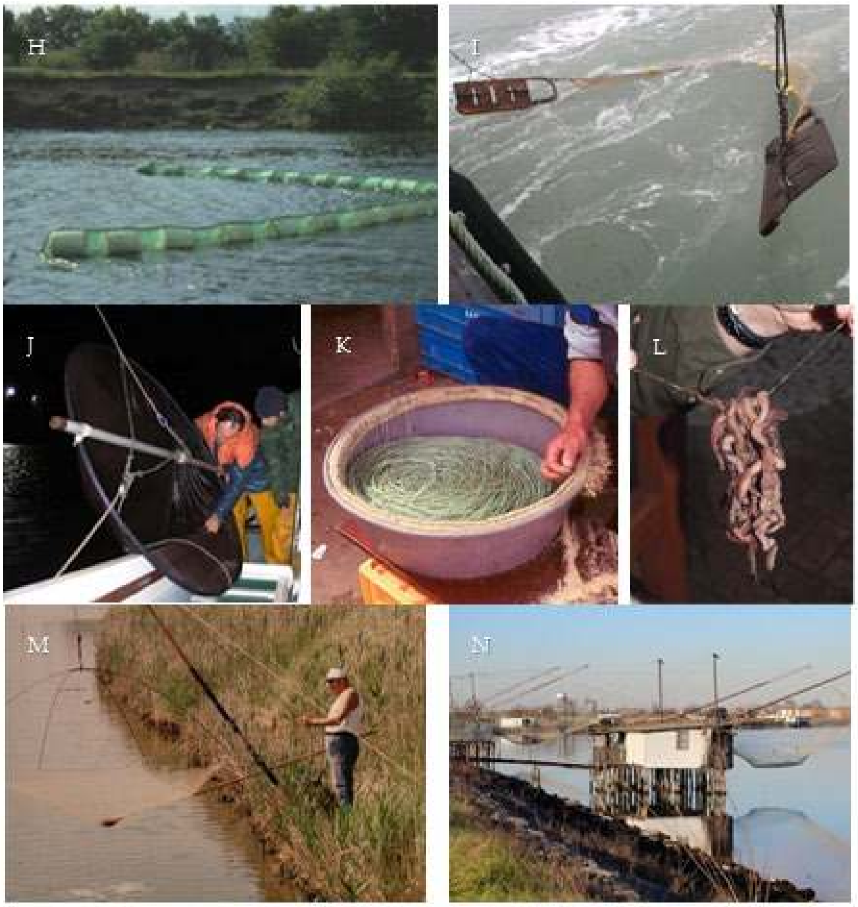


**Figure 6.5. Types of fishing gears used to catch eels (glass eel, yellow and silver eel) continued. Tela (H). Trawling nets (I and J). Linefishing: longlines (K); Umbrella/Snigging (L and M); Shore lift net (N).**

**Photo credits for Figures 6.4 and 6.5.**

**A: Fixed barrier in Greece; photo by courtesy of Argyris Sapoundis**

**B: Fixed barrier in Italy; photo by courtesy of Chiara Leone**

**C: Fish trap from freshwater stream in Norway; photo by courtesy of Eva Thorstad**

**D: Passive traps: pot and fykenet; photo by courtesy of Eva Thorstad**

**E: Fykenet; photo by courtesy of Tomasz Nermer**

**F: Glass eel fykenet in Italy; photo by courtesy of Chiara Leone**

**G: Glass eel fykenet "Busso" in Spain; photo by courtesy of Estibaliz Diaz**

**H: Glass eel stow net "Tela" used in the Minho River; photo by courtesy of Carlos Antunes**

**I: Otter boat trawls; photo @google.com**

**J: Sieve boat trawls; photo by courtesy of Estibaliz Diaz**

**K: Longline; photo @w3.ualg.pt**

**L: Hookless linefishing; photo by courtesy of Jan-Dag Pohlmann**

**M: Hookless linefishing "sniggling"; photo @google.com**

**N: Shore lift net in Italy; photo @google.com**

### 6.3.2 Quantitative Analysis

The practice in some countries of combining fishing methods under one licence, makes it impossible to determine how much fishing effort (number of gears, nets, nights) was undertaken to reach the declared eel catch. Table 6.2 shows the types of fishing methods combined under different licence regimes by country. This is a practice that does not provide the required data for the WGEEL (as an enduser) to analyse.

An exploratory analysis of the effort data was undertaken for the key commercial eel fishing methods (fykenets and longlines). The following graphs are the results of this exploratory analysis and are presented here to illustrate the complex nature of the data provided. Detailed analysis was not undertaken due to time constraints in verifying reported data.

**Table 6.2. Fishing methods and grouped methods reported in 2019 Data call.**

| Fishing method | Countries | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| angling | DE | IE | IT | LT | | | | | | | | | | |
| baited pot | IE | | | | | | | | | | | | | |
| barrier | IT | | | | | | | | | | | | | |
| barriers, fences, weirs | DE | | | | | | | | | | | | | |
| beach seines | DE | | | | | | | | | | | | | |
| beam trawls | DE | HR | | | | | | | | | | | | |
| dip net | ES | GB | | | | | | | | | | | | |
| eel pot | LV | | | | | | | | | | | | | |
| eel trap | LT | LV | | | | | | | | | | | | |
| eelbox | NL | | | | | | | | | | | | | |
| eelpout trap net | LV | | | | | | | | | | | | | |
| EF | DE | | | | | | | | | | | | | |
| fixed trap | IE | | | | | | | | | | | | | |
| fyke | DE | EE | ES | GB | GR | HR | IE | IT | LT | NL | NO | PL | SE | TN |
| fykenets, stow nets | DE | | | | | | | | | | | | | |
| fykenet (eelfyke, large fyke, fixed fyke) | NL | | | | | | | | | | | | | |

| Fishing method | Countries |
|---|---|
| fykenet, chinchorro (hand dragged trawl net), sniggling, longline, rod | PT |
| handlines and pole-lines | HR |
| harpoon | EE HR IT |
| hooked fishing gear (except longlines) and fykenets | GR |
| Longline | DE EE GB GR IE IT LV NL |
| Longlines and fykenets | GR |
| miscellaneous | DE |
| mixed | DE |
| otter trawls | HR |
| paranza | ES |
| portable lift nets | DE |
| pot | DE |
| pound nets | IE GB LV SE |
| poundnet, fykenet, longline | DK |
| round goby fykenet | LV |
| SAF | DE |
| set gillnets | HR |

| Fishing method | Countries | | |
|---|---|---|---|
| set Longlines | DE | HR | PL |
| shore lift net | IT | | |
| sieve, boat trawling | ES | | |
| stow net | DE | | |
| tela net | ES | PT | |
| trammel nets | HR | | |
| trap net | LV | | |
| umbrella | IT | | |
| vessel seines | HR | | |
| ZUG | DE | | |

## 6.4 Fykenet Fishing

Figure 6.6 depicts fykenet catches by country and habitat, showing the variation in catches within countries, waterbodies and years. Without the corresponding effort data, the catch levels cannot be interpreted accurately to represent trends in the commercial fishery for eel.

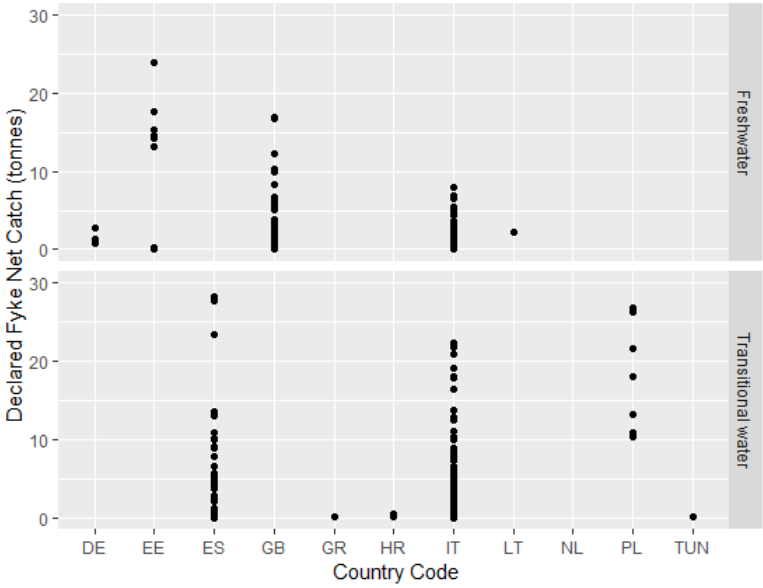


**Figure 6.6. Fykenet catch (tonnes) and country for the years 2008 and 2014–2018.**

For scenarios without details on the number of fykenets, an examination of the average number of days shows no link to fykenet catches (Figure 6.7); however, the data had to be restricted as some countries reported an average number of days by number of traps with values exceeding 365 days. A workshop on harmonising the reporting of fishery data would improve the availability of effort and capacity data for stock assessment.

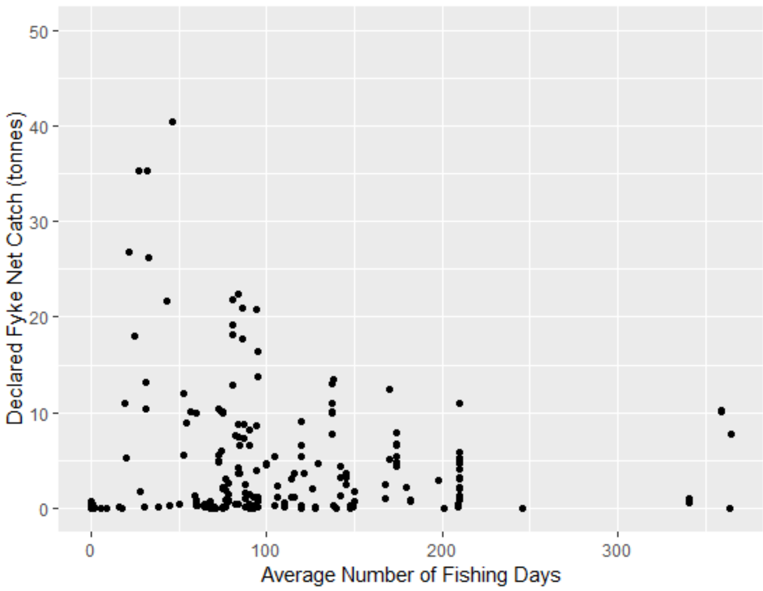


**Figure 6.7. Fykenet catch and average number of fishing days for the years 2008, 2014–2018.**

An examination of the number of licences did not reveal any relationship with fykenet eel catch (Figure 6.8). The number of licences issued by a governing body does not necessarily relate to the number of active fishers. Fishers can continue to apply for a licence despite the likelihood that they will not fish the season if the economic benefits of fishing are not there (FAO, 1997).

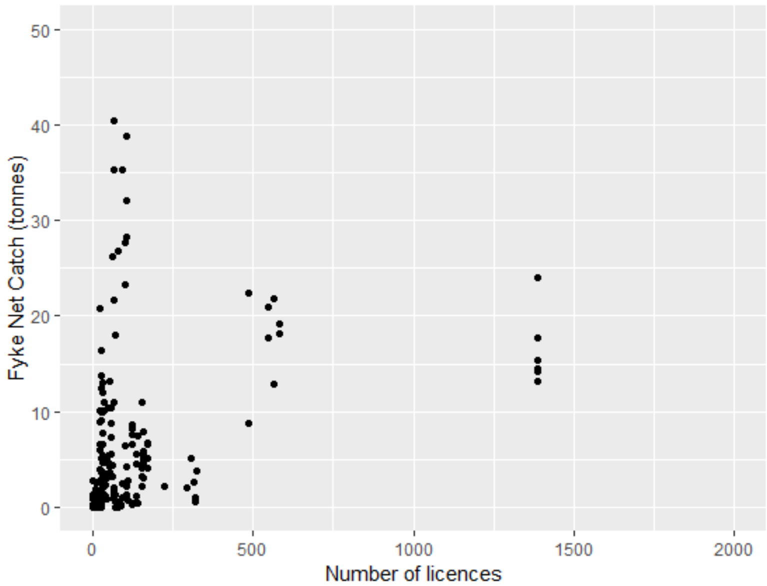


**Figure 6.8. Fykenet catches and number of licences for the years 2008, 2014–2018.**

Figure 6.9 shows an overview of fykenet catch with a metric of unit of effort*average number of days fished (graph on the left) and unit of effort*average number of days fished*number of licences (graph on the right). It would be expected that the fykenet catch would increase with fishing effort, be it with number of days fishing and amount of gear. However, due to the variation in the reporting of these metrics the reliability of these data are questionable and further investigation is required. The information is shown here for completeness.


**Figure 6.9. Fyke catch (tonnes) and unit of fishing effort * days (left graph) and unit of effort*days*number licences (right graph).**

## 6.5 Longline fishery

Six countries included Longline fishing in the effort part of the Data call 2019. There are more countries involved in Longline fishing (n = 10) however the licences are grouped with other methods such as fykenets and cannot be separated. In some instances, the number of licences was included but no corresponding eel catch. The effort associated with a Longline licence can vary from 1000 hooks to 100 hooks or can be unspecified. Figure 6.10 shows the Longline catch and number of licences as reported in the data call.

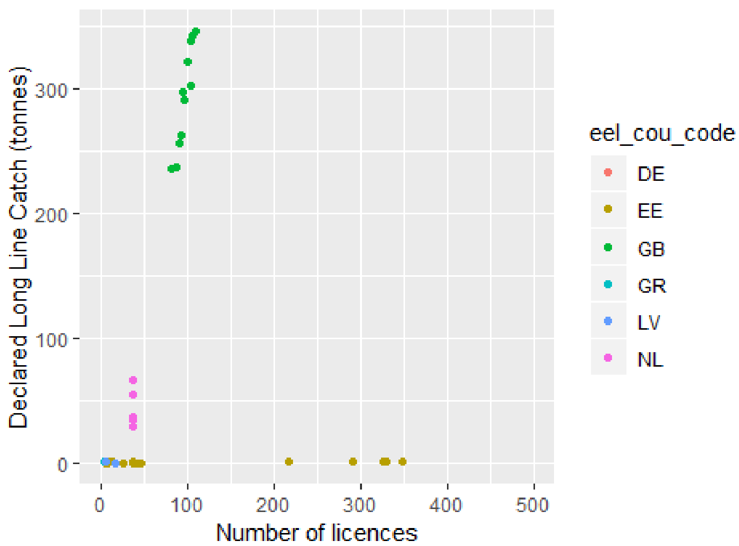


**Figure 6.10. Longline catch and number of licences years 2008, 2014–2018.**

For Longline fishing, the Data call-reported average number of fishing days shows an upward trend with Longline catch (tonnes) (Figure 6.11). Catch and average number of fishing days were only supplied by the United Kingdom and Latvia, and the average number of days in some cases was calculated using other metrics (days * number of boats). This will require further investigation.

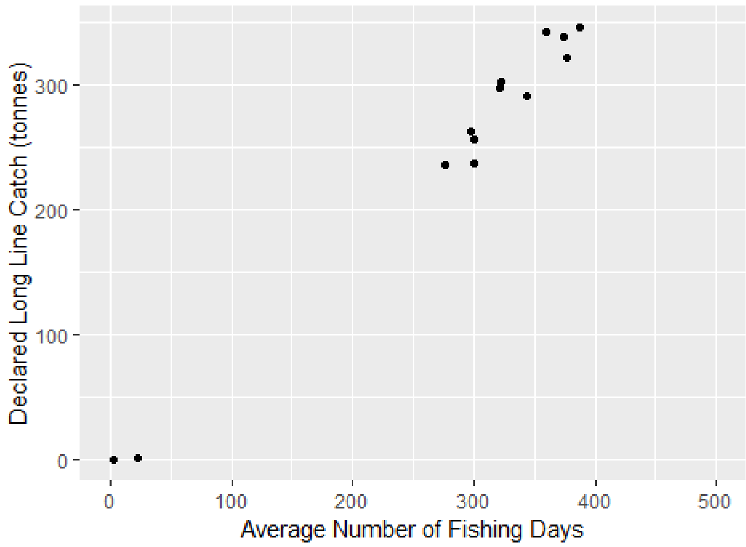


**Figure 6.11. Longline catch and average number of fishing days years 2008, 2014–2018.**

## 6.6 Discussion

Eels are fished at all life stages in continental waters, through commercial and recreational fisheries. These fisheries can include both active (e.g. rod and line, spear, dipnet), and passive fishing methods (e.g. traps, pots, fykenets). The lack of a standardised reporting of fishing effort to accompany the landings data requested by the WGEEL affects the interpretation of the changes that have occurred over the years, as acknowledged in a previous working group report (ICES, 2018b). Despite remaining largely unquantified, the impact of recreational fisheries on the eel stock is thought to be at a similar order of magnitude to that of commercial fisheries (ICES, 2018b). Therefore, the analysis of the Country Reports on fishing effort has raised doubts that need to be carefully addressed.

Describing and quantifying the capacity and fishing effort that is undertaken in the commercial eel fisheries around Europe is extremely challenging. In total, 19 countries have completed the Data call fishing effort tables and submitted all available information about fishery and license types. It should be noted however, that in some cases data are only available for some EMUs, due to the absence of fisheries in the remaining EMUs.

Effort is hard to quantify for a number of reasons. First, there is a large diversity in administrative responsibilities both between and within the countries and habitat types. The eel fishery occurs in different types of habitats, such as marine waters, estuaries, coastal lagoons and freshwater rivers and lakes. These habitats can be under different jurisdictions in each country. The eel fisheries can be managed at different scales (national, regional or local level e.g. EMU or river basin) and be ruled by a variety of regulations with different requirements at different scales of application.

Secondly, fishing licences can be either multispecies or eel-specific, and in some countries there can be both licence types within the same EMU. Licences for the commercial fishery can be issued to individual fishermen or boats or to companies. These licences can fix the number and type of gears; set the season or the targeted life-stage. In some cases, there are no restrictions issued with the licence in relation to gear type or number.

