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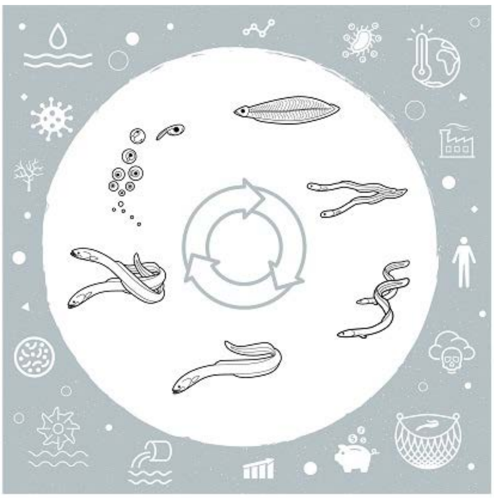
Research for PECH Committee - Environmental, social and economic sustainability of European eel management



Fisheries

Policy Department for Structural and Cohesion Policies
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Research for PECH Committee - Environmental, social and economic sustainability of European eel management

Abstract

The diversity of detrimental factors impacting the European eel and the number of involved stakeholders pose a challenge for an effective stock management. Knowledge on the economic consequences of single management measures is required to better assess their implications for the involved sectors. This study summarizes the current knowledge on threats and provides economic data from hydropower generation, fisheries and aquaculture impacting the European eel in order to evaluate management measures and estimate their repercussions for stakeholders.

This document was requested by the European Parliament's Committee on Fisheries.

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LIST OF ABBREVIATIONS

CFP	Common Fisheries Policy
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS	Convention on Conservation of Migratory Species of Wild Animals
COGEPOMI	Comités de Gestion des Poissons Migrateurs
CPUE	Catch per unit of effort
CR	Country Report
DCF EU	Data Collection Framework
DG	Directorate-General
EDA	Eel Density Analysis (modelling tool)
EIFAAC	European Inland Fisheries and Aquaculture Advisory Commission
EMFF	European Maritime and Fisheries Fund
EMP	Eel Management Plan
EMU	Eel Management Unit
EU-MAP	EU-Multi Annual Program
EVE	Eel Virus European
EVEX	Eel Virus European X
FAO	Food and Agriculture Organisation
FTE	Full Time Equivalent
GFCM	General Fisheries Commission for the Mediterranean
GW	Gigawatt
HEMP	Hellenic Eel Management Plan
HP	Hydropower
HPP	Hydropower Plant
HVA	*Herpesvirus anguillae*
IA	Economic Impacts
ICES	International Council for the Exploration of the Sea
IUCN	International Union for Conservation of Nature
IUU	ILLEGAL, UNREPORTED AND UNREGULATED
MARM	Ministry of Environment, and Rural and Maritime Environment
MLS	Minimum Landing Size
MS	Member State

MTOE	Million Tonnes of Oil Equivalent
MW	Megawatt
NDF	Non Detrimental Finding
ONEMA	Office National de l'Eau et des Milieux Aquatiques, France (ex-CSP)
PCB	Polychlorinated biphenyl
PO	Producer Organisation
RBD	River Basin District
RD	Royal Decree
SEPRONA	The environmental division of the Spanish Guardia Civil / Servicio de Protección de la Naturaleza
STECF	Scientific, Technical and Economic Committee for Fisheries
SUDOANG	SUDOE project (https://www.sudoang.eu/)
SUDOE	The Interreg Sudoe Programme supports regional development in Southwest Europe financing transnational projects through the European Regional Development Fund (ERDF)
TWH	Terrawatt-hour
WFD	Water Framework Directive
WGEEL	Joint EIFAAC/ICES/GFCM Working Group on Eel
WKEPEMP	Workshop on Evaluation Progress in Eel Management Plans

EXECUTIVE SUMMARY

Within the last 50 years the European eel (*Anguilla anguilla*) has turned from one of the largest freshwater fishery resources in many areas of Europe and northern Africa to an endangered species. While the reasons for this tremendous decline of the eel population are still not fully understood, three anthropogenic causes of mortality are thought to have a significant impact at least in specific habitats. Together with the unpredictable risks caused by water and sediment pollution, intensive fisheries on all continental life stages as well as habitat fragmentation and destruction play a major role.

The European eel has a complex life cycle, which is characterised by distant oceanic and freshwater migrations between its spawning area in the Sargasso Sea and the coastal and freshwater feeding habitats. The different phases in the life cycle are related to several metamorphoses and distinct life stages: After their oceanic journey as leptocephalus larvae they reach the continental shelf areas and metamorphose to glass eels, which aggregate in river estuaries before colonising freshwater and coastal habitats for their growth and feeding yellow eel life stage. Yellow eels spend 4 to more than 20 years in fresh and coastal waters before they metamorphose again to silver eels and start their unique migration back to the spawning area in the Sargasso Sea. As a result, eels colonize and migrate through a great variety of habitats in the ocean, in brackish water and of course a variety of different inland waters. Furthermore, all life stages from glass eel to silver eel are fished in coastal and freshwater habitats by commercial and recreational fisheries. European eel aquaculture is exclusively capture-based, depending totally on wild caught glass eels, since artificial reproduction of the species is still not possible.