Thirdly, fishing gears can vary from region to region and can be specific for each Region/EMU/Country due to local traditions. A good example is given by the small-scale artisanal fishery that has been practised for centuries in the coastal lagoons of the Mediterranean and the Atlantic areas. Furthermore, the lack of standardization in the name or typology of gears in terms of mesh size, dimensions, and methods of use render this task even more arduous. In particular, in the case of fykenets, which can be used individually or linked together, the fishing effort can be biased by the catch ability of the gear. Finally, in many places, fishing effort has changed over time, as a result of specific regulations for the eel fishery (different life stages) that have been put into force to comply with the targets of the Eel Management Plans. Any attempt to compare fishing effort before and after the implementation of these measures remains challenging and requires careful attention that needs to be addressed.

In order to interpret the eel landings data there is a need to develop a consistent approach to licensing eel-specific fishing across all types of natural eel habitat. Some countries have already adapted their licensing in the last few years by requesting additional information from the fishers. In Norway since 2016, the commercial fishery is limited to a total quota of 20 t, corresponding to approximately 30 fishers. Fishers are asked to report data per fishing trip: number and total weight of eels, number of fykenets, soak time, and bycatch (in numbers). In Greece, the commercial licensing system was updated in 2017. Finland implemented a logbook-based registry for inland commercial fisheries since 2016.

## 6.7 Conclusion

Inland fisheries are mainly managed at the national level and do not fall under the Common Fisheries Policy except in relation to diadromous species during the marine phase (such as the eel). The changes to the European Maritime and Fisheries Fund (EMFF) and the Data Collection Multi Annual Programme (EU MAP) have resulted in funding support for inland fisheries in EU Member States. Under the Data Collection Regulation (EU) 2017/1004 there is a requirement on 'data on the activity of union fishing vessels in and outside Union waters including levels of fishing and on effort and capacity of the Union fleet'. The use of 'Union waters' in this regulation can be misinterpreted to exclude data on inland waters as Union waters often refers to shared waters, whereas Union waters constitute all waters of Member States of the European Union. The inclusion of eel-specific requirements under the Commission Implementing Decision (2016/1251) has resulted in an increase in the biological data available to the WGEEL.

The data collected under the Framework of EU MAP are well aligned with the ICES data call requesting data on all three continental life stages of the European eel (i.e. glass eel recruitment, standing stock of yellow eels, and silver eel escapement) as well as annual catch quantities (note, however, that the WG only uses landings data). While data on recruitment have been an integral part of past assessments, data on the standing stock and silver eel escapement were collected in the 2019 data call for the first time. These dataseries will provide valuable additions for the stock assessment in the future, since the limitation to recruitment is considered one of the major shortcomings of past assessments. Though stock-related variables are not directly used by the WG, they are important for national assessments, which provide towards the assessment of the WG and are thus indispensable.

However, the inclusion of detailed effort data together with eel catches by fishing method and life stage would ensure the availability of suitable eel related data for fishery managers. All EU

Member States with "waters that constitute natural habitats for European eel" should fully implement the Eel Regulation requirement of adequate reporting of effort in the commercial and recreational fisheries in all waterbodies.

| **Recommendations** | **Addressed to** |
|---|---|
| As an end user of the DCF data, WGEEL recommends the inclusion of detailed fishing effort and capacity data for eel fisheries in the DC-MAP regulation to ensure the availability of adequate fishery data to undertake stock assessments. | Diadromous sub-group of the RCGs |
| A workshop is required with fishery managers from across the eel range states to determine how to harmonise the reporting on key commercial eel fisheries in order to provide adequate data to WGEEL and national stock assessors. | ACOM, EIFAAC, GFCM |

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# Annex 2: Acronyms and Glossary

| ACRONYMS | DEFINITION |
| --- | --- |
| ACFM (ICES) | Advisory Committee on Fisheries Management |
| ACOM (ICES) | Advisory Committee on Management |
| ADGEEL (ICES) | Advice drafting group on eel, for ICES |
| AngHV-1 | Anguillid herpes virus 1 |
| BERT | Bayesian Eel Recruitment Trend model |
| CAGEAN | The Catch-at-Age Analysis Model |
| CITES | Convention on International Trade in Endangered Species |
| CMS | Convention on Migratory Species |
| CPUE | Catch per unit of effort |
| C&R | Catch and release |
| DD | Density-dependent |
| DCF | Data Collection Framework |
| DEMCAM | Demographic Camargue Model |
| DG MARE | Directorate-General for Maritime Affairs and Fisheries, European Commission |
| DNA | Deoxyribonucleic acid |
| DPMA | Direction des Pêches Maritimes et de l'Aquaculture, France |
| e-DNA | Environmental DNA |
| EC | European Commission |
| EDA | Eel Density Analysis (modelling tool) |
| EIFAAC | European Inland Fisheries & Aquaculture Advisory Commission |
| EIFAC | European Inland Fisheries Advisory Commission |
| EMP | Eel Management 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 Union Multi Annual Plan |
| EVEX | Eel Virus European X |
| FAO | Food and Agriculture Organisation |
| FEAP | The Federation of European Aquaculture Producers |
| GEM | German Eel Model |
| GFCM | General Fisheries Commission of the Mediterranean |
| GIS | Geographic Information Systems |
| GLM | Generalised Linear Model |
| HPS | Hydroelectric power Station |
| ICES | International Council for the Exploration of the Sea |
| IMESE | Irish model for estimating silver eel escapement |
| IUCN | The International Union for the Conservation of Nature |
| IUU | Illegal, unreported, unregulated fisheries |

| ACRONYMS | DEFINITION |
|---|---|
| GST | Glutathione-S-transferase |
| LAM | Lifetime anthropogenic mortalities |
| MS | Member State |
| MSY | Maximum Sustainable Yield |
| MoU | Memorandum of Understanding |
| NAO | North Atlantic Oscillation |
| NC | "Not Collected", activity / habitat exists but data are not collected by authorities (for example where a fishery exists but the catch data are not collected at the relevant level or at all). |
| NDF | Non-Detriment Finding |
| NP | "Not Pertinent", where the question asked does not apply to the individual case (for example where catch data are absent as there is no fishery or where a habitat type does not exist in an EMU). |
| ONEMA | Office National de l'Eau et des Milieux Aquatiques, France (ex-CSP) |
| PAH | Polyaromatic hydrocarbons |
| PBDE | Polybrominated diphenyl ether |
| PCB | Polychlorinated biphenyl |
| PFOS | Perfluorooctane sulfonate |
| POSE | Pilot projects to estimate potential and actual escapement of silver eel |
| RBD | River Basin District |
| RGEEL | Review Group on Eel (ICES) |
| SAC | The GFCM Scientific and Advisory Committee on Fisheries |
| SCICOM | The Science Committee of ICES |
| SGIPEE | Study Group on International Post-Evaluation on Eels |
| SLIME | Restoration the European Eel population; pilot studies for a scientific framework in support of sustainable management |
| SMEP II | Scenario-based Model for Eel Populations, vII |
| SPR | Estimate of spawner production per recruiting individual. |
| SRG | Scientific Review Group |
| SSB | Spawning–Stock Biomass |
| ToR | Terms of Reference |
| WG | Working Group |
| WGEEL | Joint EIFAAC/ICES/GFCM Working Group on Eel |
| WGRFS | The Working Group on Recreational Fisheries Surveys |
| WKAREA | Workshop on Age Reading of European and American Eel |
| WKBECEEL | Working Group on Biological Effects of Contaminants in Eel |
| WKEPEMP | The Workshop on Evaluating Progress with Eel Management Plans |
| WKESDCF | Workshop on Eels and Salmon in the Data Collection Framework |
| WKPGMEQ | The Workshop of a Planning Group on the Monitoring of Eel Quality |
| WFD | Water Framework Directive |
| WKEMP | ICES Workshop on Eel Management Plans |
| 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 |
|---|---|
| WGRFS | Working Group on Recreational Fisheries Surveys |
| YFS1 | Young Fish Survey: North Sea Survey location |
| IYFS | International Young Fish Survey |

# Glossary

| | DEFINITION |
|---|---|
| Bootlace | Intermediate sized eels, approx. 10–25 cm in length (fingerlings). 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. |
| 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 Management Unit (Eel River Basin) | "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 (silver eel) | The amount of silver eel that leaves (escapes) a waterbody, after taking account of all natural and anthropogenic losses. |
| 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. In some cases, however, also includes the early pigmented stages. |
| 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. |
| On-grown eels | Eels that are grown in culture facilities for some time before being restocked. |
| Silver eel production | The amount of silver eel produced from a water body. Sometimes referred to as escapement + anthropogenic losses, or production-anthropogenic losses = escapement. |
| River Basin District | The area of land and sea, made up of one or more neighbouring river basins together with their associated surface and groundwaters, transitional and coastal waters, which is identified under Article 3(1) of the Water Framework Directive as the main unit for management of river basins. The term is used in relation to the EU Water Framework Directive. |
| 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. |
| Restocking | Restocking is the practice of adding fish [eels] to a waterbody from another source, to supplement existing populations or to create a population where none exists. |

| | DEFINITION |
|---|---|
| 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). |
| Yellow eel (Brown 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). Sometimes yellow eel is also called ‘brown eel’. |

| | DEFINITION |
|---|---|
| **EEL REFERENCE POINTS/POPULATION DYNAMICS** | |
| $B_{current}$ or $B_{curr}$ (Current escapement biomass) | The amount of silver eel biomass that currently escapes to the sea to spawn, corresponding to the assessment year. |
| $B_{best}$ (Best achievable biomass) | Spawning biomass corresponding to recent natural recruitment that would have survived if there was only natural mortality and no restocking, corresponding to the assessment year. |
| $B_0$ (Pristine biomass) | Spawner escapement biomass in absence of any anthropogenic impacts. |
| $B_{lim}$ (Limit spawner escapement biomass) | Spawner escapement biomass, below which the capacity of self-renewal of the stock is considered to be endangered and conservation measures are requested. |
| $B_{MSY}$ | Spawning–stock biomass (SSB) that is associated with Maximum Sustainable Yield (MSY) |
| $B_{pa}$ (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. |
| F | Fishing mortality rate |
| $F_{lim}$ | $F_{lim}$ 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 $F_{lim}$. |
| $F_{MSY}$ | $F_{MSY}$ is estimated as the fishing mortality with a given fishing pattern and current environmental conditions that gives the long-term maximum yield. |
| M | Natural mortality |
| MSY | Maximum Sustainable Yield |
| MSY $B_{trigger}$ | 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. |
| Precautionary spawner escapement biomass (Bpa) | 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. |
| Pristine | Conditions not affected by humans |
| R(s) | The amount of eel (<20 cm) restocked into national waters annually |
| R2 | Determination coefficient |
| Spawner per recruitment (SPR) | 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. |
| 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 |

| **EEL REFERENCE POINTS/POPULATION DYNAMICS** | |
|---|---|
| ΣA | The sum of anthropogenic mortalities, i.e. ΣA = ΣF + ΣH. It refers to mortalities summed over the age groups in the stock. |
| 3 Bs & ΣA | Refers to the three biomass indicators ($B_0$, $B_{best}$ and $B_{current}$) and anthropogenic mortality rate (ΣA). |

Definition: 40% EU Target: "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.

# Annex 3: Participants list

| Name | institution | country | e-mail |
|---|---|---|---|
| Elsa Amilhat | University of Perpignan | France | elsa.amilhat@univ-perp.fr |
| Tea Basic | Cefas | United Kingdom | Tea.basic@cefas.co.uk |
| Laurent Beaulaton | French Agency for Biodiversity | France | Laurent.beaulaton@afbiodiversite.fr |
| Claude Belpaire | Instituut voor Natuur- en Bosonderzoek | Belgium | Claude.Belpaire@inbo.be |
| Priit Bernotas | Estonian University of Life Sciences | Estonia | pbernotas@emu.ee |
| Cedric Briand | Institution d'Amenagement de la Viliane | France | cedric.briand@eptb-vilaine.fr |
| Andreas Bryhn | Swedish University of Agricultural Sciences | Sweden | andreas.bryhn@slu.se |
| Fabrizio Capoccioni | Consiglio per la Ricerca in Agricoltura e l@analisi dell’Economia Agraria (CREA) | Italy | fabrizio.capoccioni@crea.gov.it |
| Eleonora Ciccotti | Dept of Biology<br>Universitá di Roma Tor Vergata | Italy | ciccotti@uniroma2.it |
| Willem Dekker | Swedish University of Agricultural Sciences<br>Department of Aquatic Resources<br>Institute of Freshwater Research | Sweden | Willem.Dekker@slu.se |
| Estibaliz Diaz | AZTI-Tecnalia<br>Sukarrieta | Spain | ediaz@azti.es |
| Isabel Domingos | Universidade de Lisboa<br>Faculdade de Ciências (Sciences) | Portugal | idomingos@fc.ul.pt |
| Hilaire Drouineau | National Research Institute of Science and Technology for Environment and Agriculture | France | Hilaire.Drouineau@irstea.fr |
| Caroline Durif | Institute of Marine Research<br>Austevoll Aquaculture Research Station | Norway | caroline.durif@hi.no |
| Derek Evans | Agri-food and Biosciences Institute (AFBI) | NI, UK | derek.evans@afbini.gov.uk |
| Lukasz Giedrojc | National Marine Fisheries Research Institute | Poland | lgiedrojc@mir.gdynia.pl |
| Matthew Gollock | Zoological Society of London, London | United Kingdom | Matthew.gollock@zsl.org |

| Name | institution | country | e-mail |
|---|---|---|---|
| Tessa van der Hammen | Wageningen University & Research<br>Wageningen Marine Research | Netherlands | tessa.vanderhammen@wur.nl |
| Reinhold Hanel | Thünen Institute<br>Institute for Fisheries Ecology<br>Branch Hamburg-Rothenburgsort | Germany | reinhold.hanel@thuenen.de |
| Lisa Horn | North Rhine Westfalian State Agency for Nature, Environment and Consumer Protection<br>Department 26 - Fishery Ecology | Germany | lisa.horn@lanuv.nrw.de |
| Katarzyna Janiak<br>Observer | DGMARE | Belgium | Katarzyna.JANIAK@ec.europa.eu |
| Kenzo Kaifu<br>Observer | Chuo University | Japan | kaifu@tamacc.chuo-u.ac.jp |
| Chiara Leone | Universitá di Roma Tor Vergata<br>Consorzio Nazionale Interuniversitario per le Scienze del Mare (CoNISMa) | Italy | chiara.leone@uniroma2.it |
| Linas Lozys | Laboratory of Marine Ecology<br>Nature Research Centre | Lithuania | linas.lozys@gamtc.lt |
| Lasse Marohn | Institute for Fisheries Ecology | Germany | Lasse.marohn@thuenen.de |
| Tomasz Nermer | National Marine Fisheries Research Institute | Poland | nermer@mir.gdynia.pl |
| Ciara O'Leary | Inland Fisheries Ireland | Ireland | ciara.oleary@fisheriesireland.ie |
| Michael Ingemann Pedersen | Danmarks Teknologisk Universitet (DTU-Aqua) | Denmark | mip@aqua.dtu.dk |
| Jan-Dag Pohlmann | Institute for Fisheries Ecology | Germany | jan.pohlmann@thuenen.de |
| Russell Poole | Marine Institute<br>Fisheries Ecosystem Advisory Services | Ireland | russell.poole@marine.ie |
| Justas Povliūnas | Fisheries service under the ministry of Agriculture of the Republic of Lithuania | Lithuania | justas.poviliunas@zuv.lt |
| Robert Rosell | Agri-food and Biosciences Institute-AFBI | NI, UK | robert.rosell@afbini.gov.uk |
| Mehis Rohtla | Estonian Marine Institute<br>University of Tartu | Estonia | mehis.rohtla@ut.ee |
| Argyris Sapoundis | Fisheries Research Institute | Greece | asapoun@inale.gr |
| Janek Simon | Institute of Inland Fisheries Potsdam | Germany | janek.simon@ifb-potsdam.de |

| Name | institution | country | e-mail |
|---|---|---|---|
| Josefin Sundin | Swedish University of Agricultural Sciences<br>Department of Aquatic Resources<br>Institute of Freshwater Research | Sweden | Josefin.sundin@slu.se |
| Arvydas Svagzydys | Klaipeda University<br>Marine Research Institute | Lithuania | arvydasrusne@gmail.com |
| Eva Thorstad | Norwegian Institute for Nature Research | Norway | eva.thorstad@nina.no |
| Sami Vesala | Natural Resources Institute Finland–Luke | Finland | Sami.vesala@luke.fi |
| Alan Walker<br>Chair | Centre for Environment, Fisheries and Aquaculture Science-Cefas<br>Lowestoft Laboratory | UK | alan.walker@cefas.co.uk |
| Håkan Wickström | Swedish University of Agricultural Sciences<br>Department of Aquatic Resources<br>Institute of Freshwater Research | Sweden | hakan.wickstrom@slu.se |

# Annex 4: Meeting agenda

**Tuesday 27th August**

10:00–11:00 Welcome, tour de table, reminder of ToR, adopting the agenda, declarations of potential Conflict of Interests, rules and procedures, etc.

11:00–11:15 Chair's report on activities in last year.

11:15–12:00 SG 1: WKEELDATA2, data call, Overview of status (Cedric & Jan-Dag)

12:00–13:00 Lunch

13:00–13:30 SG 2: science

13:30–14:00 SG 3: precautionary approach

14:00–14:30 Coffee break

14:30–15:00 SG 5: threats to assessment dataseries

15:00–15:30 SG 6: fishing effort

15:30–16:00 GFCM research plan

16:00–16:10 Other presentations (eel viruses)

**Wednesday 28th**

09:00–10:00 Presentations of six Country Reports (maximum 10 minutes per country)

10:00–10:30 Other presentations (DIADes, CITES)

10:30–12:00 All Task Groups breakout

12:00–13:00 Lunch

13:00–17:00 All task groups breakout

17:00–17:30 Plenary to review any urgent actions or discussion points

**Thursday 29th**

09:00–10:00 Presentations of six Country Reports (maximum 10 minutes per country)

10:00–12:00 All Task Groups breakout

12:00–13:00 Lunch

13:00–17:00 All task groups breakout

17:00–17:30 Plenary to review any urgent actions or discussion points

**Friday 30th**

09:00–10:00 Presentations of six Country Reports (maximum 10 minutes per country)

10:00–12:00 All Task Groups breakout

12:00–13:00 Lunch

13:00–15:00 Discuss draft advice

15:00–18:00 All Task groups breakout

**Saturday 31st**

09:00–13:00 Task groups finalise & QA their report sections

13:00 Deadline for providing report sections to AW for compilation

14:00 Break/reading/whatever

**Sunday 1st September**

09:00–13:00 Reading the report

13:00–14:00 Lunch

14:00–18:00 Plenary to agree the report (as long as it takes!)