Despite the lack of a quantified assessment of the impact of fisheries on the whole stock and a decrease in the number of fishers targeting eels in the four focus countries since 2006, it is noteworthy that any further mortality caused by fisheries contributes to losses in silver eel escapement and therefore spawning stock biomass. During the 2015-2017 period, 193 million glass eels were caught annually compared to roughly 6.1 million yellow and silver eels. In many areas yellow and silver eel fishing is only sustained through extensive stocking activities. Stocking of wild caught glass eels, carried out usually by regional authorities, commercial or recreational fishing associations or even individual fishers without scientific evaluation, is still continued under the premise of a potential net benefit for the recovery of the overall eel population, but effectively may even further increase the pressure on the panmictic stock.

The introduction of barriers represents one of the major factors affecting riverine fish populations, in particular of migratory species. With regard to eels, different types of obstacles and barriers, including culverts, weirs, bridge aprons, dams, hydropower stations, pumping stations, tidal flaps and sluices, can adversely affect their continental life stages during migration. Typical negative effects of barriers include the loss of upstream habitats due to restrictions in river continuity, delays in migration and, of course, direct mortality at pumping stations, water intakes and, especially for downstream migrating silver eels, hydropower turbines.

In light of these developments, several measures were taken to facilitate an internationally coordinated management and aid the recovery of the eel stock: In 2007, the European Union passed Council Regulation 1100/2007 "establishing measures for the recovery of the stock". Accordingly, Member States were obliged to identify natural habitats of the European eel and develop Eel Management Plans (EMP) in order to achieve an escapement target of 40% of silver eels as compared

to pristine conditions. In 2009, the European eel was listed under CITES Appendix II, requiring export permits for eels. In 2011 EU Member States published a zero export quota for the species. However, illegal, unreported and unregulated (IUU) fishing is still regarded a major threat for the European eel.

Many measures have been proposed and implemented to comply with the goals of Council Regulation 1100/2007. Possible instruments were already listed in the Regulation, but MS could also implement other measures to reach the target in a results-based-management-approach.

In general, results-based-management-approaches are preferable to a command and control approach, where everything is decided at the central level. For European eel management, however, it is to discuss, if the 40% biomass-based objective is the preferable target over a mortality-based target. The 40% biomass target is largely influenced by the definition of B0, the estimate of escapement that would have existed if no anthropogenic influences had impacted the eel. The scientific basis for such an estimation is lacking and therefore, these estimates vary substantially between EMPs. In addition, this approach does not consider that natural recruitment has dramatically declined since the 1970s. In areas of low to completely absent natural recruitment, stocking is the only possible way to fulfil the escapement target. For this reason, stocking programs have been introduced in many countries, despite stocking being heavily disputed as a suitable method for a stock recovery within the scientific community. ICES (2018) requests internationally coordinated research to determine any net benefit of stocking on the overall population, including carrying capacity estimates of glass eel source estuaries, detailed mortality estimates at each step of the stocking process, and performance estimates of stocked vs. non-stocked eels. Stocking is even performed upstream of hydropower dams and other obstacles, which effectively impede silver eel escapement. Finally, the 40% escapement target has never been scientifically evaluated for compliance with the Precautionary Approach. Shifting to a mortality target would overcome these problems and ensure a distributed effort from all Member States. A mortality target needs to be sufficiently low to further reduce direct anthropogenic impacts and allow the restoration of the stock above a safe biological limit.

This study revealed not only large knowledge gaps and data deficiencies in European eel management from a biological perspective but also from an economic point of view. To better assess the implications of different protection measures for industries like fisheries, aquaculture, fish processing and energy production, deeper knowledge on the economic impact of management measures on stakeholders is required.

On the basis of the available economic data on cost structures of fishers that carry out commercial fisheries (marine and freshwater) only a vague analysis of impacts is yet possible. Accordingly, the loss of direct revenues at a total closure of fisheries in Europe (glass, yellow and silver eels) is estimated to EUR 50 million per year. The most severe economic impacts may be caused by a closure of the glass eel fishery, since, as a secondary effect, the loss of seed would also result in a cessation of European eel aquaculture, with losses of EUR 37 million in revenues, and, consequently, to a large extent also of fish processing companies specialised on eel.

The putative costs to mitigate hydropower mortalities exceed the loss of revenues for a total closure of fisheries in Europe by far. In France alone, the impact of a seasonal shut down of hydropower facilities for 10 weeks on the aggregated revenue would range from EUR 127 million to EUR 634 million at a total loss in power generation from 1.5 to 7.7 Terawatt-hour (TWh). The possible costs of constructing upstream and downstream migration facilities are estimated to range between EUR

1,051 million to 3,110 million. This is 1.7 to 4.9 times as costly as a 10-week seasonal closure of the affected hydropower facilities, which means that migration facilities would be more cost effective after a two to five-year period. For Spain, losses are in the same range as in France, while for Greece and Germany losses were lower.

As a consequence, there is an urgent need to evaluate the effectiveness of measures for the protection and recovery of the European eel for conformity with the Precautionary Approach. All regulatory measures adopted for its stock recovery should directly target at a significant and verifiable reduction of eel mortalities. These include river continuity restoration and habitat quality improvement as well as significant reductions in commercial and recreational fisheries related mortalities. Prior to a decision on possible management actions a robust scientific impact assessment should be issued to inform decision makers about the costs and benefits to reach a certain management target.

Overall, it would be highly recommended to move from the current 40% regional level escapement targets to a mortality-based target in a revised version of an EU Regulation.

1 BACKGROUND AND OBJECTIVES

The European eel (*Anguilla anguilla*) stock has been in steep decline since the end of the 1980s and glass eel recruitment dropped to less than 10% of the 1960 – 1979 average, intermittently dropping to less than 1% in the North Sea (ICES 2017a, b). Though a similar trend is evident in yellow eels, where recruitment levels remained somewhat higher and fluctuate around 10 to 30%, the available time series are mostly limited to the Baltic and do not accurately depict the overall trends in yellow eel recruitment.

Following these developments, the species is listed in the IUCN red list of endangered species as "critically endangered" (Jacoby and Gollock 2014) and the status of the European eel stock is considered critical by the International Council for the Exploration of the Sea (ICES) advising that "all anthropogenic impacts (e.g. recreational and commercial fishing on all stages, hydropower, pumping stations, and pollution) that decrease production and escapement of silver eels should be reduced to – or kept as close to – zero as possible" (ICES 2017b). A proper assessment and management of the European eel is challenging, however, and the current advice is solely based on recruitment time-series of glass and yellow eels across Europe, with the above-mentioned data limitations. Though additional stock related data (e.g. size of the standing stock, catch quantities or effort) is at least partly available within the EU (yet, widely missing outside the EU) no standards for the data collection or quality of these data have been set. Consequently, not only is there a lack of spatial coverage, but also differences in the applied methodologies (e.g. use of different population models) and reporting standards across Europe, thus restricting their scope in the assessment of the eel stock or the evaluation of management measures. While the EIFAAC/ICES/GFCM Working Group on Eels (WGEEL) has addressed these issues (ICES 2017a), a standardization of stock assessment procedures seems unlikely, given the different preconditions concerning e.g. legislative structures, predominant fisheries or data availability between countries (both, within and outside the EU). One of the major challenges is the occurrence of eels in various marine, coastal and freshwater habitats across Europe and North Africa (e.g. Tesch 2003). Furthermore, many details of the facultative catadromous life cycle of the European eel remain elusive, particularly concerning the remote offshore spawning in the Sargasso Sea, the associated spawning migrations and larval feeding. It is thus difficult to pinpoint the exact cause for the decline and identify the stakeholders involved but it is likely attributed to the interplay of several factors acting on global and local levels (e.g. Miller et al. 2016).

With all three continental life stages of the European eel being commercially exploited (i.e. glass eel, yellow eel and silver eel), fisheries are amongst the most commonly discussed factors for the decline of the stock. Besides fisheries, habitat loss is also considered a major contributor. In migratory freshwater and diadromous species, the construction of dams and weirs is the most obvious cause for habitat loss and while hydropower plants provide notable financial and ecological benefits (e.g. renewable energy), they often act as impassable migration barriers rendering habitats inaccessible and thus effectively lost to the fish populations. However, human actions impact the stock on a much broader scale (e.g. environmental pollution and climate change), which also lead to the degradation, fragmentation or loss of habitat across the globe (Dudgeon et al. 2006). In addition, these factors might have further associated direct impacts on the reproductive success of eels, such as the reduction of spawner quality due to high contaminant loads (Freese et al. 2016, 2017) or changes in oceanic conditions potentially resulting in increased larval mortalities (e.g. Knights 2003; Bonhommeau et al. 2008).

In light of these developments, several measures were taken to facilitate an internationally coordinated management and aid the recovery of the eel stock: In 2007, the European Union passed Council Regulation (EC) 1100/2007 "establishing measures for the recovery of the stock" (EU 2007). Accordingly, Member States (MS) were obliged to identify natural habitats of the European eel and develop Eel Management Plans (EMPs) in order to achieve an escapement of 40% of silver eels as compared to pristine conditions (i.e. silver eel escapement that would have existed if no anthropogenic impacts had ever influenced the stock). In 2008, the European eel was included in the EU Data Collection Framework (DCF, EC 199/2008) (EU 2008), requesting the collection of stock related data from each MS to address the fundamental lack of information on local sub-populations and, in 2009, the European eel was listed in CITES Appendix II, requiring export permits for eels. In 2011, MS published a zero-export quota for the species, which directly reduced the economic interest in the species.

Despite the European eel is a single panmictic stock distributed widely from northern Africa in the south to the Barents Sea in the north (including Mediterranean, Atlantic, North- and Baltic Sea) it is managed at national and regional levels as if it was divided in isolated populations, resulting in large differences in the management measures adopted. Roughly a decade after the implementation of the EMPs, eel management across Europe differs widely and includes minor adaptation of national fishing restrictions and increased stocking efforts but also drastic and expensive measures like complete closures of eel fisheries and the construction of fish passes at dams and hydropower stations. While the evaluation of such measures from a strictly conservational perspective has proven difficult, a comprehensive management approach has to further account for complex interactions between the numerous stakeholders involved in commercial and recreational eel fisheries, aquaculture, processing, species conservation and other associated industries. Sociological and economic research on eel is generally scarce in the context of the eco-system approach to fish management. However, the consideration of the socio-economic dimension of the eel management is a key element for the successful development of conservation strategies (ICES 2016a). Up to date, however, no such approach has been conducted and the financial and economic impacts for the relevant stakeholders remain poorly documented.