**Monday 2nd September**

09:00–13:00 Tying up loose ends, finalising the report and plans for 2020

13:00 Close Working Group

# Annex 5: Country Reports

In preparation for the Working Group, participants of each country have prepared a Country Report, in which the most recent information on eel stock and fishery is presented. These Country Reports aim at presenting the best information that does not necessarily coincide with the official status.

Participants from the following countries provided an updated report to the 2019 meeting of the Working Group on Eels:

- Belgium
- Denmark
- Estonia
- Finland
- Germany
- Greece
- Ireland
- Italy
- Latvia
- Lithuania
- Netherlands
- Norway
- Poland
- Portugal
- Spain
- Sweden
- The United Kingdom of Great Britain and Northern Ireland

For practical reasons, this report presents the Country Reports in electronic format only (URL).

Country Reports 2018/2019

# Annex 6: Data call 2020 – DRAFT

## 1. Rationale

This Data call is intended to formalize data reporting across all countries with natural production of European eel. Therefore, this is a joint call from ICES, EIFAAC and GFCM to seek data from all range states of the European eel. Please note that no DCF/EU MAP activity does not exempt any Country from reporting.

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'.

Recognizing that the collection and provision of all eel and metadata is a huge task, the introduction of the Data call has been phased in over three years (2017, 2018, 2019), giving time to clarify the process for those providing the data and for the WGEEL and ICES to organize the data in the most efficient manner. In 2017, the Data call focused on data directly required to achieve the annual stock assessment in support of the ICES Advice, while in 2018 the Data call included the request for the data on silver eel stock indicators, biomass production and escapement and anthropogenic mortality rates, etc., as specified by the Eel Regulation 1100/2007 and associated EMPs. According to the Regulation and the Joint Declaration between the EU and Member States (December, 2017), these data will be reported every three years and are thus not part of the present (2020) Data call.

In addition to the annual update on data required for the stock assessment (recruitment, landings, releases and stocking, and aquaculture data), the 2020 Data call includes a request for data concerning silver eel escapement and yellow eel abundance (in the following called yellow eel abundance and silver eel indices).

### Output

The data and metadata provided for the Data call 2020 will be used as the basis for the annual stock assessment in support of the advice for the eel stock, and will be integrated in an electronic database for the European Eel stock. This database will be 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.

### Legal framework

The legal framework for the Data call is as follows, though noting that these don't all apply to every eel producing country:

- Council Regulation (EC) No 2017/1004 concerning the establishment of a Union framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy.
- Council Regulation (EU) No 1380/2013 on the Common Fisheries Policy, amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and repealing Council Regulations (EC) No 2371/2002 and E(EC) No 639/2004 and Council Decision 2004/585/EC.

- Council Regulation (EC) No 1100/2007 of 18 September 2007 establishing measures for the recovery of the stock of European eel.

## Legal framework rationale

ICES is mandated to request all fisheries-dependent and -independent data used to provide this advice. This mandate is supported by international agreements and the current EU data collection framework (DCF/EU MAP).

All the governments and intergovernmental commissions requesting and receiving advice from ICES have signed international agreements under UNCLOS 1995* Fish Stocks agreement article 5 and 6 (to incorporate fisheries impacts on other components of marine ecosystems) and WSSD 2002 article 30 (to implement an ecosystem approach in relation to oceans policy including fisheries). These agreements include an obligation to collect and share data on, *inter alia*, vessel position (UNCLOS FSA art 5) and to support assessment of the impacts of fisheries on non-target species and the environment (UNCLOS FSA art 6).

For EU Member States, this Data call is under the DCF regulation ((EC) No 2017/1004 and Commission Decision 2016/1251/EU) and in particular, Article 17(3) of regulation (EC) No 2017/1004 which states "*..requests made by end-users of scientific data in order to serve as a basis for advice to fisheries management, Member States shall ensure that relevant detailed and aggregated data are updated and made available to the relevant end-users of scientific data within the deadlines set in the request*,.."

This Data call follows the principles of personal data protection, as referred to in paragraph (9) of the preamble in Council Regulation (EC) No 2017/1004.

* United Nations (UN). 2011. Agreement related to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks. Available at: https://documents-dds-ny.un.org/doc/UNDOC/GEN/N95/274/67/PDF/N9527467.pdf?OpenElement

# 2. Scope of the Data call

This Data call is addressed to those countries within the geographic range of the European eel. These countries are distributed across different global and regional management organisations such as those represented in WGEEL (EIFAAC, ICES, GFCM).

Concerning all Annexes, if any of the values already integrated require corrections/an update (e.g. due to incomplete reporting in past data calls), please provide new data for the respective year(s).

**Table 1. List of species.**

| Common name | Code | Scientific name |
|---|---|---|
| European eel | EEL | *Anguilla anguilla* |

In this 2020 Data call, we ask for submission of all available 'eel data' (with the respective 'metadata'), including historical data that have not yet been integrated to the database, for European eel on:

- Silver eel indices (only empirical data; no model output);
- Yellow eel abundance indices (only empirical data; no model output). Note, that these do not refer to yellow eel recruitment time-series, but only to those that provide a measure of the standing stock.

In addition to the annual update on:

- Recruitment (only empirical data; no model output);
- Landings (formerly Catch);
- Releases (formerly Stocking);
- Aquaculture production.

And a general request concerning:

- the public status of the data provided (including data already in the database); and
- information on fishing effort by eel fisheries in all waters.

Alongside each of these eel data, we request the following 'metadata' (only provide not previously reported or an update/corrections are necessary):

- Data Steward: name and email address of a person who can be contacted about the dataset.
- Method used: short description of the method used to collect the data. Should be filled under ser_comment.

These metadata are further described in the data input sheets of Annexes 1 to 9.

# 3. Deadlines

ICES requests the data to be delivered to provide enough time for additional quality assurance prior to the WGEEL meeting. Therefore, data should be submitted by e-mail to the WGEEL stock coordinator by (to be confirmed), 2020. This deadline is set according to the ICES standards. Missing the reporting deadline will compromise the indispensable data quality checking (on a stock basis) before the use of that data to update assessments.

# 4. Data submission

The data should be submitted using the templates supplied in Annexes 1–6 to this Data call. A detailed list of data formats, instructions and codes (e.g. treatment of nil values) to be used in the database can be found in Annexes 1–7. Whenever the input is constrained (in the form of a drop-down menu), do not use any input other than the given options. Also, ICES area should not be provided for freshwater. Please refer to dictionary tables (labelled tr…) in the sheets, and follow the detailed instructions about stages in the following annex description.

In the case of GFCM Experts and/or Focal Points participating in WGEEL, please complete the Annexes 1–7 to for this Data call as much as it is possible and, when submitting them to ICES, also send a copy to the GFCM DCRF team (DCRF@gfcmonline.org) for information.

# 5. Recruitment (Annex 1)

- Recruitment data are defined as the quantities of eel caught at specific (index) locations as they 'recruit' to the local vicinity. These captures can be either by fisheries or fishery-independent studies, using gears that include handnets, fykenets, trapping ladders and other means of capture.

- The WGEEL uses these time-series data to calculate the Recruitment Indices, relative to the reference period of 1960–1979, and the results form the basis of the annual Single Stock Advice reported to the European Commission.
- Data should be provided as annual values.
- The units of data are either numbers or biomass (kg). Equivalents (e.g. glass eel equivalents, gee) do not suffice. If only equivalents are available, they do not need to be reported.
- Those recruitment dataseries used in the Recruitment Indices are described in detail in the ICES European eel Stock Annex: (http://www.ices.dk/sites/pub/Publication%20Reports/Stock%20Annexes/2016/Anguilla_anguilla_SA.pdf). However, the Data call also seeks new dataseries not listed in the Stock Annex.
- The recruitment series are categorized as glass eel (G), mixture of glass and yellow eels dominated by glass eel (GY), and larger yellow eel (Y) recruiting to continental habitats. Do not use any other stage. The young or larger yellow eel may consist of multiple year classes of eel but they are all 'recruiting' to the stock past the survey point in the same year.
- Note that glass eel series relates to spring of reported year.
- Please do not fill series_info unless the series has not been previously reported or information needs to be updated/corrected.
- A separate excel file should be provided for each dataseries. Extend the name of each file by the short name of the series.
- Note, that a biometry tab has been added to the Annex. Providing these data is optional, and does not need to be done if it would prevent the data call being publicly available.

# 6. Yellow eel abundance Indices (Annex 2)

- The WGEEL requires data on time-series of yellow eel abundance (i.e. standing stock, in contrast to mixed and yellow eel recruitment time-series) as an independent measure in order to confirm local trends in the standing stock. Data in this sheet should be based on empirical observations in a specific location, such as scientific surveys or fisheries-based surveys of yellow eel abundance (e.g. based on CPUE).
- A separate excel file should be provided for each dataseries. Extend the name of each respective file by the short name of the series.
- Data should be reported by year
- The units of data are either numbers, biomass (kg) or indices
- Where there are multiple sites surveyed, for example throughout a river basin, mean values for the river basin should be reported.
- An additional sheet called biometry has been provided to enter biological information (average length, weight and age of yellow eels) related with the time series of yellow eel abundance.
- Note, that a biometry tab has been added to the Annex. Providing these data are optional, and do not need to be done if it would prevent the data call being publicly available.

# 7. Silver eel indices (Annex 3)

- The WGEEL requires data on silver eel indices in order to assess relative trends in the escapement and use them as an independent measure of local trends in escapement. Data in this sheet should be based on empirical observations in a specific location, such as scientific surveys or fisheries-based time series of silver eel escapement (e.g. based on CPUE).

- Data should be reported by year.
- The units of data are either numbers, biomass (kg) or indices.
- A separate excel file should be provided for each dataseries. Extend the name of each respective file by the short name of the series.
- An additional sheet called biometry has been provided to enter data about the average length, weight and age of silver eels collected each year in the time-series. In this sheet you can enter separate information for female and males and the sex-ratio. See readme for columns definition.
- Note, that a biometry tab has been added to the Annex. Providing these data are optional, and do not need to be done if it would prevent the data call being publicly available.
- Note that the silver eel series relates to autumn of reported year.

# 8. Landings (Annex 4)

- Landings data are defined as the quantity of eel that are harvested and brought to land. That is, they include regular landings from fisheries. They also include eels that are later released, which also need to be reported in the Releases (Annex 5), except for eels that were caught and released within the same EMU, with no change in mortality; these should not be reported in both Landings and Releases (in compliance with Annex 5). Trap and Transport data should be reported as "Other landings".
- The WGEEL uses these data to report trends in landings in the ICES Single Stock Advice. This information is requested by the Administrative Agreement between ICES and the European Commission.
- Data should be provided as annual total values, according to life stage (glass (G), yellow (Y), silver (S)) and fishing activity type (commercial or recreational). When they are not possible to separate, a mixing of yellow and silver eel (YS) can be used in the reports. Do not use any other stage for landings, those will be refused at data integration.
- The units of data are kg.

# 9. Releases (Annex 5)

- Releases data are defined as the quantity of eel that are released alive into waters of a basin or management unit. That is, they include activities described as Restocking, Assisted Migration, Trap and Transport, or Catch and Release, except if the released eels were caught and released within the same waterbody, with no change in mortality, which should not be reported in both Landings and Releases (in compliance with Annex 4).
- The WGEEL uses these data to check against eel production estimates and anthropogenic mortality rates reported by countries.
- Data must be provided in annual totals <u>both</u> in weight (kg) and numbers, per eel management unit. If you do not have either one of the two values, calculate an estimate based on an average eel weight.
- The units of data are numbers <u>and</u> kg of eel when they are released, except where reporting Glass Eel Equivalents (GEE) that should be numbers only.
- The stages can be glass (G), yellow (Y), ongrown eel (OG) quarantined glass eel (QG) or silver (S). Do not use the GY stage here, it is used only to describe recruitment series.

# 10. Aquaculture production (Annex 6)

- Aquaculture production data are defined as the quantity of eel produced on an annual basis from aquaculture facilities.
- Data should be provided as annual total weights per country.
- The units of data are kg.
- Some aquaculture production data have previously been included in official landings statistics, but this must be avoided.
- Some eels are grown in aquaculture for periods of time and then released alive to waters not necessarily those from where they were caught. This can be done for a variety of reasons. Such eels should be registered as landed when they are caught and then stocked (released) and not as aquaculture production.
- All pre-grown eels produced should be reported as ongrown eels (code OG).

# Contacts

The national response to the Data call should be sent to:

- Jan-Dag Pohlmann. WGEEL Stock Coordinator. Email: jan.pohlmann@thuenen.de

For support concerning issues about the data call please contact:

- Cédric Briand. WGEEL Stock Assessor. Email: Cedric.Briand@eptb-vilaine.fr
- Jan-Dag Pohlmann. WGEEL Stock Coordinator. Email: jan.pohlmann@thuenen.de

For questions about the content of the data call, please contact: advice@ices.dk

For questions on data submission, please contact: data.call@ices.dk

# Annex 7: Stock Annex

The table below provides an overview of the WGEEL Stock Annex. Stock Annexes for other stocks are available on the ICES website Library under the Publication Type "Stock Annexes". Use the search facility to find a particular Stock Annex, refining your search in the left-hand column to include the *year*, *ecoregion*, *species,* and *acronym* of the relevant ICES expert group.

| **Stock ID** | **Stock name** | **Last updated** | **Link** |
|---|---|---|---|
| *Anguilla anguilla* | European eel | September 2016 | *Anguilla anguilla* |

# Annex 8: Additional Figures and Tables for Section 3

### Additional figures

We provide the same figures as in the main text but Figure A7.1 (below) is the same as Figure 3.2.2 without log scale on the y-axis. For the prediction, figures with log scales are provided (Figures 7.8 and 7.9).