This study aims at providing an overview on the current knowledge of eel biology and stock status, presenting an overview of management measures from MS, assessing the economic importance of sectors affecting the European eel stock and, where possible, quantifying the repercussions for stakeholders caused by eel management.

To achieve this, this study addresses the following objectives:

1. Provide an overview of the state of the art of knowledge and emerging research on the European eel
2. Summarise the public measures taken to aid recovery of the stock indicating the relevant competent authorities
3. Identify the main economic actors impacting the eel stock at its different life stages
4. Identify the type of industrial installations that are major obstacles to the escapement and migration of the spawning stock
5. Assess the impact of the main economic actors on the eel stock and their socio-economics
6. Assess socio-economic repercussions to stakeholders of possible stock management measures

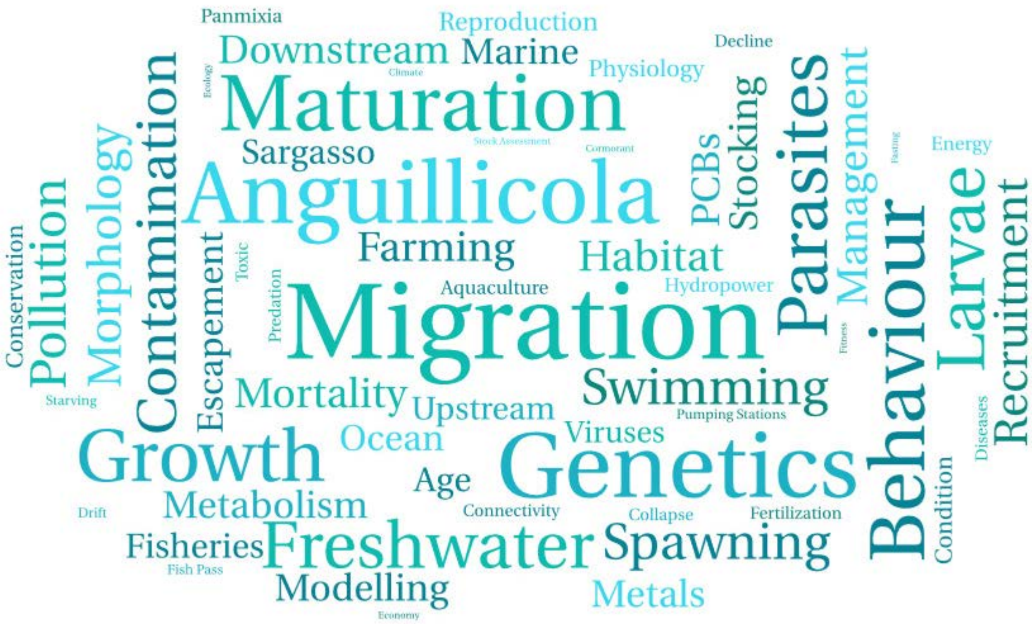
2 OVERVIEW ON THE STATE OF KNOWLEDGE AND EMERGING RESEARCH ON THE EUROPEAN EEL

Key findings

- There is broad consensus among scientists that no particular impact can be singled out having caused the decline of the European eel stock and preventing its recovery. Instead, a combination of various impacts is thought to have contributed to the decline.
- Among the quantifiable continental factors, hydropower, river obstruction and fisheries are considered the most important impacts.
- Recent studies suggest that climate driven oceanic factors may have also contributed towards the decline, mostly by affecting larval survival in the spawning area of the Sargasso Sea.
- Though notable progress was made, it remains not possible to artificially reproduce the European eel and it will not be a feasible management option in the near future.
- While the general theory of panmixia prevails, there are some indications for genetic stock structures that might affect the success or outcome of stocking measures.

To provide an actual overview of the emerging research on the European eel stock, a comprehensive literature search of selected relevant peer reviewed literature from recent 3 to 5 years (Scopus and Google Scholar) and a review of grey literature from diverse expert groups and stakeholders was conducted. The following sections will summarize novel information on life-history specific traits, topic-related emerging research and expert opinions to provide an overview of the current knowledge regarding the European eel stock situation and its management. This section also provides an overview of known threats for the European eel stock. The variety and importance of research areas related to the European eel is illustrated in Figure 1. In total, 738 scientific papers referring to the European eel in the title were published since 2008, demonstrating the effort of the scientific community to increase knowledge about this species.

Figure 1: Frequency of recently studied topics in relation with the European eel

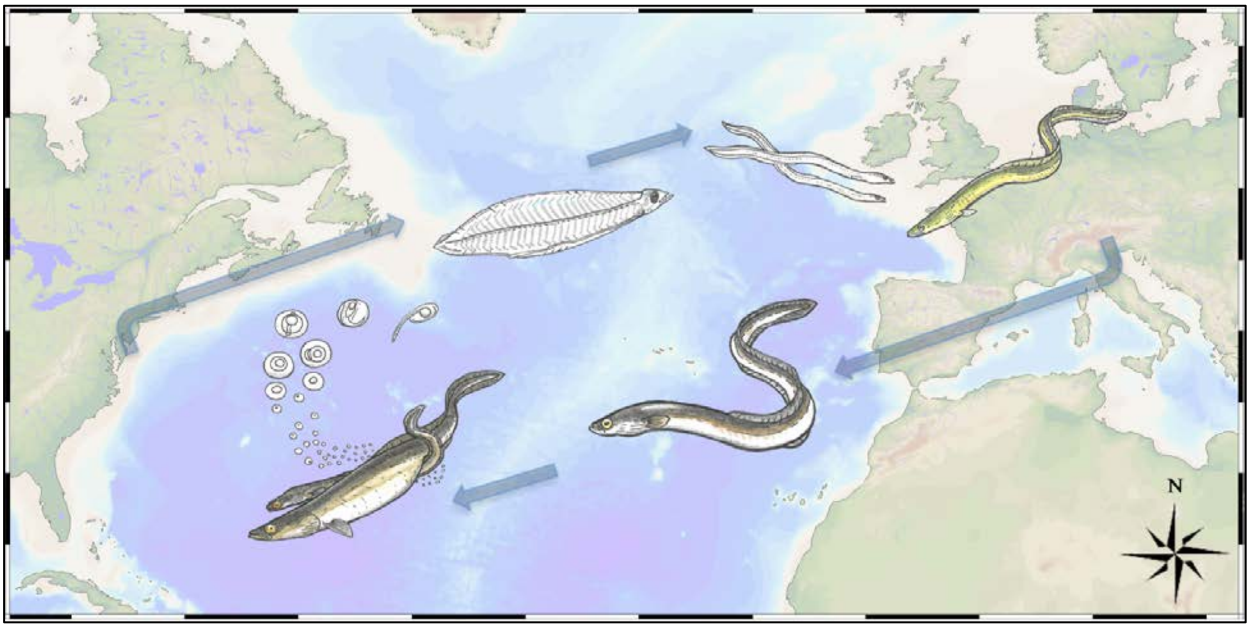


This illustration is based on a Web of Science database search. The size of words indicates how often these (and closely related words) occurred in the title of scientific papers in conjunction with the European eel between 2008 and 2019.

2.1 Knowledge and emerging research on the European eel stock

After their oceanic journey as willow-leaf or leptocephalus larvae, when reaching continental shelf areas, eels metamorphose to glass eels and aggregate in river estuaries before colonising fresh water and coastal habitats for their growth and feeding yellow eel life stage. Yellow eels spend 4 to more than 20 years in fresh and coastal waters before they metamorphose again to silver eels to meet the demands of their final spawning migration back to the spawning area in the Sargasso Sea (Fig. 2).

Figure 2: Lifecycle of the European Eel



Lifecycle of the European Eel displayed in clockwise rotation beginning with spawning silver eels (left), eggs and larvae (top), glass eels (top right), yellow eel stage (right), and silver eels (bottom). Designed by Eric Otten

2.1.1 Genetic stock structure

The European eel is a migratory and diadromous species. Its wide natural distribution ranges across European and North African countries connected to or associated with the Atlantic, North Sea, the Baltic Sea and the Mediterranean as well as parts of the Black Sea. The species is known for a complex life cycle, as it repeatedly changes its morphology and develops through multiple distinct life stages. Both Atlantic Eel species, the European eel (*Anguilla anguilla*) and the American eel (*Anguilla rostrata*), are considered panmictic species, meaning that all individuals of the entire natural range form one single stock for reproduction (Als et al. 2011; ICES 2011; Cote et al. 2013). As a result, this gives every individual the same probability to mate with another individual from the stock, with no further influence of origin. However, the finding of true panmixia has repeatedly been challenged in the scientific community over time and also recently has been discussed controversially or at least partially amended with yet no clear consensus. Strong evidence for a true panmictic reproduction strategy has been presented by a comprehensive molecular population genetics study by Als et al. (2011) and was confirmed by Pujolar et al. (2014), who discusses signs of spatially and temporally varying selection. Nonetheless, the species itself is considered of relatively high genetic diversity as shown in numerous genetic studies (Jacobsen et al. 2014; Pujolar et al. 2014; Baltazar-Soares and Eizaguirre 2016). This genetic feature is thought to provide a higher probability of recombination and thus reproduction success and eventually species survivability. However, some recent studies (Baltazar-Soares et al. 2014; Ragauskas et al. 2017) point out the possibility of a maternal population structure of the species characterized as a genetic mosaic (see also Daemen et al. 2001) formed by reproductively isolated female groups. Such findings, if confirmed, would have implications for management, as then stocking of wild-caught glass eels may alter natural selection scenarios and recruitment mechanisms.

Stacey et al. (2014) in a study on the American eel describe how eels from distant donor areas in Canada, deported and released into the more than 2000 km distant St Lawrence river, showed different life-history specific traits and exhibited differences in sex ratios, growth and size at silvering than natural recruits from this area. The authors conclude that this was likely a result from a spatially varying selection, which implies that the regional population genetics of eels can be influenced by geographically induced environmental conditions during the leptocephalus and glass eel ingress stages as a primary mechanism for locally adaptive selection (Als et al. 2011; ICES 2011; Gagnaire et al. 2012).