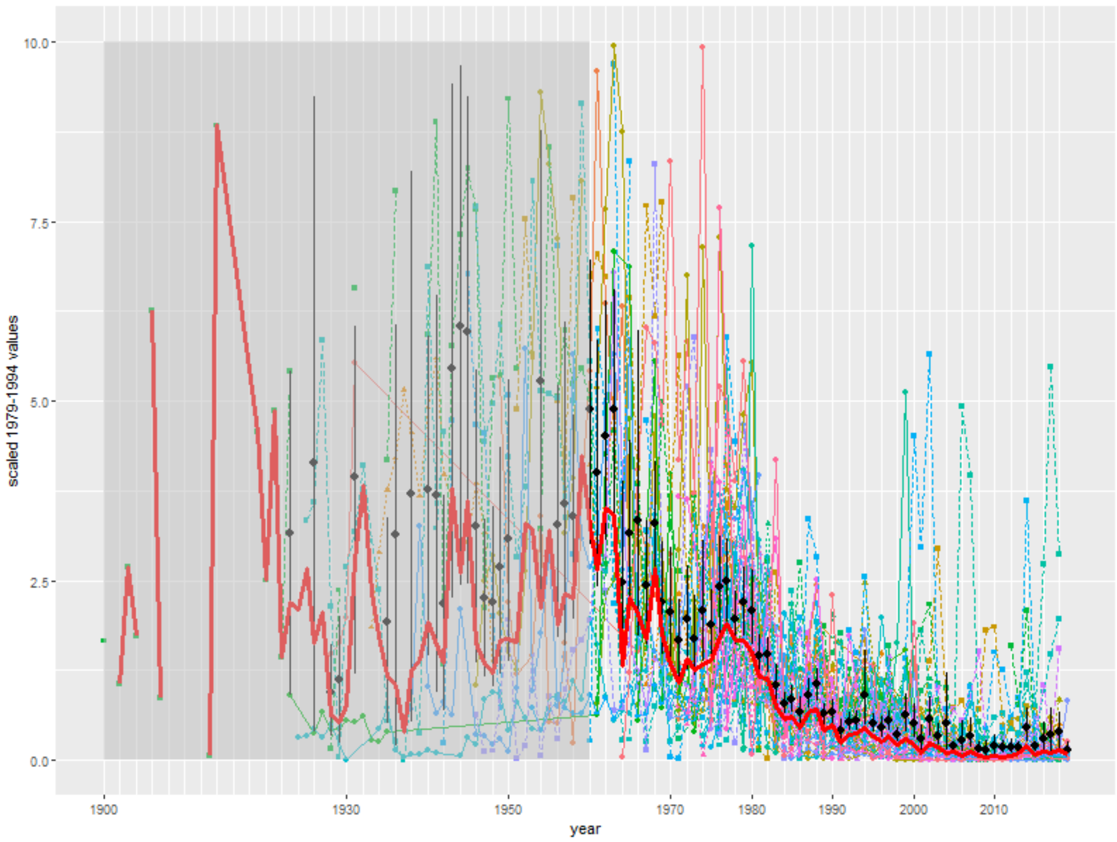


**Figure A7.1. Same as Figure 3.2.2 (in, the body of the report) but without log scale.**

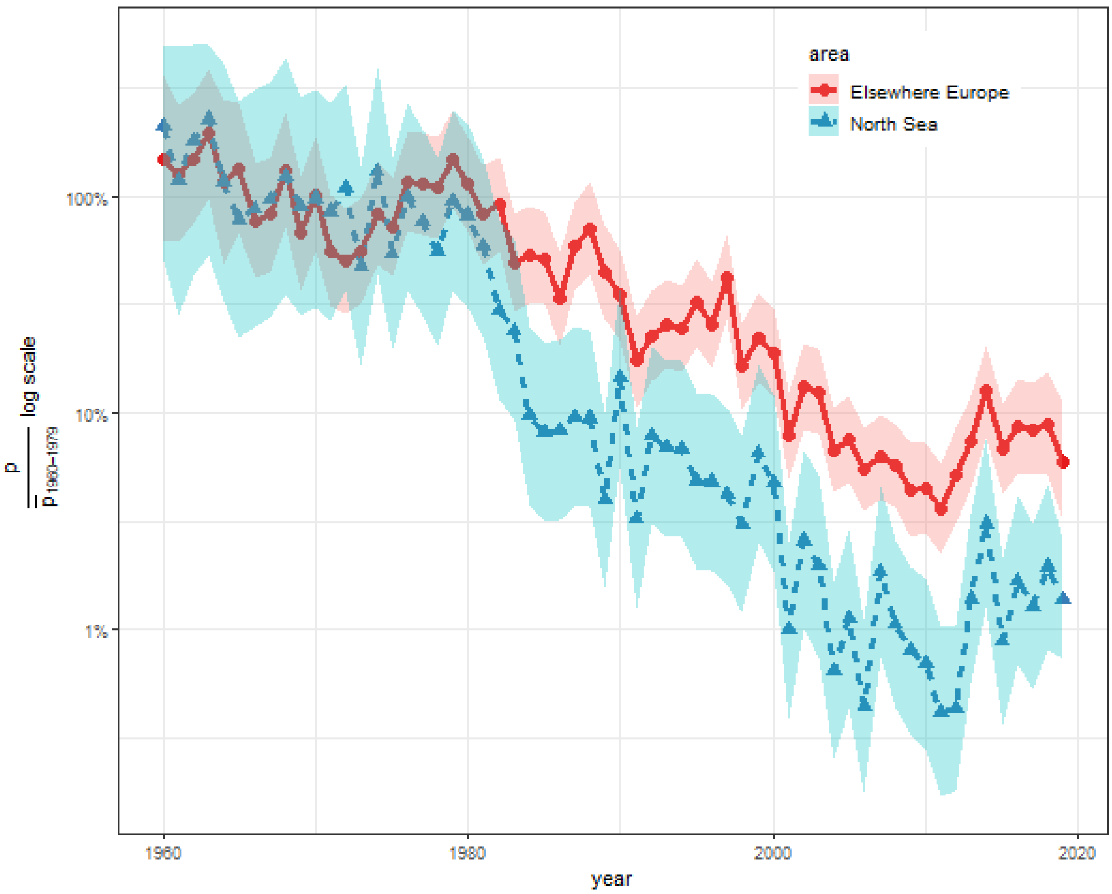


**Figure A7.2. Same as Figure 3.2.5 but with a log scale.**

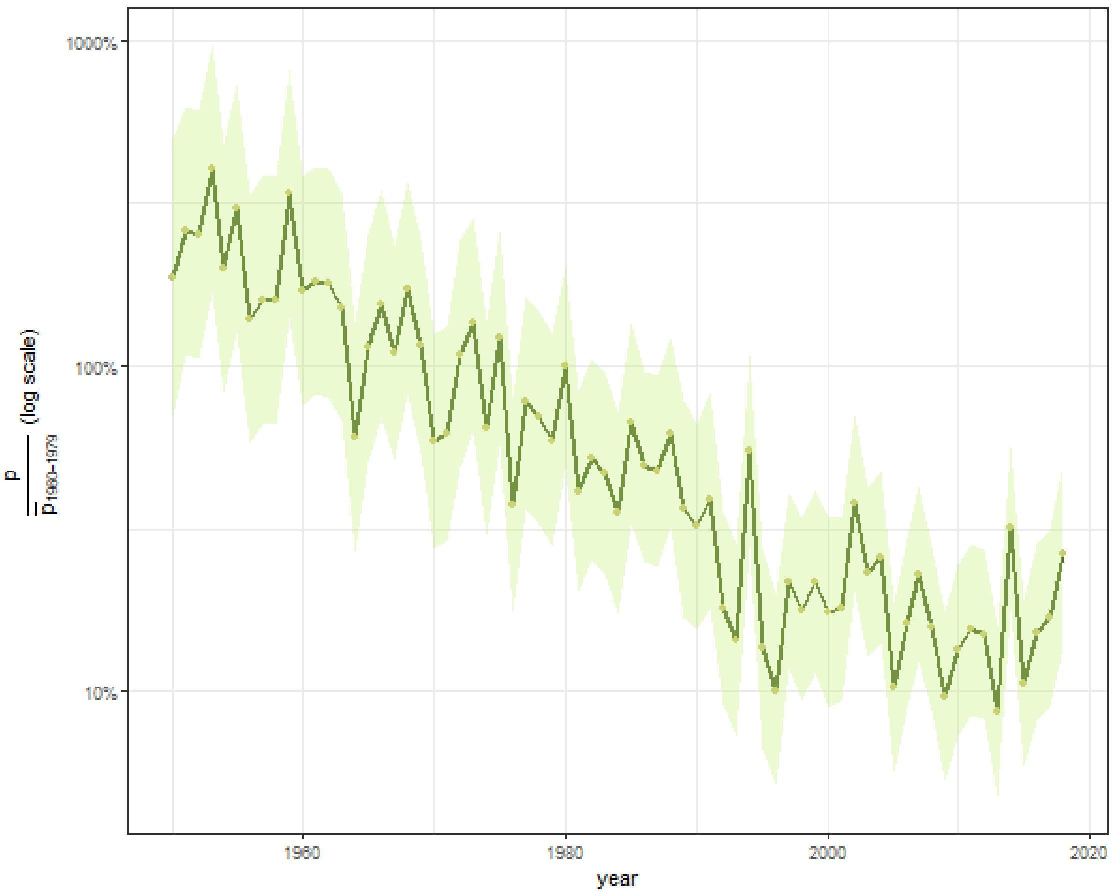


**Figure A7.3. Same graph as Figure 3.2.6 but with a log scale.**

**Table A7.1. Aquaculture for all stages in tonnes from 1980 to 2019, reported by countries: SE Sweden, FI Finland, EE Estonia, LT Lithuania, DE Germany, DK Denmark, NL Netherlands, IE Ireland, GB United Kingdom, FR France, ES Spain, PT Portugal, IT Italy, GR Greece.**

| eel_year | SE | FI | EE | LT | DE | DK | NL | IE | ES | PT | IT | GR | sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1984 | | | | | | 18 | | | | | | | 18 |
| 1985 | | | | | | 40 | | | | | | | 40 |
| 1986 | | | | | | 200 | | | | | | | 200 |
| 1987 | | | | | | 240 | 100 | | | | | | 340 |
| 1988 | | | | | | 195 | 300 | | | | | | 495 |
| 1989 | | | | | | 430 | 200 | | | | | | 630 |
| 1990 | | | | | | 586 | 600 | | | | | | 1186 |
| 1991 | | | | | | 866 | 900 | | | | | | 1766 |
| 1992 | | | | | | 748 | 1100 | | | | | | 1848 |
| 1993 | | | | | | 782 | 1300 | | | | | | 2082 |
| 1994 | | | | | | 1034 | 1450 | | | | | | 2484 |
| 1995 | | | | | | 1324 | 1540 | | | | | | 2864 |
| 1996 | | | | | | 1568 | 2800 | | | | | | 4368 |
| 1997 | | | | | | 1913 | 2450 | | | | | | 4363 |
| 1998 | | | | 2 | | 2483 | 3250 | | 347 | | | | 6082 |
| 1999 | | | | 2 | | 2718 | 3500 | | 383 | | | | 6603 |
| 2000 | | | | 1 | | 2674 | 3800 | | 411 | | | | 6886 |
| 2001 | | | | 5 | | 2000 | 4000 | | 339 | | | | 6344 |
| 2002 | | | 20 | 17 | | 1880 | 4000 | | 295 | | | | 6212 |
| 2003 | | | 40 | 20 | | 2050 | 4200 | | 292 | | | | 6602 |
| 2004 | 158 | | 50 | 9 | 328 | 1500 | 4500 | | 377 | | 1220 | 500 | 8642 |
| 2005 | 222 | | 80 | 8 | 329 | 1700 | 4500 | | 321 | | 1131 | 500 | 8791 |
| 2006 | 191 | | 100 | 12 | 567 | 1900 | 4200 | | 275 | | 807 | 385 | 8437 |
| 2007 | 175 | | 100 | 13 | 774 | 1617 | 4000 | | 369 | | 1000 | 454 | 8502 |
| 2008 | 248 | | 90 | 11 | 749 | 1740 | 3700 | | 460 | | 551 | 489 | 8038 |
| 2009 | 286 | | 60 | 12 | 667 | 1707 | 3200 | 0 | 493 | | 677 | 428 | 7530 |
| 2010 | 186 | | 40 | 8 | 681 | 1537 | 2000 | 0 | 392 | 0.285 | 641 | 428 | 5913.285 |
| 2011 | 182 | | 50 | 13 | 692 | 1156 | 2300 | 0 | 468 | 0.562 | 510 | 372 | 5743.562 |

| eel_year | SE | FI | EE | LT | DE | DK | NL | IE | ES | PT | IT | GR | sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2012 | 186 | | 70 | 4 | 744 | 1093 | 2600 | 0 | 373 | 0.886 | 737 | 490 | 6297.886 |
| 2013 | 184 | 0 | | 7 | 758 | 824 | 2900 | 0 | 393 | 1 | 642 | 971 | 6680 |
| 2014 | 128 | 1 | 56 | 14 | 926 | 842 | 2300 | 0 | 406 | 0.916 | 572 | 837 | 6082.916 |
| 2015 | 208 | 1 | 52 | 0.41 | 1176 | 1234 | 2000 | 0 | 454 | 0.89 | 460 | 1084 | 6670.3 |
| 2016 | 234 | 0 | 61 | 73 | 1099 | 1033 | 2000 | 0 | 330 | 2 | 432 | 1148 | 6412 |
| 2017 | 154 | 0 | 50 | | 1203 | 550 | 2005 | 0 | 292 | 33 | 478 | 732 | 5497 |
| 2018 | 130 | | | | 1 | 182 | 2155 | | | | | 128 | 2414 |

**Table A7.2. Glass eel commercial fisheries landings (in tonnes) from 1984 to 2018, reported by countries: GB United Kingdom, FR France, ES Spain, PT Portugal, IT Italy.**

| Year | GB | FR | ES | PT | IT | sum |
|---|---|---|---|---|---|---|
| 1980 | 40 | 1491 | 15 | 20 | | 1566 |
| 1981 | 37 | 890 | 13 | 36 | | 976 |
| 1982 | 48 | 866 | 19 | 44 | | 977 |
| 1983 | 17 | 791 | 10 | 13 | | 831 |
| 1984 | 25 | 528 | 16 | 32 | | 601 |
| 1985 | 20 | 444 | 18 | 30 | | 512 |
| 1986 | 19 | 423 | 6 | 14 | | 462 |
| 1987 | 21 | 461 | 9 | 19 | | 510 |
| 1988 | 21 | 504 | 10 | 5 | | 540 |
| 1989 | 21 | 410 | 10 | 6 | | 447 |
| 1990 | 21 | 325 | 5 | 9 | | 360 |
| 1991 | 1 | 179 | 7 | 6 | | 193 |
| 1992 | 5 | 183 | 4 | 9 | | 201 |
| 1993 | 6 | 329 | 5 | 7 | | 347 |
| 1994 | 10 | 329 | 2 | 6 | | 347 |
| 1995 | 12 | 413 | 5 | 11 | | 441 |
| 1996 | 19 | 262 | 15 | 17 | | 313 |
| 1997 | 9 | 287 | 12 | 9 | | 317 |
| 1998 | 11 | 195 | 14 | 9 | | 229 |
| 1999 | | 242 | 14 | 7 | | 263 |
| 2000 | | 206 | 11 | 6 | | 223 |
| 2001 | 0.809 | 101 | 12 | 2 | | 115.809 |
| 2002 | 0.521 | 202 | 9 | 2 | | 213.521 |
| 2003 | 2 | 151 | 10 | 3 | | 166 |
| 2004 | 0.97 | 89 | 5 | 2 | | 96.97 |
| 2005 | 2 | 89 | 6 | 2 | | 99 |
| 2006 | 1 | 67 | 4 | 5 | | 77 |
| 2007 | 2 | 77 | 5 | 2 | | 86 |

| Year | GB | FR | ES | PT | IT | sum |
|---|---|---|---|---|---|---|
| 2008 | 0.817 | 79 | 5 | 2 | | 86.817 |
| 2009 | 0.291 | | 4 | 3 | | 7.291 |
| 2010 | 1 | 41 | 6 | 5 | | 53 |
| 2011 | 2 | 31 | 5 | 2 | | 40 |
| 2012 | 3 | 34 | 5 | 2 | | 44 |
| 2013 | 6 | 34 | 7 | 2 | | 49 |
| 2014 | 12 | 35 | 11 | 2 | 0.425 | 60.425 |
| 2015 | 3 | 36 | 9 | 3 | 0.159 | 51.159 |
| 2016 | 4 | 46 | 7 | 0.856 | 0.06 | 57.916 |
| 2017 | 3 | 46 | 11 | 4 | 0.146 | 64.146 |
| 2018 | 4 | 54 | 3 | 1 | 0.243 | 62.243 |
| 2019 | 4 | 50 | 4 | 0.587 | | 58.587 |

**Table A7.3. Glass eel recreational fisheries landings (in tonnes) from 1980 to 2019, reported by countries: FR France, ES Spain.**

| Year | FR | ES | sum |
|---|---|---|---|
| 1980 | 1303 | | 1303 |
| 1981 | 904 | | 904 |
| 1982 | 219 | | 219 |
| 1983 | 161 | | 161 |
| 1984 | 156 | | 156 |
| 1985 | 71 | | 71 |
| 1986 | 87 | | 87 |
| 1987 | 172 | | 172 |
| 1988 | 40 | | 40 |
| 1989 | 110 | | 110 |
| 1990 | 54 | | 54 |
| 1991 | 87 | | 87 |
| 1992 | 77 | | 77 |
| 1993 | 130 | | 130 |
| 1994 | 74 | | 74 |
| 1995 | 113 | | 113 |
| 1996 | 25 | | 25 |
| 1997 | 39 | | 39 |
| 1998 | 6 | | 6 |
| 1999 | 6 | | 6 |
| 2000 | 2 | | 2 |
| 2001 | 1 | | 1 |
| 2002 | 37 | | 37 |
| 2004 | | 0.858 | 0.858 |
| 2005 | 0 | 1 | 1 |
| 2006 | 1 | 2 | 3 |
| 2007 | 0 | 1 | 1 |
| 2008 | 0 | 2 | 2 |

| Year | FR | ES | sum |
|---|---|---|---|
| 2009 | 0 | 0.439 | 0.439 |
| 2010 | 0 | 0.821 | 0.821 |
| 2011 | 0 | 0.389 | 0.389 |
| 2012 | 0 | 1 | 1 |
| 2013 | 0 | 2 | 2 |
| 2014 | 0 | 2 | 2 |
| 2015 | 0 | 2 | 2 |
| 2016 | 0 | 2 | 2 |
| 2017 | 0 | 2 | 2 |
| 2018 | 0 | 2 | 2 |
| 2019 | 0 | 0.865 | 0.865 |

**Table A7.4. Commercial fisheries landings (in tonnes) for yellow eel and silver eel from 1980 to 2019 (part 1), reported by countries: NO Norway, SE Sweden, FI Finland, EE Estonia, LV Latvia, LT Lithuania, PL Poland, DE Germany, DK Denmark, NL Netherlands (to be continued for other countries in next table).**

| Year | NO | SE | FI | EE | LV | LT | PL | DE | DK | NL |
|---|---|---|---|---|---|---|---|---|---|---|
| 1980 | 387 | 1112 | | 26 | 9 | 45 | 1214 | | 2288 | 664 |
| 1981 | 369 | 887 | | 22 | 10 | 27 | 944 | | 2227 | 722 |
| 1982 | 385 | 1161 | | 14 | 12 | 28 | 911 | | 2541 | 842 |
| 1983 | 324 | 1212 | | 29 | 9 | 23 | 868 | | 2119 | 937 |
| 1984 | 310 | 963 | | 72 | 12 | 27 | 819 | | 1871 | 691 |
| 1985 | 352 | 1029 | | 75 | 18 | 29 | 1022 | 1097 | 1630 | 679 |
| 1986 | 272 | 829 | | 61 | 19 | 32 | 921 | 1119 | 1672 | 721 |
| 1987 | 282 | 700 | | 67 | 25 | 20 | 887 | 1031 | 1279 | 538 |
| 1988 | 513 | 933 | | 110 | 15 | 23 | 943 | 1018 | 1878 | 425 |
| 1989 | 313 | 903 | | 55 | 13 | 21 | 813 | 964 | 1696 | 526 |
| 1990 | 336 | 918 | | 61 | 13 | 19 | 768 | 830 | 1675 | 472 |
| 1991 | 323 | 1060 | | 52 | 14 | 16 | 670 | 725 | 1465 | 573 |
| 1992 | 372 | 1154 | | 39 | 17 | 12 | 638 | 762 | 1451 | 548 |
| 1993 | 340 | 1121 | | 59 | 19 | 10 | 568 | 790 | 1080 | 293 |
| 1994 | 472 | 1265 | | 47 | 19 | 12 | 635 | 833 | 1200 | 330 |
| 1995 | 454 | 950 | | 45 | 38 | 9 | 642 | 778 | 892 | 354 |
| 1996 | 353 | 1053 | | 55 | 24 | 9 | 629 | 603 | 752 | 300 |
| 1997 | 467 | 1065 | | 59 | 25 | 11 | 526 | 616 | 797 | 285 |
| 1998 | 331 | 646 | | 44 | 30 | 17 | 544 | 567 | 597 | 323 |
| 1999 | 447 | 702 | | 65 | 26 | 18 | 599 | 645 | 717 | 332 |
| 2000 | 281 | 531 | | 67 | 15 | 11 | 444 | 591 | 628 | 382 |
| 2001 | 304 | 643 | | 67 | 19 | 12 | 435 | 569 | 707 | 440 |
| 2002 | 311 | 591 | | 50 | 11 | 13 | 373 | 544 | 614 | 371 |
| 2003 | 240 | 565 | | 49 | 11 | 12 | 366 | 498 | 648 | 311 |
| 2004 | 237 | 583 | | 39 | 11 | 16 | 337 | 475 | 546 | 311 |
| 2005 | 249 | 676 | | 31 | 12 | 22 | 220 | 455 | 534 | 256 |
| 2006 | 293 | 732 | | 33 | 8 | 16 | 184 | 472 | 596 | 241 |
| 2007 | 194 | 702 | | 31 | 10 | 15 | 181 | 424 | 537 | 197 |

| Year | NO | SE | FI | EE | LV | LT | PL | DE | DK | NL |
|---|---|---|---|---|---|---|---|---|---|---|
| 2008 | 211 | 671 | 1 | 31 | 13 | 14 | 160 | 408 | 466 | 148 |
| 2009 | 69 | 514 | 2 | 22 | 5 | 9 | 161 | 374 | 467 | 109 |
| 2010 | 32 | 525 | 2 | 19 | 9 | 19 | 173 | 366 | 422 | 447 |
| 2011 | 0 | 450 | 2 | 16 | 6 | 11 | 119 | 279 | 370 | 127 |
| 2012 | 0 | 340 | 2 | 18 | 6 | 8 | 119 | 245 | 317 | 354 |
| 2013 | 0 | 374 | 1 | 17 | 5 | 14 | 137 | 265 | 356 | 321 |
| 2014 | 0 | 324 | 1 | 17 | 4 | 8 | 117 | 232 | 346 | 321 |
| 2015 | 0 | 246 | 0.609 | 14 | 5 | 6 | 102 | 224 | 282 | 293 |
| 2016 | 3 | 279 | 1 | 15 | 4 | 14 | 138 | 205 | 265 | 313 |
| 2017 | | 244 | 1 | 16 | 9 | 10 | 173 | | 257 | 422 |
| 2018 | | 250 | 1 | 18 | 6 | | 146 | | 182 | 461 |
| 2019 | | | | | | | | | | |