In conclusion, despite remaining knowledge gaps concerning details of the reproduction biology of Atlantic eels, the management of this species is strictly based on perception of general true panmixia. Hence, the importance in understanding the entire life-history strategy including recruitment mechanisms remains crucial.

2.1.2 Novel Information on the oceanic larval phase (Leptocephalus)

The lives of all European eels are believed to begin in the Sargasso Sea, a region of the North-West Atlantic Ocean south to southeast of Bermuda. This large marine ecosystem is thought to comprise the European eels' unique spawning area, since it is the only area on earth where scientists have found early larval stages of this species.

It is assumed that the larvae are transported from there towards the coasts of their natural distribution range within less than 1 to more than 3 years by a combination of active swimming and passive drifting via ocean currents (McCleave et al. 2008; Bonhommeau et al. 2010; Rodriguez-Diaz and Gómez-Gesteira 2017; Westerberg et al. 2018a). When the leptocephalus larvae reach the continental shelves of Europe and North Africa, they metamorphose to glass eels, a life stage resembling a small, translucent version of their adult counterparts. Many details of this oceanic larval phase are still considered unclear and albeit recent research has provided important novel insights to eel migration and reproduction, many uncertainties remain.

Miller et al. (2014) reviewed a large and comprehensive dataset comprising multiple expeditions over the past decades and analysed distributions, maximum sizes and growth rates of *A. anguilla* and *A. rostrata* larvae. The authors concluded that *A. anguilla* leptocephali originate from a further eastern spawning area, grow slower and change their appearance to glass eels at larger sizes (up to almost 90 mm) than *A. rostrata*. The duration of the larval phase of the European eel is suggested to be quite variable and the distribution of larvae of largest size classes suggests their capability to swim directional. Calculated main spawning time in the Sargasso Sea varies according to different authors from December to February (Righton et al. 2016) and February to March (Kuroki et al. 2017) with American eels predominantly hatching in February while European eels rather hatch around March. The latter analyses suggested additional hatching times in November/December as well as in July. Also Westerberg et al. (2018a) suggested spawning of the European eel to be earlier than in February/March, which is the prevailing, widely accepted hypothesis.

Concerning larval abundance, recent studies show evidence about reduced recruitment already at early larval stages in the Sargasso Sea (Hanel et al. 2014; Westerberg et al. 2018b). Authors conclude that oceanic factors may be of high relevance in the overall stock decline, be it due to high leptocephalus mortality or due to large geographic shifts in glass eel arrival.

There is still considerable debate on the natural feed of eel larvae. While recent literature based on next-generation gene sequencing techniques revealed that gut contents of eel larvae were dominated by gene sequences of hydrozoans and other gelatinous zooplankton taxa (Riemann et al. 2010; Ayala et al. 2018), other studies highlight the importance of aggregated particulate organic matter, referred to as marine snow as a natural diet for leptocephali (Miller et al. 2019).

Knowledge about the oceanic phase in the larval biology of anguillid eels still is subject to several uncertainties and it remains of great relevance to deepen our understanding concerning the involved mechanisms connected to oceanic recruitment. Research in the spawning area such as gathering new information on larval abundance as well as on ecological (biotic and abiotic) interactions may help to further close the still existing knowledge gaps in connection to the interrelation of continental spawning stock, spawning success and eventually successful recruitment. WGEEL explicitly supports proposals for standardized larval surveys in the Sargasso Sea with a clear target on monitoring and evaluating eel leptocephali and/or egg densities in the spawning area (ICES 2012a), which, if continued on a regular basis, could enable a faster detection of changes in recruitment and possibly spawning stock size. Furthermore, such surveys could also provide indications of changes in the survival of eel larvae during their oceanic phase. WGEEL (ICES 2012b) also stated that such surveys could be linked to the Data Collection Framework of the EU (DCF, now EU MAP).

2.1.3 Artificial Reproduction / Breeding

Even a long history of research on artificial reproduction of anguillid eels in captivity has not yet led to successful production of viable European eel larvae in captivity. As a result, artificial reproduction of the European eel is still not possible and thus cannot be considered a realistic option for directed stock recovery effort at any time soon. Novel insights and data deriving from recent research continue to challenge the diverse difficulties in the artificial breeding of the eel. In an experimental study by Støttrup et al. (2016) on the improvement of aquaculture feeds for eel held for the research-related production of eggs and larvae, the authors found out how feeds with different nutrient properties concerning vitamins and fatty acids influenced the fatty acid composition in muscles and ovaries of broodstock fish. Results also revealed an effect on fecundity and the viability of eggs and larvae. In feeding experiments with artificially bred European eel larvae, Butts et al. (2016) were able to show that diets consisting of rotifers or based on rotifers were accepted as food items and ingested by eel larvae (with no positive effect on larval survival, however). Further findings gave insights how the exhibited phototactic and chemotactic behaviour of eel larvae could be beneficially used for rearing and growth trials.

To investigate the effect of parental origin, Benini et al. (2018) fertilized eggs from 4 different wild caught females with 5 cultured and 4 wild-caught male eels and investigated variations of fertilization and hatching success, embryonic survival and larval deformities. Observed differences were unrelated to paternal origin, whereas paternity and maternity in general significantly influenced early life history performance traits of European eels. The highest influence was shown by maternity, validating that spawner quality is crucial and suggesting that mate choice and thus genetic compatibility might also be of high importance for successful propagation of high-quality offspring.

In 2018, Politis et al. published a set of studies providing novel information on progresses made in research on the captive rearing of European eel larvae. In one study (Politis et al. 2018), the authors investigated the effects of salinity on morphology, development, survivability and gene expression of pre-leptocephalus larvae reared from 0 to 12 days post hatch in different salinity scenarios. The authors found that a slow salinity reduction of 2 psu/day from 36 psu on 3 days post hatch towards iso-osmotic conditions had a beneficial effect on pre-leptocephalus development. The same research group published experimental data on the influence of different temperatures on phenotypic variability, gene expression, hatch success, yolk utilization, survival and prevalence of deformities in experimental reared *A. anguilla* larvae. Optimal temperature was 18°C while 16-22°C represent lower and upper thermal tolerance limits. 24°C resulted in 100% mortality (Politis et al. 2017). In another study by Politis et al. (2018b) on temperature effects in the artificial reproduction of anguillid eels, the authors investigated the effects of temperature on the expression of genes associated with thyroid hormone receptors and deiodenase enzymes. Their results demonstrated that thyroid hormone receptors and deiodenase enzymes show sensitivity to temperature and are involved in early life development of European eel.

Even though artificial reproduction will not be a feasible tool for stock enhancement any time soon, research on artificial eel reproduction is nonetheless contributing to a better understanding of eel biology with a certain relevance for eel stock management. The research field itself holds new opportunities and is classified as a research need by ICES (2016a). In 2010, ICES noted, that such investigations may ultimately relieve pressure on the requirement of glass eel seed. Hence, WGEEL recommended studies on the improvement of early larval survival in culture (ICES 2010, 2016a).

2.1.4 Recruitment

***Glass eel recruitment*:** Time-series data on the arrival of young of the year glass eels in estuaries and rivers allowed scientists and stakeholder to first notice the decline of the stock. Monitoring data of arriving glass eels in various places revealed dropping numbers. The amount of glass eel arriving in continental waters declined dramatically in the early 1980s, and has been very low in all years after 2000. The decline has reached an all-time low in 2011 and has remained at this low state since then. In 46 time-series comprising either glass eel or a mixture of yellow and glass eels located at various stations and various countries/rivers referred to continental North Sea and Elsewhere time series by ICES, the number of arriving glass eels declined to 2-10% (North Sea 2.1 %, Elsewhere 10.1%) of the 1960-1979 average (ICES 2018a). Bornarel et al. (2017) recently published a comprehensive recruitment estimation approach through a model, which uses all recruitment time-series available at European scale since 1960. Data analyses and outcome of the model confirmed **overall recruitment decline** to dramatically low levels in 2009 *(3.5% of the 1960-1979 recruitment average)* with a more severe decline in the North Sea time-series compared to the Elsewhere series.

A recent, more locally focused study by Stratoudakis et al. (2018) analysed catch per unit effort (CPUE) as well as biometric data of glass eels in basins of western Portugal and meteo-oceanographic data from the Iberian margin and shelf, suggesting a reduction in mean eel recruitment over the past three decades, yet lower than that reported across the stock area by ICES (2016a). A study on the German Ems river system (Diekmann et al. 2018) also revealed a substantial decline in recruitment which the authors rate to be in a similar range as estimated by ICES (2016a).

Anguillid eels are supposed to be born sexually undetermined and their sex differentiation and determination are thought to manifest during their early juvenile growth phase. Geffroy and

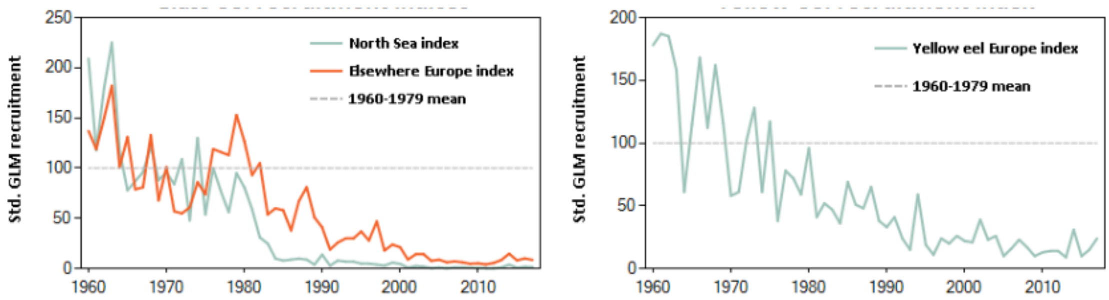
Bardonnet (2016) published a review article, which summarized known influential factors on the cryptic sex differentiation and sex determination in eels of the genus *Anguilla*. The authors conclude that aquaculture production in high densities, or pre-growing of eel seeds for stocking, may have a direct impact on sex ratios, as sex ratios in aquaculture production reach 90% males. This knowledge about major influencing factors such as density of individuals as well as early growth may influence conservation measures, such as stocking.