**Table A7.5. Commercial fisheries landings (in tonnes) for yellow eel and silver eel from 1980 to 2019 (part 2), reported by countries: IE Ireland, GB United Kingdom, FR France, ES Spain, PT Portugal, IT Italy, Sl Sovenia, HR Croatia, GR Greece, TR Turkey, TN Tunisia (continued from previous table).**

| Year | IE | GB | FR | ES | PT | IT | SI | HR | GR | TR | TN | sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1980 | 75 | 912 | | 90 | | 2198 | | | 227 | 224 | | 9471 |
| 1981 | 94 | 907 | | 98 | | 2270 | | | 251 | 374 | | 9202 |
| 1982 | 144 | 943 | | 20 | | 2025 | 0.795 | | 255 | 424 | | 9705.795 |
| 1983 | 117 | 866 | | 18 | | 2013 | 0.67 | | 201 | 588 | | 9324.67 |
| 1984 | 88 | 973 | | 11 | | 2050 | 1 | | 285 | 616 | | 8789 |
| 1985 | 87 | 750 | | 17 | | 2135 | 2 | | 190 | 583 | | 9695 |
| 1986 | 87 | 651 | 1944 | 13 | | 2134 | 3 | | 152 | 517 | | 11147 |
| 1987 | 230 | 684 | 2062 | 21 | | 2265 | 2 | | 266 | 543 | | 10902 |
| 1988 | 215 | 934 | 2265 | 14 | | 2027 | 2 | | 268 | 756 | | 12339 |
| 1989 | 400 | 875 | 1746 | 5 | 27 | 1243 | 1 | | 156 | 472 | | 10229 |
| 1990 | 256 | 784 | 1778 | 9 | 26 | 1088 | 2 | | 194 | 230 | | 9459 |
| 1991 | 245 | 737 | 1645 | 50 | 47 | 1097 | 1 | | 209 | 262 | | 9191 |
| 1992 | 234 | 715 | 1321 | 54 | 59 | 1084 | 0.061 | | 185 | 245 | | 8890.061 |
| 1993 | 260 | 671 | 1280 | 66 | 68 | 782 | 0.066 | | 182 | 261 | | 7850.066 |
| 1994 | 300 | 778 | 1280 | 51 | 53 | 771 | 0.718 | | 201 | 329 | | 8576.718 |
| 1995 | | 900 | 1280 | 69 | 47 | 1047 | 0.01 | | 201 | 390 | | 8096.01 |
| 1996 | | 805 | 1280 | 62 | 51 | 953 | 0.012 | | 151 | 342 | | 7422.012 |
| 1997 | | 731 | 1223 | 61 | 49 | 727 | 0.002 | | 137 | 400 | | 7179.002 |
| 1998 | | 693 | 1150 | 44 | 47 | 666 | 0.003 | | 88 | 300 | | 6087.003 |
| 1999 | 250 | 668 | 1005 | 48 | 46 | 634 | | | 81 | 200 | | 6483 |
| 2000 | 250 | 588 | 986 | 55 | 44 | 588 | 0.004 | | 88 | 176 | 53 | 5778.004 |
| 2001 | 98 | 584 | 1002 | 130 | 30 | 520 | 0.019 | | 93 | 122 | 93 | 5868.019 |
| 2002 | 123 | 551 | | 106 | 54 | 415 | 0.009 | | 136 | 147 | 251 | 4661.009 |
| 2003 | 111 | 552 | | 96 | 21 | 446 | | | 77 | 158 | 137 | 4298 |
| 2004 | 136 | 472 | | 85 | 18 | 379 | | | 58 | 165 | 95 | 3963 |
| 2005 | 101 | 476 | | 88 | 14 | 75 | 0.002 | | 116 | 176 | 107 | 3608.002 |
| 2006 | 133 | 382 | | 116 | 20 | 56 | 0.014 | | 77 | 162 | 288 | 3809.014 |
| 2007 | 114 | 451 | | 82 | 21 | 277 | 0.009 | | 90 | 179 | 257 | 3762.009 |

| Year | IE | GB | FR | ES | PT | IT | SI | HR | GR | TR | TN | sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2008 | 108 | 393 | | 66 | 14 | 56 | 0.031 | | 71 | 171 | 194 | 3196.031 |
| 2009 | 0 | 460 | | 89 | 16 | 330 | 0.002 | | 78 | 158 | 141 | 3004.002 |
| 2010 | 0 | 455 | | 76 | 22 | 265 | 0.003 | | 59 | 182 | 114 | 3187.003 |
| 2011 | 0 | 456 | 368 | 61 | 12 | 190 | 0 | | 83 | 28 | 122 | 2700 |
| 2012 | 0 | 414 | 473 | 84 | 8 | 182 | 0 | | 55 | 38 | 141 | 2804 |
| 2013 | 0 | 427 | 504 | 86 | 5 | 172 | 0.001 | | 38 | 48 | 180 | 2950.001 |
| 2014 | 0 | 406 | 434 | 125 | 7 | 185 | 0 | 0.516 | 58 | 56 | 137 | 2778.516 |
| 2015 | 0 | 341 | 357 | 60 | 6 | 170 | 0 | 0.149 | 60 | 71 | 95 | 2332.758 |
| 2016 | 0 | 347 | 443 | 83 | 5 | 205 | 0 | 0.595 | 84 | 75 | 299 | 2778.595 |
| 2017 | 0 | 321 | 294 | 75 | 2 | 214 | | 0.56 | 62 | | 149 | 2249.56 |
| 2018 | | 365 | 544 | 45 | 4 | 159 | | | 41 | | 153 | 2375 |
| 2019 | | | | 26 | | | | | | | | 26 |

**Table A7.6. Releases for yellow eel and silver eel combined from 1980 to 2019 in millions, reported by countries SE Sweden, IE Ireland, DE Germany, NL Netherlands, IE Ireland, FR France, ES Spain, PT Portugal, IT Italy, GR Greece.**

| Year | SE | DE | NL | IE | FR | ES | IT | GR | sum |
|---|---|---|---|---|---|---|---|---|---|
| 1980 | 16 | | 1 | 0.265 | | | | | 17.265 |
| 1981 | 35 | | 0.7 | 0.107 | | | | | 35.807 |
| 1982 | 33 | | 0.7 | 0.122 | | | | | 33.822 |
| 1983 | 25 | | 0.7 | 0.088 | | | | | 25.788 |
| 1984 | 5 | | 0.7 | 0.042 | | | | | 5.742 |
| 1985 | 25 | 4 | 0.8 | 0.099 | | | | | 29.899 |
| 1986 | 10 | 3 | 0.7 | 0.156 | | | | | 13.856 |
| 1987 | 13 | 3 | 0.4 | 0.099 | | | | | 16.499 |
| 1988 | 16 | 2 | 0.3 | 0.127 | | | | | 18.427 |
| 1989 | 5 | 2 | 0.1 | 0.058 | | | | | 7.158 |
| 1990 | 5 | 2 | 0 | 0.098 | | | | | 7.098 |
| 1991 | 9 | 2 | 0 | 0.037 | | | | | 11.037 |
| 1992 | 7 | 2 | 0 | 0.047 | | | | | 9.047 |
| 1993 | 4 | 2 | 0.2 | 0.061 | | | | | 6.261 |
| 1994 | 7 | 3 | 0 | 0.013 | | | | | 10.013 |
| 1995 | 2 | 3 | 0 | 0.08 | | | | | 5.08 |
| 1996 | 2 | 4 | 0.2 | 0.01 | | | | | 6.21 |
| 1997 | 3 | 5 | 0.4 | 0.091 | | | | | 8.491 |
| 1998 | 4 | 5 | 0.6 | 0.026 | | | | | 9.626 |
| 1999 | 4 | 5 | 1 | 0.071 | | | | | 10.071 |
| 2000 | 2 | 7 | 1 | 0.039 | | | | | 10.039 |
| 2001 | 2 | 6 | 0.1 | 0.007 | | | | | 8.107 |
| 2002 | 7 | 7 | 0.1 | 0.088 | | | | | 14.188 |
| 2003 | 4 | 7 | 0.1 | 0.096 | | | | | 11.196 |
| 2004 | 2 | 7 | 0.1 | 0.047 | | | | | 9.147 |
| 2005 | 3 | 6 | 0 | 0.073 | | | | | 9.073 |
| 2006 | 3 | 9 | 0 | 0.085 | | | | | 12.085 |
| 2007 | 5 | 9 | 0 | 0.094 | | | | | 14.094 |

| Year | SE | DE | NL | IE | FR | ES | IT | GR | sum |
|---|---|---|---|---|---|---|---|---|---|
| 2008 | 2 | 9 | 0.23 | 0.183 | | 0.016 | | | 11.429 |
| 2009 | 2 | 9 | 0.3 | 0.178 | | 0.031 | | | 11.509 |
| 2010 | 3 | 9 | 0.062 | 0.203 | | 0.013 | | | 12.278 |
| 2011 | 4 | 7 | 0.408 | 0.225 | 0.094 | 0.039 | | | 11.766 |
| 2012 | 2 | 6 | 0.392 | 0.246 | 0.111 | 0.039 | | | 8.788 |
| 2013 | 3 | 7 | 0.506 | 0.24 | 0.116 | 0.004 | | 0.042 | 10.908 |
| 2014 | 8 | 8 | 0.903 | 0.374 | 0.164 | 0.024 | | 0.067 | 17.532 |
| 2015 | 2 | 9 | 0.742 | 0.317 | 0.214 | 0.001 | 0.085 | 0.079 | 12.438 |
| 2016 | 7 | 7 | 0.49 | 0.298 | 0.17 | 0.188 | 0.122 | 0.108 | 15.376 |
| 2017 | 0.017 | | 0.574 | 0.207 | 0.213 | 0.154 | 0.2 | 0.086 | 1.451 |
| 2018 | 13 | | 4 | | 0.198 | 0.148 | | 0.035 | 17.381 |
| 2019 | | | 6 | | | 0.001 | | | 6.001 |

**Table A7.7. Release of glass eel, (stages glass eel, ongrown glass eels and quarantined glass eel) in millions, reported by countries SE Sweden, FI Finland, EE Estonia, LV Latvia, LT Lithuania, PL Poland, DE Germany, DK Denmark, BE Belgium, IE Ireland, GB United Kingdom, FR France, ES Spain, IT Italy, GR Greece.**

| Year | SE | FI | EE | LV | LT | PL | DE | DK | NL | BE | IE | GB | FR | ES | IT | GR | sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1980 | 0.138 | | 1 | | | 52 | | | 25 | | 26 | | | | | | 104.138 |
| 1981 | | | 3 | 2 | | 60 | | | 22 | | 17 | | | | | | 104 |
| 1982 | 0.02 | | 3 | 0.29 | | 63 | | | 17 | | 26 | | | | | | 109.31 |
| 1983 | | | 2 | 2 | | 26 | | | 14 | | 10 | | | | | | 54 |
| 1984 | | | 2 | | | 48 | | | 17 | | 8 | 4 | | | | | 79 |
| 1985 | 0.634 | | 2 | 1 | | 36 | 22 | | 12 | | 6 | 11 | | | | | 90.634 |
| 1986 | 0.08 | | | | | 50 | 37 | | 10 | | 5 | 18 | | | | | 120.08 |
| 1987 | 0.648 | | 2 | 0.26 | | 57 | 38 | | 8 | | 14 | 14 | | | | | 133.908 |
| 1988 | 0.637 | | 0.18 | 3 | | 17 | 40 | | 8 | | 13 | 6 | | | | | 87.817 |
| 1989 | 0.914 | | | | | 14 | 20 | | 7 | | 7 | 0 | | | | | 48.914 |
| 1990 | 1 | | | | | 11 | 29 | | 6 | | 10 | 0 | | | | | 57 |
| 1991 | 0.586 | | 2 | | | 2 | 13 | | 2 | | 2 | 0 | | | | | 21.586 |
| 1992 | 0.681 | | 2 | | | 14 | 17 | | 4 | | 6 | 2 | | | | | 45.681 |
| 1993 | 0.987 | | | | | 10 | 21 | | 4 | | 7 | 0 | | | | | 42.987 |
| 1994 | 2 | | 2 | | | 13 | 23 | | 6 | | 19 | 2 | | | | | 67 |
| 1995 | 2 | | 0.15 | 0.572 | | 24 | 20 | | 5 | | 11 | 2 | | | | | 64.722 |
| 1996 | 3 | | 1 | | | 4 | 11 | | 2 | | 4 | 0.1 | | | | | 25.1 |

| Year | SE | FI | EE | LV | LT | PL | DE | DK | NL | BE | IE | GB | FR | ES | IT | GR | sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997 | 3 | | 0.9 | | | 7 | 9 | | 2 | | 15 | 0.2 | | | | | 37.1 |
| 1998 | 2 | | 0.5 | | | 3 | 8 | | 2 | | 6 | 0.052 | | | | | 21.552 |
| 1999 | 3 | | 2 | 0.294 | | 5 | 9 | | 3 | | 8 | 4 | | | | | 34.294 |
| 2000 | 1 | | 1 | | | 5 | 6 | | 3 | | 6 | 0.45 | | | | | 22.45 |
| 2001 | 0.908 | | 0.44 | | | 1 | 3 | | 0.9 | | 3 | 0 | | | | | 9.248 |
| 2002 | 2 | | 0.36 | 0.251 | | 0.751 | 3 | | 2 | | 1 | 3 | | | | | 12.362 |
| 2003 | 0.702 | | 0.54 | | | 1 | 2 | | 2 | | 4 | 4 | | | | | 14.242 |
| 2004 | 1 | | 0.44 | 0.06 | | 3 | 2 | | 0.3 | | 1 | 1 | | | | | 8.8 |
| 2005 | 1 | | 0.37 | 0.12 | | 0.74 | 2 | | 0.1 | | 4 | 2 | | | | | 10.33 |
| 2006 | 1 | | 0.38 | 0.003 | | 0.918 | 1 | | 0.582 | | 0.616 | 1 | | | | | 5.499 |
| 2007 | 0.972 | | 0.33 | 0.015 | | 1 | 1 | | 0.216 | | 1 | 4 | | | | | 8.533 |
| 2008 | 1 | | 0.19 | | | 2 | 0.51 | | 0 | | 0.418 | 1 | | | | | 5.118 |
| 2009 | 0.763 | | 0.42 | | | 1 | 0.787 | | 0.3 | | 0.375 | 0.719 | | | 0 | | 4.364 |
| 2010 | 2 | 0.306 | 0.21 | | | 1 | 5 | | 3 | | 0.444 | 3 | 0.627 | | 0.3 | | 15.887 |
| 2011 | 3 | 0.612 | 0.88 | 0.304 | 0.152 | 3 | 3 | | 0.529 | | 0.318 | 3 | 2 | 0.014 | 0.9 | | 17.709 |
| 2012 | 3 | 0.354 | 1 | 1 | 0.494 | 2 | 4 | | 2 | | 0.647 | 4 | 9 | 1 | 0.9 | | 29.395 |
| 2013 | 3 | 0.394 | 1 | | 1 | 3 | 5 | | 2 | | 0.972 | 6 | 9 | 1 | 0.9 | 0.419 | 33.685 |
| 2014 | 3 | 0.294 | 3 | 1 | 0.38 | 2 | 10 | | 6 | | 2 | 8 | 17 | 0.245 | | 0.204 | 53.123 |

| Year | SE | FI | EE | LV | LT | PL | DE | DK | NL | BE | IE | GB | FR | ES | IT | GR | sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2015 | 2 | 0.204 | 2 | | 0.45 | 4 | 6 | | 0.863 | | 3 | 2 | 3 | 0.045 | 0.366 | 0.017 | 23.945 |
| 2016 | 3 | 0.158 | 1 | | 0.273 | 2 | 5 | 2 | 3 | | 4 | 0.053 | 10 | 0.003 | 0.21 | 0.471 | 31.168 |
| 2017 | 14 | 0.241 | 0.31 | 1 | 0 | 4 | | 2 | 3 | 0.727 | 0.685 | 2 | 7 | 0.767 | 0.437 | 0.149 | 36.316 |
| 2018 | | 0.082 | 1 | 0.718 | 2 | | | | 4 | | | 2 | 9 | 4 | | 0.094 | 22.894 |
| 2019 | | | | | 2 | | | 2 | 5 | | | 4 | 10 | 0.885 | | | 23.885 |

**Table A7.8. Recreational fisheries landings (in tonnes) for yellow eel and silver eel from 1985 to 2019, reported by countries: FI Finland, EE Estonia, LV Latvia, LT Lithuania, PL Poland, DE Germany, DK Denmark, NL Netherlands, BE Belgium, IE Ireland, FR France, ES Spain, IT Italy, SI Slovenia, GR Greece.**

| Year | FI | EE | LV | LT | PL | DE | DK | NL | BE | IE | FR | ES | IT | SI | GR | sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | | | | | | 523 | | | | | | | | 0 | | 523 |
| 1986 | | | | | | 496 | | | | | | | | 0.07 | | 496.07 |
| 1987 | | | | | | 495 | | | | | | | | 0.14 | | 495.14 |
| 1988 | | | | | | 490 | | | | | | | | 0.134 | | 490.134 |
| 1989 | | | | | | 467 | | | | | | | | 0.11 | | 467.11 |
| 1990 | | | | | | 444 | | | | | | | | 0.06 | | 444.06 |
| 1991 | | | | | | 438 | | | | | | | | 0.058 | | 438.058 |
| 1992 | | | | | | 432 | | | | | | | | 0.092 | | 432.092 |
| 1993 | | | | | | 421 | | | | | | | | 0.078 | | 421.078 |
| 1994 | | | | | | 439 | | | | | | | | 0.036 | | 439.036 |
| 1995 | | | | | | 400 | | | | | | | | 0.029 | | 400.029 |
| 1996 | | | | | | 387 | | | | | | | | 0.143 | | 387.143 |
| 1997 | | | | | | 378 | | | | | | | | 0.207 | | 378.207 |
| 1998 | | | | | | 403 | | | | | | | | 0.088 | | 403.088 |
| 1999 | | | | | | 386 | | | | | | | | 0.023 | | 386.023 |
| 2000 | | | | | | 391 | | | | | | | | 0.004 | | 391.004 |
| 2001 | | | | | | 386 | | | | | | | | 0.02 | | 386.02 |
| 2002 | | | | | | 389 | | | | | | | | 0.033 | | 389.033 |
| 2003 | | | | | | 385 | | | | | | | | 0.004 | | 385.004 |
| 2004 | | | | | | 380 | | | | | | | | 0.006 | | 380.006 |
| 2005 | | 2 | | | | 357 | | | | | | | | 0 | | 359 |
| 2006 | | 1 | | | | 359 | | | | | 684 | | | 0.004 | | 1044.004 |
| 2007 | | 0.958 | | | | 346 | | | | | | | | 0 | | 346.958 |
| 2008 | 17 | 1 | | | | 293 | | | | | | | | 0 | | 311 |
| 2009 | | 1 | | | | 286 | 100 | | | | | | | 0 | | 387 |
| 2010 | 10 | 1 | | | | 253 | 118 | 111 | | | | | 150 | 0 | | 643 |
| 2011 | | 0.98 | | | | 251 | 80 | | | | | | 61 | 0 | | 392.98 |

| Year | FI | EE | LV | LT | PL | DE | DK | NL | BE | IE | FR | ES | IT | SI | GR | sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2012 | 5 | 0.612 | | 1 | 32 | 246 | 52 | 59 | | | 5 | | 74 | 0 | | 474.612 |
| 2013 | | 0.589 | 0.037 | 3 | 27 | 251 | 50 | | | | 5 | | 70 | 0 | | 406.626 |
| 2014 | 20 | 0.536 | 0.038 | 2 | 30 | 254 | 57 | 70 | | | 4 | | 70 | 0 | | 507.574 |
| 2015 | | 0.744 | 0.007 | 5 | 26 | 256 | 118 | | | | 4 | | 60 | 0 | | 469.751 |
| 2016 | | 0.634 | 0.009 | 2 | 34 | 258 | 164 | 24 | | | 3 | | 57 | 0 | | 542.643 |
| 2017 | | 0.579 | 0.447 | 3 | | | 117 | | 30 | 0 | 3 | | 41 | | | 195.026 |
| 2018 | | 1 | 0.162 | | | | 105 | | | | 3 | | 38 | | 1 | 148.162 |
| 2019 | | | | | | | | | | | | 0.265 | | | | 0.265 |

**Table A7.9. Releases of yellow eel from 1980 to 2019 in millions, reported by countries SE Sweden, DE Germany, NL Netherlands, IE Ireland, ES Spain, IT Italy.**

| Year | SE | DE | NL | IE | ES | IT | sum |
|---|---|---|---|---|---|---|---|
| 1980 | 16 | | 1 | 0.265 | | | 17.265 |
| 1981 | 35 | | 0.7 | 0.107 | | | 35.807 |
| 1982 | 33 | | 0.7 | 0.122 | | | 33.822 |
| 1983 | 25 | | 0.7 | 0.088 | | | 25.788 |
| 1984 | 5 | | 0.7 | 0.042 | | | 5.742 |
| 1985 | 25 | 4 | 0.8 | 0.099 | | | 29.899 |
| 1986 | 10 | 3 | 0.7 | 0.156 | | | 13.856 |
| 1987 | 13 | 3 | 0.4 | 0.099 | | | 16.499 |
| 1988 | 16 | 2 | 0.3 | 0.127 | | | 18.427 |
| 1989 | 5 | 2 | 0.1 | 0.058 | | | 7.158 |
| 1990 | 5 | 2 | 0 | 0.098 | | | 7.098 |
| 1991 | 9 | 2 | 0 | 0.037 | | | 11.037 |
| 1992 | 7 | 2 | 0 | 0.047 | | | 9.047 |
| 1993 | 4 | 2 | 0.2 | 0.061 | | | 6.261 |
| 1994 | 7 | 3 | 0 | 0.013 | | | 10.013 |
| 1995 | 2 | 3 | 0 | 0.08 | | | 5.08 |
| 1996 | 2 | 4 | 0.2 | 0.01 | | | 6.21 |
| 1997 | 3 | 5 | 0.4 | 0.091 | | | 8.491 |
| 1998 | 4 | 5 | 0.6 | 0.026 | | | 9.626 |
| 1999 | 4 | 5 | 1 | 0.071 | | | 10.071 |
| 2000 | 2 | 7 | 1 | 0.039 | | | 10.039 |
| 2001 | 2 | 6 | 0.1 | 0 | | | 8.1 |
| 2002 | 7 | 7 | 0.1 | 0.068 | | | 14.168 |
| 2003 | 4 | 7 | 0.1 | 0.088 | | | 11.188 |
| 2004 | 2 | 7 | 0.1 | 0.032 | | | 9.132 |
| 2005 | 3 | 6 | 0 | 0.066 | | | 9.066 |
| 2006 | 3 | 9 | 0 | 0.047 | | | 12.047 |
| 2007 | 5 | 9 | 0 | 0.076 | | | 14.076 |

| Year | SE | DE | NL | IE | ES | IT | sum |
|---|---|---|---|---|---|---|---|
| 2008 | 2 | 9 | 0.23 | 0.131 | 0.016 | | 11.377 |
| 2009 | 2 | 9 | 0.3 | 0.015 | 0.03 | | 11.345 |
| 2010 | 3 | 9 | 0.062 | 0.016 | 0.013 | | 12.091 |
| 2011 | 4 | 7 | 0.408 | 0.011 | 0.039 | | 11.458 |
| 2012 | 2 | 6 | 0.392 | 0.003 | 0 | | 8.395 |
| 2013 | 2 | 7 | 0.506 | 0.003 | 0.004 | | 9.513 |
| 2014 | 8 | 8 | 0.903 | 0.038 | 0.021 | | 16.962 |
| 2015 | 2 | 9 | 0.742 | 0.033 | | 0.085 | 11.86 |
| 2016 | 7 | 7 | 0.49 | 0.092 | 0.183 | 0.122 | 14.887 |
| 2017 | | | 0.574 | 0.014 | 0.15 | 0.2 | 0.938 |
| 2018 | 13 | | 4 | | 0.148 | | 17.148 |
| 2019 | | | 6 | | | | 6 |

**Table A7.10. Releases of silver eel from 2001 to 2019 in millions, reported by countries SE Sweden, IE Ireland, FR France, ES Spain, GR Greece.**

| Year | SE | IE | FR | ES | GR | sum |
|---|---|---|---|---|---|---|
| 2001 | | 0.006 | | | | 0.006 |
| 2002 | | 0.02 | | | | 0.02 |
| 2003 | | 0.008 | | | | 0.008 |
| 2004 | | 0.014 | | | | 0.014 |
| 2005 | | 0.008 | | | | 0.008 |
| 2006 | | 0.038 | | | | 0.038 |
| 2007 | | 0.018 | | | | 0.018 |
| 2008 | | 0.052 | | | | 0.052 |
| 2009 | | 0.163 | | 0.001 | | 0.164 |
| 2010 | 0.005 | 0.187 | | | | 0.192 |
| 2011 | 0.008 | 0.215 | 0.094 | | | 0.317 |
| 2012 | 0.01 | 0.243 | 0.111 | 0.039 | | 0.403 |
| 2013 | 0.013 | 0.238 | 0.116 | | 0.042 | 0.409 |
| 2014 | 0.021 | 0.336 | 0.164 | | 0.067 | 0.588 |
| 2015 | 0.018 | 0.284 | 0.214 | | 0.079 | 0.595 |
| 2016 | 0.017 | 0.206 | 0.17 | | 0.108 | 0.501 |
| 2017 | 0.017 | 0.193 | 0.213 | | 0.086 | 0.509 |
| 2018 | 0.016 | | 0.198 | | 0.035 | 0.249 |
| 2019 | | | | 0.001 | | 0.001 |

# Annex 9: Ecosystem overview draft texts

The WGEEL was requested by ICES to produce a short text concerning eel for each of the following Ecosystem Overviews: Icelandic Waters, Biscay and Iberian Waters, Norwegian and Barents Sea, Celtic Seas, North Sea and Baltic. Figure A8.1 illustrates the ecoregions.

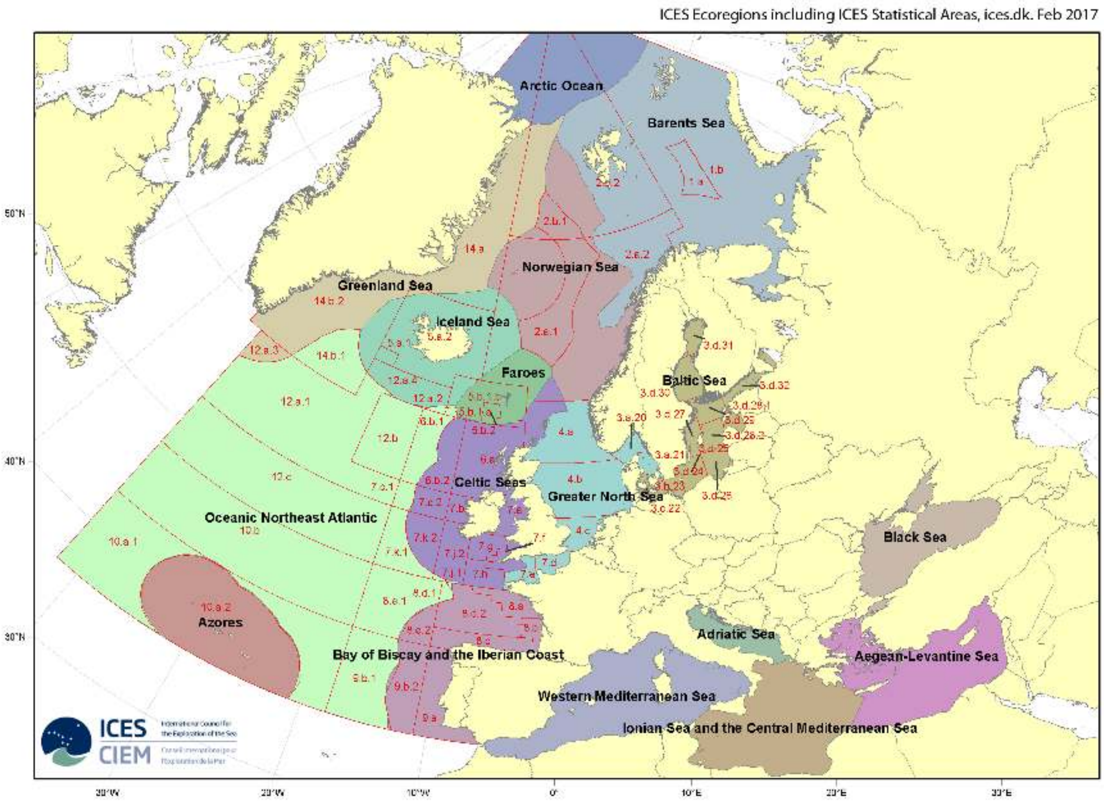


**Figure A8.1. Map of marine ecoregions.**

The WGEEL proposes the texts below. Note that as the Ecoregion Reviews are expected to be 'standalone' documents, text that reflects a common situation for eel across the ecoregions is repeated in all.

## Baltic Sea

Recruitment to the transcontinental European eel (*Anguilla anguilla*) population has declined sharply in recent decades due to a range of potential threats. All Baltic Sea countries have fisheries targeting eel in the coastal zone to various extents, catching resident immature eels or migrating spawners. Other potential threats such as decreased inland water habitat, hydropower turbine mortality, climate change, and toxic pollutants may also affect the eel stock in, or recruitment to, the ecoregion.

## North Sea

Recruitment to the transcontinental European eel (*Anguilla anguilla*) population has declined sharply in recent decades due to a range of potential threats. Some coastal waters in the North

Sea ecoregion have fisheries targeting resident immature eels or migrating spawners. In addition, there are also fisheries targeting resident or migrating eel in some transitional waters. Other potential threats such as decreased inland water habitat, hydropower turbine mortality, climate change, and toxic pollutants may also affect the eel stock in, or recruitment to, the ecoregion.

## Celtic Sea

Recruitment to the transcontinental European eel (*Anguilla anguilla*) population has declined sharply in recent decades due to a range of potential threats. Eels migrate through the Celtic Sea, but there is no marine fishery targeting eel in the ecoregion. However, in some transitional waters of the United Kingdom, there are fisheries targeting glass eels (recruits). Other potential threats such as decreased inland water habitat, hydropower turbine mortality, climate change, and toxic pollutants may affect the eel stock in, or recruitment to, the ecoregion.

## Icelandic Waters

Recruitment to the transcontinental European eel (*Anguilla anguilla*) and American eel (*Anguilla rostrata*) populations has declined sharply in recent decades due to a range of potential threats. Both of these eel species migrate through Icelandic waters, but there is no targeted marine fishing for eel there. Other potential threats such as decreased inland water habitat, hydropower turbine mortality, and climate change may affect the eel stock in, or recruitment to, the ecoregion.

## Bay of Biscay and Iberian Waters

Recruitment to the European eel (*Anguilla anguilla*) population has declined sharply in recent decades due to a range of potential threats. Some coastal waters in the ecoregion have fisheries targeting resident immature eels or migrating spawners. In addition, there are also fisheries targeting resident or migrating eel in some transitional waters. Other potential threats such as decreased inland water habitat, hydropower turbine mortality, climate change, and toxic pollutants may also affect the eel stock in, or recruitment to, the ecoregion.

## Norwegian Sea

Recruitment to the European eel (*Anguilla anguilla*) population has declined sharply in recent decades due to a range of potential threats. Eels migrate through the Norwegian Sea, but there is currently no significant marine fishing targeting eel there. Other potential threats such as decreased inland water habitat, hydropower turbine mortality, climate change, and toxic pollutants may affect the eel stock in, or recruitment to, the ecoregion.

## Barents Sea

Recruitment of European eel (*Anguilla anguilla*) has declined sharply in recent decades due to a range of potential threats. Eels in low abundances migrate through the Barents Sea, but there is currently no significant marine fishing targeting eel there. Other potential threats such as decreased inland water habitat, hydropower turbine mortality, climate change and toxic pollutants may affect the eel stock in, or recruitment to, the ecoregion.

# Annex 10: Working papers

## Precautionary management of the European Eel

Willem Dekker, Willem.Dekker@SLU.SE

This working paper presents the results of earlier analyses, and preparatory work for the WGEEL. The intention is to make this material available, as a basis for further discussion.

## Introduction

In the light of the growing evidence on the long-term decline of the eel stock across Europe, ICES, (2000a through to 2007) recommended, "that a recovery plan should be implemented for the eel stock". As a long-term goal for recovery, ICES (2002) suggested rebuilding recruitment to levels "similar to those of the 1980s" (meant is: pre-1980?). Although "the ecology of the eel makes it difficult to demonstrate a stock-recruitment relationship, […] the precautionary approach requires that such a relationship should be assumed to exist for the eel until demonstrated otherwise" (ICES, 2002). A spawning stock biomass of "30% of the virgin (F=0) [state] is generally considered to be a reasonable provisional reference target. However, for eel a preliminary value could be 50%" (ICES, 2002 through to 2007).

In 2007, the European Union adopted Council Regulation (EC) No. 1100/2007 of 18 September 2007 establishing measures for the recovery of the stock of European eel, with the objective "to reduce anthropogenic mortalities so as to permit […] the escapement […] of at least 40 % of the silver eel biomass [relative to the notional pristine biomass]." The Eel Regulation aims to achieve this reduction in anthropogenic mortalities through the implementation of national or river basin specific Eel Management Plans, obligatorily developed by the EU Member States. Subsequently, EU-Com requested ICES a review service to pre-evaluate these national Eel Management Plans (ICES, 2009), and (amongst others) requested a review of progress reports of those EMPs (ICES, 2018c). Although ICES responded to these requests, ICES did not evaluate the Eel Regulation itself, and its annual advice (ICES, 2008 through to 2018b) did not relate to the ongoing implementation of Eel Management Plans in EU Member States. Instead, ICES provided elementary precautionary advice, based on a single whole-stock indicator (recruitment) only. The advice addressing the whole stock (all of Europe and the Mediterranean), while the stock is actually managed and protected in national (or lower level) Eel Management Plans, there is a mismatch between the management needs and the scientific advice provided. This mismatch has been paralysing progress in the implementation of the European eel recovery plan (Dekker, 2016).

This working paper now explores a wider range of options for scientific advice, including stock indicators and reference values, under the precautionary approach (FAO 1995), that can address the needs for scientific advice of the Eel Management Plans implemented under the Eel Regulation. This addresses ToR d - "Consider the consequences of the Precautionary Approach on advice for European eel."

## Precautionary Approach

ICES provides advice on fisheries management, in the context of several international agreements and policies (ICES 2018d). These include the United Nations Straddling Fish Stocks Agreement (UN 1995), and the FAO Code of Conduct for Responsible Fisheries (FAO 1995). The FAO

Code “calls on … all those involved in fisheries to collaborate in the fulfilment and implementation of the objectives and principles contained in this Code.” The other policies and agreements listed by ICES (2018d) do apply in coastal waters and at high seas - but have no competence in inland waters, where most anthropogenic impacts on eel occur. The Code of Conduct specifies that "States should apply the precautionary approach widely to conservation, management and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment” (Art. 7.5.1). ICES (2000b) and Russell and Potter (2003) have discussed the implications of the precautionary approach for the management of the European eel before. Major elements relevant to the current discussion are (formatting added):

a) The adoption of “measures for the **long-term conservation and sustainable use** of fisheries resources” (FAO 1995, Art. 7.1.1),
b) “Conservation and management measures, whether at local, national, subregional or regional levels, should be based on **the best scientific evidence**” (FAO 1995, Art. 7.1.1),
c) “**Depleted stocks [should be] allowed to recover** or, where appropriate, are actively restored” (FAO, 1995, Art. 7.2.2.e),
d) “To be effective, fisheries management should be concerned with the **whole stock unit over its entire area of distribution** … and other biological characteristics of the stock” (FAO 1995, Art. 7.3.1),
e) “In order to conserve and manage… highly migratory fish stocks … throughout their range, conservation and management measures [should be] established for such stocks **in accordance with the respective competences of relevant States**” (FAO 1995, Art. 7.3.2),
f) “Long-term management **objectives should be translated into management actions**, formulated as a fishery management plan or other management framework” (FAO 1995, Art. 7.3.3),
g) “The **absence of adequate scientific information** should not be used as a reason for postponing or failing to take conservation and management measures” (FAO 1995, Art. 7.5.1),
h) “**Two types of precautionary reference points** should be used: conservation, or limit, reference points and management, or target, reference points“ (UN 1995, Annex II, point 2),
i) “Precautionary **reference points should be stock-specific** to account, inter alia, for the **reproductive capacity, the resilience** of each stock and the characteristics of fisheries exploiting the stock, as well as **other sources of mortality** and **major sources of uncertainty**” (UN 1995, Annex II, point 3),
j) “When information for determining reference points for a fishery is poor or absent, **provisional reference points** shall be set” (UN 1995, Annex II, point 6),
k) “**Prior identification of undesirable outcomes and of measures** that will avoid them or correct them promptly” (FAO 1996, point 6.b) [not used? Then can go out],
l) “Where the likely impact of resource use is uncertain, **priority should be given to conserving** the productive capacity of the resource” (FAO 1996, point 6.d),
m) “A precautionary approach requires that the feasibility and reliability of the management options be evaluated. … The evaluation should attempt to determine if the management plan is **robust to both statistical uncertainty and to incomplete knowledge** …” (FAO 1996, point 35),
n) “Establish a recovery plan that will **rebuild the stock over a specific time period** with reasonable certainty” (FAO 1996, point 48.b),
o) “**Do not use artificial propagation as a substitute** for the precautionary measures …” (FAO 1996, point 48.g).

## European Eel

A comprehensive overview of eel biology, stock status, human impacts, management frameworks, and scientific advice on eel is presented in ICES (2016b); updates of the major time-series in ICES (2018a). For the current discussion, the following issues are relevant:

1. **Spatial**. The eel occurs in inland and coastal waters, all over Europe and the Mediterranean (Dekker, 2003b). The stock is scattered over a multitude of smaller habitats, with little or no connection between substocks in different river systems during their continental life (Dekker, 2000). The whole stock constitutes a single, panmictic stock (Palm *et al*., 2009). It is not known which part (or all) of the continental distribution actually contributes to the oceanic spawning stock (Dekker, 1999; 2016).
2. **Life cycle**. For the current discussion, it is relevant to note that reproduction takes place in the ocean, not in continental waters. All life stages in continental waters, in waters under national or EU jurisdiction, in waters where protective measures can be taken, are immature. Stock assessments and management measures are therefore focused on the (maturing) silver eel stage, escaping towards the ocean. Where international agreements and protocols write "spawning stock", we read that as "silver eel escapement".
3. **Landings trend**. Commercial landings data are troublesome, with incomplete reporting within and between countries, as well as inconsistencies. Trend analysis indicates that reported landings have diminished since the 1960s, declining by about 5% per year to below 10 % of the quantity caught half a century ago (Dekker 2003a). There is circumstantial evidence of a much longer (mid-1800s) downward trend - partly masked by expansion of fisheries to new, larger-scaled habitats (larger lakes, major rivers) and other countries (Dekker, 2019). For recreational fisheries, far less information is available – preliminary analyses indicate that recreational landings can be in the same order as commercial landings.
4. **Recruitment trend**. Monitoring of the immigration from the ocean has taken place for many decades, at many places (mostly on the Atlantic coast), in fisheries-dependent and independent settings. Results show a strong coherence among sites, over the years. Trend analysis indicates that, from 1980 until 2010, glass eel recruitment from the ocean has declined by on average 10–15% per year to 1–10% of the 1960–1970s level (ICES, 2018a). From 2011 onward, the trend has turned upward (10–20% per year), but recruitment is still at a very low level (in 2018: 2–10%), and the upward trend has lasted yet not long enough to become statistically significant (ICES, 2018a).
5. Non-**fishing impacts**. In addition to fisheries, many other anthropogenic activities have an impact on the stock, including land reclamation, water management, water pollution, hydropower generation, and many more. Their impacts vary from country to country, as well as from habitat to habitat type. Recent assessments (ICES, 2016) indicate that fishing and non-fishing mortalities often have a comparable impact (Dekker, 2016).
6. **Restocking**. Since 1840, immigrating young eel have been re-distributed, from areas of highest abundance in river mouths (especially in countries around the Bay of Biscay), to other countries (mostly DE, PO and NL; foremost after 1950) and further inland. The aim of this restocking was to support dwindling fisheries, or even to enable new fisheries (Dekker and Beaulaton, 2016a). The restocking-based production has remained small in comparison to the total reported landings, until the landings declined considerably in the 1990s (Dekker and Beaulaton, 2016a). The higher restocking after 2010 will potentially bring this contribution to 30%, in coming years.

## Population, stock and management unit

"To be effective, fisheries management should be concerned with the whole stock unit over its entire area of distribution" (FAO, 1995). While there is little doubt, that the European eel species consists of a single, panmictic population (Secor, 2005), the identification of unit stock(s) and management unit(s) is less straightforward.

Before the Sargasso Sea was identified as the most likely spawning place, it was generally assumed that eels reproduce in the lower river, the river mouth, or in front of the coast; eel stocks would be river-specific, or at least regionally subdivided. Eel fisheries being organised at national (or lower) level, the management framework effectively matched the presumed biological stock structure. The discovery of the Sargasso Sea as the single spawning location (Schmidt, 1922) changed this picture completely: all eels across the continent might well constitute a single panmictic population, and reproduction takes place far outside the area of anthropogenic impacts, and far outside the legislative powers of individual states.

In 1997, the European Commission requested ICES for "information about the status of eel stock(s) and on any possible management actions". In its advice, (ICES, 1999) indicated, "there is no evidence against a hypothesis of a single spawning stock". Writing "there is no stock-wide objective stated for this stock", ICES implicitly decided to consider the whole population as a single stock. In the years following, discussions focused on uniform management across the continent, but available data and existing knowledge appeared insufficient to develop such a system. Subsequently, the European Union adopted the Eel Regulation, following the suggestion of Dekker (2004, 2009) to implement a distributed control system (Dekker, 2016). The Regulation adopted common objectives, uniform reference points and an international evaluation process for the Union as a whole, but delegated design and implementation of protective measures, as well as monitoring and assessment to its Member States (Dekker, 2016). While the objective is set at the central level, the means to implement were found at the decentralised level.

Stock identification should consider the genetic structure of the population, the existence of spatially isolated sub-units (potentially with different phenotypes, or dissimilar human impacts), and the needs and competences of fisheries managers (Begg *et al*., 1999). These requirements are reflected in the FAO Code of Conduct, in "the whole stock unit over its entire area of distribution" (Art. 7.3.1), "in accordance with the respective competences of relevant States" (Art. 7.3.2), and "objectives should be translated into management actions" (Art. 7.3.3). For the European Eel: while the genetic homogeneity of the population across the whole distribution area pleads to consider the whole population as a single stock, the (phenotypic) variation in life-history characteristics, the geographic diversity in human impacts, and the precedence of national competences over centralised management (subsidiarity) favour much smaller geographical entities.

While there is commonly no doubt on the single spawning stock, the geographical origin of the spawners in continental waters is fully unknown. One might hypothesise, that either substocks from all continental waters contribute to the common spawning process, or some geographical subset of the whole continent actually reproduces successfully, whereas the remainders then constitute a non-reproducing diaspora (Harden Jones, 1968; Tsukamoto *et al*., 1998; Dekker, 2003b). Suggestions for the reproducing core-area may include: marine habitats (best accessibility), the Baltic (most female silver eel), the Biscay Bay (most recruits), the Mediterranean (preferred temperature and evolutionary origin) or northwestern Africa (closest to the Sargasso). Not knowing which of these hypotheses is real, the prudent approach is to manage each and all areas to the same sustainability standards (Dekker, 1999).

"Conservation and management measures, whether at local, national, subregional or regional levels, should be based on the best scientific evidence" (FAO, 1995, Art. 7.1.1). Latest scientific advice (ICES 2018b) indicated that available information (on catches, impacts, other mortalities) is inadequate to derive a full assessment, and therefore advised - on precautionary grounds - to minimise all impacts across the whole stock. However, for individual management areas (especially in the EU), the required information is available, and assessments of the impacts have been made (ICES, 2018c), but these have not been included in the advice on eel. Hence, the absence of fully adequate scientific information in many areas leads to putting aside the available information in other, better documented areas; and hence, not "all the available information [is] used" (ICES, 2018d). While the available information is currently insufficient for an assessment of the whole stock, this information is unlikely to be completed in the near future or ever (Dekker, 2016). Le mieux est l'ennemi du bien.

At the bottom line, a differentiation of the scientific advice is recommended/inevitable. For setting the long-term objective, and for assessing the overall status of the stock, stock-wide indicators need to be considered. For assessing the protection status, only a regionalised assessment of human impacts will make use of the best scientific evidence, and only a regionalised assessment can be translated into management actions. The long-term objectives are necessarily central, the means to protect are only found at the decentralised level.

## Information poor, provisional advice

The Code of Conduct calls upon parties to use "best scientific evidence", to derive "stock-specific" reference points, to translate "objectives […] into management actions". "When information for determining reference points for a fishery is poor or absent, provisional reference points shall be set."

For the eel, the decline of the stock in inland waters had been noted for more than a century (Dekker and Beaulaton, 2016b), but it is only in most recent decades, that the decline in glass eel recruitment (since 1980) attracted considerable attention. ICES (2002) noted that recruitment, abundance and landings had been in decline for several decades, but "current scientific knowledge is inadequate to provide management reference points for eel".

For the glass eel recruitment, Dekker (2000) analysed the coherence among dataseries across the continent, finding no spatial differentiation in the declining trends in glass eel recruitment since 1980. Subsequently, re-analysis of longer time series in 2010 (ICES, 2010) confirmed this outcome. Testing fixed geographical areas (ICES ecoregions), ICES (2010a) found that the North Sea series declined faster than elsewhere, although this did not hold for all series within the North Sea. Most of this discrepancy between North Sea and Elsewhere occurred in the mid-1980s; the downward trends thereafter run in parallel. Overall, the available recruitment data series are considered to provide reliable indices of recruitment, representative for the major part of the distribution in the Atlantic area; for the Mediterranean, too little information is available to compile a reliable index for this whole area. All evidence points at a major reduction in glass eel recruitment, between 1980 and 2010.

For the spawner-escapement from the continent, very few long-running dataseries are available (Burrishoole, Ireland; Imsa, Norway), and those series come from unexploited river systems, questioning their relevance for other areas. Dekker (2003a, 2004) tentatively assumed that silver eel escapement from the continent is approximately proportional to the catches made from the continental stock, and analysed the relation between the trends in landings and subsequent recruitment, as a substitute for the stock–recruitment relation. This analysis found a strongly depensatory relation: recruitment fell more rapidly (-15% per year) than the spawning stock, that is: than the landings (-5% per year). Since the implementation of substantial fishing restrictions, in the context of the Eel Regulation, the relation between spawner escapement and landings will certainly have been lost. All evidence points at a major reduction in landings, between 1965 (or long before) and today.

All in all, the dynamics of the whole stock are poorly understood, barely quantified; and thus, there is hardly a basis for stock-specific reference points. ICES (2002) therefore advised to adopt provisional reference points: a spawner escapement of 30% of the virgin escapement is generally considered to be a reasonable provisional reference target, and - adding an uncertainty margin to deal with the incompleteness of knowledge - a spawner escapement of 50% was advised. The alternative - advice based on the tentative, strongly depensatory stock–recruitment-relation - would have urged for far more stringent, and far more urgent reduction of all anthropogenic mortalities. Subsequently, the EU Eel Regulation indeed adopted a provisional reference point, setting the target at 40% of the pristine escapement. This provisional reference point of 40% is higher than the universal value of 30%, to accommodate for the incomplete knowledge; it does not contain a precautionary safety margin for statistical uncertainty, and indeed, a provisional, not species-specific, stock–recruitment relation does not allow for the derivation of such.

## Maximum Sustainable Yield of eel, Fisheries & non-fisheries impacts

"An important part of ICES advice regards the management of the exploitation of living marine resources. To this end, ICES considers ecosystem-based management (EBM) as the primary way of managing human activities. ICES has developed a comprehensive framework including a set of advice rules to be applied when addressing requests for advice on fishing opportunities" (ICES, 2018d). "To address requests for advice on other topics than fishing opportunities, ICES is dependent on the clients having clearly defined the question(s) to be addressed along with the objectives and criteria to be considered so that the advice is appropriately developed" (ICES, 2018d).

The Eel Regulation "establishes a framework for the protection and sustainable use of the stock of European eel", with the objective "to reduce anthropogenic mortalities so as to permit […] the escapement […] of at least 40% of the silver eel biomass [relative to the notional pristine biomass]." Among the list of potential management measures (Art. 8), actions related to commercial and recreational fisheries, as well as a range of non-fishery-related actions have been included. The Eel Regulation aims for a comprehensive policy, addressing both fisheries and non-fisheries issues without precedence.

The eel constituted 7.5% of the total landings from European inland waters in 1950, diminishing to 1.5% in 2010. Since eel is generally three to five times higher valued than other freshwater fish (export prices), this corresponds to ~5–30% of the landings value (Dekker and Beaulaton, 2016b). Historically, management objectives were often unspecified, and governmental actions predominantly focused on local conflict resolution, among fishers or between fishers and non-fishing stakeholders (Dekker, 2016). The development of the 20th century eel fisheries was primarily triggered by rising prices, related to the development of new processing techniques and new markets (Dekker, 2019). Since the early 1900s, the eel is not a cheap folk food on the countryside, but an urban luxury good (Dekker, 2019, In press). To my knowledge, national legislation of no EU Member State refers to the concept of MSY. The objective of eel fisheries management rarely (if ever) is or has been MSY.

For an unrestricted eel fishery, maximisation of the yield per recruit can be achieved, by minimising the glass eel and yellow eel fisheries, and optimising the silver eel fisheries (Pohlman *et al.*, 2016, Figure 3b). In practise, however, silver eel fisheries dominate only in areas of low abundance, as an adaptation of the fisheries to low stock densities (Dekker, 2003b). Until the adoption of the Eel Regulation, governance was primarily aimed at local conflict resolution, opportunistically supported by arguments concerning yield maximisation, or even stock protection (Dekker, 2008). Current fisheries too appear to be dominated by maximising profit, not by maximising the production of staple food (Table 1). For the major part of the fisheries, the current state is very far from MSY.

The ICES approach to advice on fishing opportunities, integrates ecosystem-based management 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 ecosystems. Populations need to be maintained within safe biological limits to make MSY possible, but a precautionary approach is generally not a sufficient condition for MSY; to achieve MSY, more stringent conditions should be set.

Next to fisheries, many other anthropogenic activities have an impact on the eel stock. Recent assessments (ICES, 2016b) indicate that fishing and non-fishing mortalities often have a comparable impact (Dekker, 2016). Fishing and non-fishing activities, jointly or separately, have an impact exceeding minimal sustainable bounds in many areas, and hence, reductions in both fishing and non-fishing impacts need to be considered. Fisheries constitute a deliberate impact on the stock (making a profit), while non-fisheries impacts are an unintentional side-effect of human actions aimed at other benefits. If eel fisheries would be managed on the MSY-criterion (optimising yield or even profit), while other impacts are not (setting only maximum allowable limits on side-effects), that would lead to incongruous results. When minimal sustainable limits would have been achieved, more stringent restrictions would be required to bring the fishery to MSY, while for the non-fishing impacts, no further restrictions would be required. Or stronger: if the management succeeded in achieving MSY, restrictions on non-fishing impacts could be relaxed. In the long run, this would favour the replacement of fishing impacts by non-fishing impacts, which would move the stock away from the MSY-target. Managing towards MSY, increasing non-fishing impacts would bring the stock away from MSY.

While the MSY-concept is at the heart of fishery-policies related to the precautionary approach, the current eel fisheries are miles away from MSY, aiming at maximising profit rather than yield; non-fishing impacts make a major impact, thwarting the achievement of MSY; and the Eel Regulation aims at a broad and comprehensive protection, including sustainable management of non-fishing impacts. Therefore, the MSY-concept provides no basis for the development of precautionary advice on eel.

**Table 1. Annual landings in biomass (reported), numbers and value (approximated), averaged over the years 2010–2018. Data: ICES 2018a; assumed price for glass eel: 364 €/kg (ICES 2016a), and for yellow/silver eel: 10 €/kg (estimate).**

| 2010–2018 averages | Glass eel, reported | Yellow & silver eel |
|---|---|---|
| Landed weight, t | 53 | 2785 |
| Number, M | 158 | 8 |
| Value, M€ | 19 | 28 |

## Biomass and mortality, aims and means, indicators

In 2002, ICES recommended to develop an international recovery plan for the eel, aiming at a provisional target: a spawning stock of 50% [relative to the notional pristine biomass]. This advice applied a “20% precautionary buffer” (ICES, 2018d) above the provisional, generic value of 30%, because of the “incomplete knowledge” about eel stock dynamics. Subsequently, the Eel Regulation set a long-term objective for the national Eel Management Plans of “at least 40% of the escapement […] of the silver eel biomass”. ICES (2008) noted that the escapement level of 50% advised before “is higher than the escapement level of at least 40% set by the EU”, but did not indicate whether that difference was considered an infringement of the precautionary approach ("The margin of risk tolerance is a management prerogative"; ICES, 2018d). In short: $B_{lim}$=30%, $B_{pa}$=50%, $B_{mgt}$=40%.

Both the 50% advised by ICES, and the 40% adopted in the Eel Regulation, are provisional targets, not eel stock-specific reference points. Because of that, no statistical uncertainty can be calculated. The "incomplete knowledge" margin of 20% replaces the statistical uncertainty margin in the target.

ICES (2016a) classified the European eel as a "category 3" stock, "for which survey-based assessments indicate trends". This category "includes stocks for which survey or other indices are available that provide reliable indications of trends in stock metrics, such as total mortality, recruitment, and biomass". For eel, the only stock-wide data available are the recruitment trends (Figure 5); no stock-wide trends for mortality, landings or biomass exist. This categorisation does not fully make use of "the best scientific evidence" (on abundance, mortalities, protective actions), and does not allow the derivation of "precautionary reference points". With only information on the status of the whole stock (recruitment and/or spawner escapement biomass), but no information on "total mortality", the relevance of the advice for effective management is low. It does not allow "[translation] into management actions", it is not "in accordance with the respective competences of relevant States", recruitment is not likely to rebuild within a few eel generation times (Åström and Dekker, 2007), and, for reasons of statistical uncertainty, the recruit data give a much delayed significant indication of changes in the trends (Figure 1). These shortcomings question the classification in category 3.

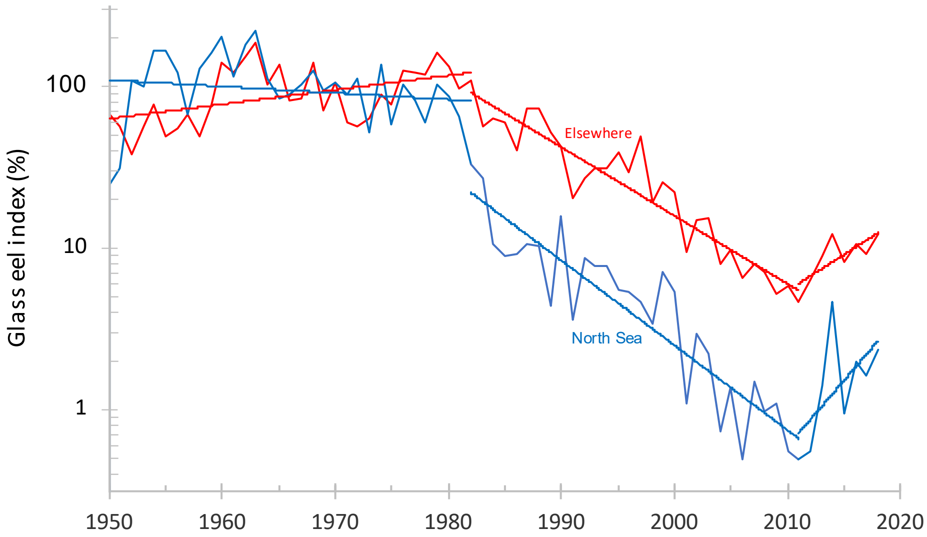


**Figure 1. Trends in the abundance of glass eel arriving at the European continent Data: ICES, 2018a. Tentative linear trend lines have been added for 1950–1982, 1982–2011 and 2011–2018. Note the logarithmic scale of the vertical axis.**

The long-term goal of the Eel Regulation is "the protection and sustainable use of the stock of European eel", leading to "the recovery of the European eel stock". Whereas this long-term goal is clearly focused on the whole stock, the spatial differentiation in biological characteristics of the stock, and spatial variation in the impacts of human activities (fisheries and non-fisheries), necessitate a national (or lower level) implementation of protective measures. The Eel Regulation achieves that, by implementing a system of distributed control (Dekker, 2016), in which common objectives, uniform reference points and an international evaluation process are set for the Union as a whole, while design and implementation of protective measures are delegated to the Member States. To relate to this European management framework, scientific advice needs to address the management measures being implemented, that is: address the national (or lower) level. Stock-wide management is hampered by lack of data on the status of and impacts on the whole stock. Compilation of a stock-wide database has been pursued for several decades, without full success (Dekker and Beaulaton, 2016b). This makes any advice strategy relying on completion of the stock-wide data base extremely uncertain, not risk-averse. While the status of the whole stock can be addressed at the international level (using the recruitment trends as current), the effect of human impacts (fishing and non-fishing), as well as the gain produced by protective measures, can only be addressed effectively at the level of individual (national or lower) spatial management units. Whereas protection can be achieved immediately and by each geographical management unit independently, recovery is necessarily a long-term, global objective, for which several generations (decades) will be required (Dekker, 2016).

The Eel Regulation sets an objective for national Eel Management Plans: "to reduce anthropogenic mortalities so as to permit […] the escapement […] of at least 40% of the silver eel biomass [relative to the notional pristine biomass]". While this appears to set a clear and quantifiable target for each management unit in terms of biomass (40% escapement biomass, assuming that the notional pristine biomass can be determined), a biomass target does not enable effective management. Current silver eel escapement in most countries/management-units is substantially below the level of 40%, and recovery is necessarily a long-term (multi-generational), global objective, outside the competence of individual management areas (because of the dependence on future recruitment), and overshadowed by uncertainties about whole stock dynamics (Dekker, 2016). However, the long-term biomass target of 40% corresponds to a short-term limit on anthropogenic mortality of %SPR=40%, equivalent to lifetime-mortality $\Sigma A=0.92$ (Dekker, 2010; 2016; ICES, 2010c), which can serve as short-term target for national (or lower level) management (see further discussion, below). In contrast to the provisional target for the stock as a whole (%SSB=40%, respectively $\Sigma A=0.92$) for which no statistical uncertainty can be derived, the actual level of mortality $\Sigma A$ can be calculated at the national (or lower) level, with any required precision.

The stock classification scheme used for ICES advice (categories 1 through 6; ICES, 2018d) is based on the work by WKLIFE (ICES, 2012 and later). For the eel, WKLIFE considered that "ICES does not have an accepted time-series of stock wide catch for eel and consequently, eel will not be considered further by WKLIFE," that is: the classification scheme was not designed with eel in mind. Subsequent application of the WKLIFE-classification scheme to eel leads to an advice, that addresses "the whole stock unit over its entire area of distribution", but is not "based on the best scientific evidence", is not "in accordance with the respective competences of relevant States", and cannot "[translate] objectives … into management actions". That is: the classification scheme does not fit for eel. It is only through the adoption of distributed control under international orchestration that a feasible management model for the European eel could be attained (Dekker, 2016). Whether this unusual approach warrants a separate generic WKLIFE-category for such widely distributed stocks, or the advice on eel is developed outside the WKLIFE classification scheme, is a discussion that goes beyond the scope of this paper.

Although restocking is considered by the Eel Regulation as a management action contributing to the recovery of the stock, its value has been disputed (ICES 2016b). Whereas the Precautionary Approach (FAO, 1996) notes that artificial propagation should not be used "as a substitute for the precautionary measures" to protect a stock, ICES (2018b) advised that restocking too "should not be used as an alternative to reducing anthropogenic mortality" on the stock. Noting that the risks involved in restocking are similar to some of those of artificial reproduction, this aligns ICES advice on restocking with the values of the precautionary approach. While restocking contributes to the silver eel escapement (and most assessments will not be able to separate them from the natural immigrants), it should not be considered as a negative mortality, substituting for other (positive) anthropogenic mortalities. (Previously, ICES, 2010c had indicated that restocking could technically be interpreted as a negative mortality).

## Mortality limits for a depleted stock, recovery, time frame

For long-lived stocks managed towards MSY, ICES (2018d) defines a minimal limit to the spawning–stock biomass (MSY $B_{trigger}$), set at the lower bound of natural fluctuation in the spawning stock when fished at $F_{MSY}$ (alternatively, MSY $B_{trigger}$ is set at $B_{pa}$, when insufficient information is available to determine the natural fluctuation). Below MSY $B_{trigger}$, the cautious response is to reduce the fishing mortality advised, in proportion to the spawning–stock biomass (i.e. F= $F_{MSY}$× spawning–stock biomass/MSY $B_{trigger}$, so that F=0 at B=0 and F= $F_{MSY}$ at B= MSY $B_{trigger}$, with linear interpolation in-between; Figure 5, left panel, shows this as the border between yellow and orange). If the stock does not recover to above MSY $B_{trigger}$ "in the short term", zero catch may be advised for stocks managed towards MSY.

The objective of the Eel Regulation is not to achieve MSY; eel fisheries have rarely (if ever) been managed for maximal yield; and non-fisheries impacts complicate the achievement of MSY (see above). Instead, the Eel Regulation aims at "the protection and sustainable use of the stock", setting a long-term target of 40% silver eel escapement. To this end, anthropogenic mortalities must be reduced, to below a level that allows recovery of the stock, within a reasonable timeframe.

Though it is evident that the eel stock is not managed towards MSY; and it is equally evident that the ICES-protocol to shrink F below MSY $B_{trigger}$ is only meant for short periods, in the neighbourhood of MSY $B_{trigger}$; we will explore here how the MSY $B_{trigger}$ rule would apply to a severely depleted stock such as the eel, aiming at recovery of the stock towards a specified abundance. Application of one and the same rule (to MSY-policies and to recovery-policies) would avoid the need to define a breakpoint where one rule replaces the other; and it would avoid discontinuous behaviour around this breakpoint.

For a long-lived semelparous species, such as the eel, the spawning stock size is directly related to the lifetime mortality, more than to conventional annual mortalities (Dekker, 2016). For eel, both once-in-a-lifetime as well as continuously impacting anthropogenic mortalities occur. Since average lifetimes may vary from 3–30 years, depending on the location, these different mortalities are difficult to compare when expressed on a per annum basis. Hence, Dekker (2010) suggested a lifetime mortality approach, relating the silver eel output directly to the glass eel input from which it originated. Additionally, plotting the size of the spawning stock (%SSB) on a logarithmic scale (Figure 2, right), a conveniently simple conceptual diagram is derived: lifetime mortalities that can be expected to recover the stock to a specified level (40%) within one generation align on a straight line; within two generations, on another line; etc. As Figure 2 shows, the ICES standard rule - shrinking F proportional to %SSB on the linear scale, Figure 2, left – can be expected to restore $B_{pa}$ within one generation if B is close to the target, but relaxes the recovery period, the lower B is. That is: with deteriorating state of the stock, a less ambiguous time-to-recovery is applied. This does not align with the requirement to "rebuild the stock over a specific time period" (FAO, 1996, point 48.b). It is therefore recommended, to apply a mortality-shrinking rule based on the expected number of lifetimes until recovery, i.e. a straight line on the logarithmic scale of %SSB, as in Figure 5 right. Whether this recommendation is equally valid for non-semelparous species, is outside the scope of this paper, but it is recommendable to investigate that.

The Eel Regulation sets an objective (of 40% spawner escapement), and obliges its Member States to develop "Eel Management Plan […] with the purpose of achieving this objective in the long term" (Art. 2.4, formatting added). Not any suggestion of an allowable time frame is made. This breaches the condition to "rebuild the stock over a specific time period" (FAO, 1996, point 48.b), and may delay recovery indefinitely. It is therefore recommended that EU considers to adopt an explicit timeframe, preferably set in number of generations until full recovery (to $B_{mgt}$). This timeframe, in turn, will translate into a maximum allowable mortality level ($\Sigma A_{mgt}$) for each spatial management unit. Since the objective of the Eel Regulation (restore to 40% escapement) is a provisional reference point, this mortality limit $\Sigma A_{mgt}$ will also constitute a provisional reference point.

For stocks managed towards MSY, ICES may advise to reduce catches to zero, if the stock is below MSY $B_{trigger}$, and does not recover "in the short term". This is of particular concern for short-lived species, in which the spawning stock comprises only very few (just one) year classes, increasing the risk to deplete the stock irreversibly. The objective of the Eel Regulation is a recovery towards $B_{lim}$ (resp. $B_{mgt}$), "in the long term". The question arises, whether for the eel too, a biomass can be defined or a number of years set, below/after which a more precautious approach is required; a lower limit, below which extreme emergency measures would be warranted. The concept of Minimal Viable Population (Shaffer, 1981) might be considered, but noting that eel stock dynamics are largely unknown, there is no basis to derive a quantitative estimate. That is: no lower cut-off point can be derived. For eel, the above suggestion for a gradual reduction in anthropogenic mortality below $B_{mgt}$, aiming at recovery within a specified number of generation times, is the means to avoid extremely low abundances.

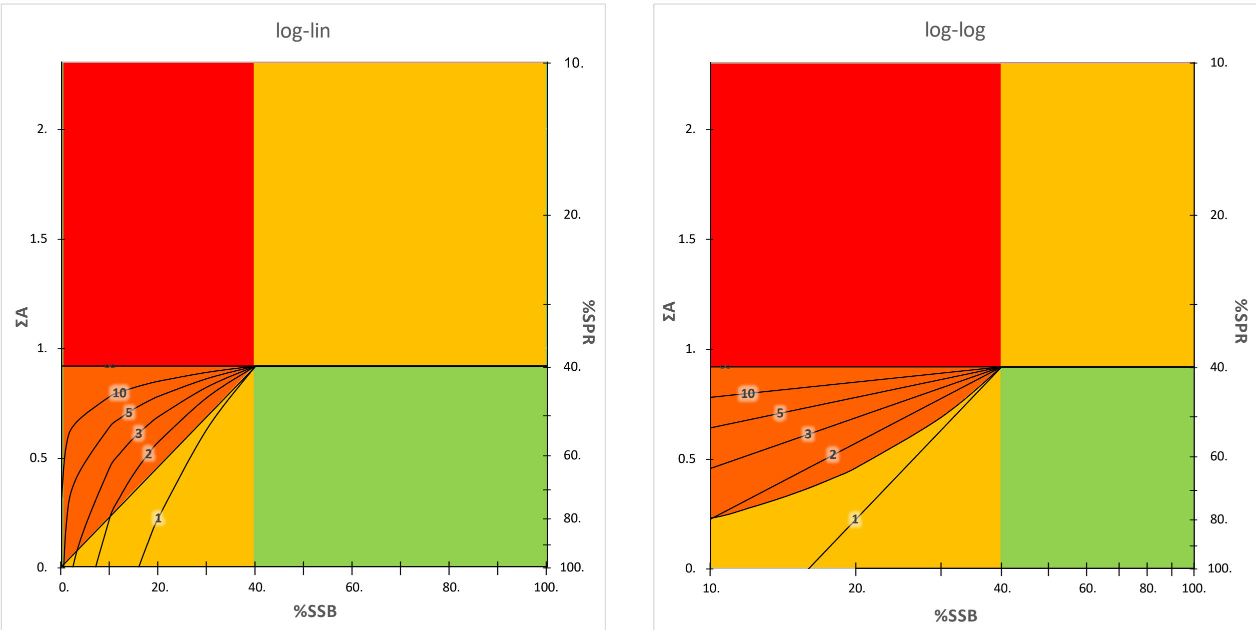


**Figure 2. Comparing two types of precautionary diagrams, showing potential rebuilding limits and targets. Left: conventional precautionary diagram, plotting mortality (ΣA, vertical) versus spawning–stock biomass (%SSB, horizontal), with %SSB on a linear scale. Right: the same, but plotting %SSB on a logarithmic scale, to correspond to the inherently logarithmic nature of the left vertical axis (Dekker, 2010). For %SSB <$B_{pa}$ (40%), mortality levels have been indicated that can be expected to recover the stock to $B_{pa}$ within respectively 1, 2, 3, 5, 10 generations; the line between the orange and the yellow zones marks the conventional ICES rule for shrinking F below MSY $B_{trigger}$.**

This is a working document, contributing to the group discussion. Hence, no discussion or final conclusion. To ease the discussion, results are summarised in Table 2, even though I am well aware that this contains value judgements.

**Table 2. Tabular summary of the whole discussion. ✓ is adherent, × is non-adherent, blank is irrelevant. For the ICES advice, as well as for the Recommended, in some cases two values are given: one for stock-wide, recruits or total biomass; the other for EMP-wise, mortality.**

| Criterion | Eel Regulation | EMPs | ICES advice | Recommended |
|---|---|---|---|---|
| Best scientific evidence | ✓ | ✓ | × | ✓ |
| Whole stock | ✓ | | ✓ | ✓ |
| Competence of States | ✓ | ✓ | × | ✓ |
| Translates into mnm action | | ✓ | × | ✓ |
| Set reference points | × | | × | × |
| Stock-specific | × | ✓ | × | ×, ✓ |
| Provisional reference points | ✓ | | ✓, × | ✓ |
| Statistical uncertainty | × | ✓ | × | ×, ✓ |
| Incomplete knowledge | ✓ | ✓ | ✓ | ✓ |
| Specific time period | × | ? | × | ✓ |

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# Annex 11: Recommendations

| Recommendations | Addressed to |
|---|---|
| As an end user of the DCF data, WGEEL recommends the inclusion of detailed fishing effort and capacity data for eel fisheries in the DC-MAP regulation to ensure the availability of adequate fishery data to undertake stock assessments. | Diadromous sub-group of the RCGs |
| A workshop is required with fishery managers from across the eel range states to determine how to harmonise the reporting on key commercial eel fisheries in order to provide adequate data to WGEEL and national stock assessors. | ACOM, EIFAAC, GFCM |