In an experimental simulation published in 2017 by Naisbett-Jones et al. the authors provided evidence that juvenile eels use the earth's magnetic field to orientate during migration. By combining their "magnetic displacement" experiment with simulations of an ocean circulation model and adaptive magnetic map of the transoceanic migration route, the authors suggest that their results can help to understand how eel larvae reach their destined continents and thus, feeding and growth habitats. In response to this publication, Durif et al. (2017) published a letter, in which a consortium of scientists criticised that paper, clarifying that leptocephalus larvae represent a completely different morphology and a different ecology than glass eels as used in the experiments by Naisbett-Jones. As a result, Durif et al. postulated that the entire interpretive framework of the study by Naisbett-Jones et al. was not suitable to assess whether leptocephalus larvae use the earth's magnetic field to guide their migration. However, the use of magnetoreception by glass eels was shown before by Cresci et al. (2017) and the authors were able to demonstrate how glass eels use an internal magnetic orientation system that seems to be linked to a circatidal rhythm.

Yellow eel recruitment: Monitoring of yellow and silver phase *A. anguilla* during their continental life history is necessary for the evaluation of stock assessment. Besides glass eel recruitment and datasets including all (potentially already pigmented) "young of the year" eels, recruitment data may also describe numbers of older yellow eel recruiting to continental habitats. Other than glass eel recruitment, yellow eel series may consist of yellow eels of several ages (like in all series from the Baltic Sea as well as data series from sites located well into freshwater).

The following text, Figure 3 and figure captions have been taken from the ICES Advice on fishing opportunities, catch, and effort Ecoregions in the Northeast Atlantic 2017 (ICES ele.2737.nea):
"The annual recruitment of glass eel to European waters in 2017 remained low, at 1.6% of the 1960–1979 level in the "North Sea" series and 8.7% in the "Elsewhere Europe" series. The annual recruitment of young yellow eel to European waters was 24% of the 1960–1979 level. These recruitment indices remain well below the 1960–1979 reference levels, and there is no change in the perception of the status of the stock."

Figure 3: Glass eel recruitment index (left) and yellow eel recruitment index (right)



Source: ICES Advice on fishing opportunities, catch, and effort Ecoregions in the Northeast Atlantic 2017 (ICES ele.2737.nea). Left panel: indices, geometric mean of estimated (GLM) glass eel recruitment for the continental "North Sea" and "Elsewhere Europe" series. The GLM (predicting recruitment as a function of area, year and site) was fitted to 43 time-series, comprising either pure glass eel or a mixture of glass eels and yellow eels and scaled to the 1960–1979 geometric mean. The "North Sea" series are from Norway, Sweden, Germany, Denmark, the Netherlands, and Belgium. The "Elsewhere" series are from UK, Ireland, France, Spain, Portugal, and Italy. Right panel: Geometric mean of estimated (GLM) yellow eel recruitment trends for Europe. The GLM (predicting recruitment as a function of year and site) was fitted to 14 yellow eel time-series and scaled to the 1960–1979 arithmetic mean.

An observed decline in yellow eel recruitment was also reported and published in locally adapted studies, such as in Matondo and Ovidio (2016), in which the authors over the last 23 years registered a decline in the number of ascending yellow eels at an average 4.2% per year in the Belgian river Meuse. Also, Matondo et al. (2018) investigated the colonization behaviour of yellow-phase eels in regulated inland rivers with severely declined eel populations in Belgium, more than 320 km upstream of the sea. By tracking the upstream movement of tagged eels, the authors found that only a small portion of the more than 1350 tagged eels that entered the population at the monitoring station moved further upstream to colonize the upper river. As a result, the authors conclude that only few nomad individuals and probably more home range dwellers are among the entering population. Furthermore, the data revealed that smaller eels were more likely to migrate further upstream than larger yellow eels. In an associated mark and recapture study published in 2017 (Matondo et al. 2017), the authors investigate migration behaviour and dynamics of incoming (stock-entering) yellow and silver eels and found that a relatively high proportion of migrant eels (80% of tagged individuals) belonged to the yellow stage while a lower proportion (6%) showed morphological traits corresponding to advanced continental silvering. This presents evidence that not all morphologically determined silver eels directly exit their habitats, which may have impact on management as eels revealing morphological traits of silvering are commonly rated as escapees when caught during monitoring. However, yellow eel recruitment is not only of interest for fisheries management and measures in upstream river sections and other inland catchments. Coastal habitats in the Atlantic, the Mediterranean and especially the Baltic Sea can constitute additional, very productive and thus valuable feeding and growth habitats for yellow-stage eels.

Coastal areas, other than river habitats, which can be monitored using a variety of different methods (e.g. electrofishing surveys, scientific stow net surveys, counting at fish passes and others), have always been challenging for scientists and stock managers to assess population numbers. Ubl and Dorow (2015) published an interesting method for non-tidal coastal waters, using a 100 x 100 m net enclosure system in a variety of habitat types in the coastal waters of the Baltic Sea. The approach allows the operator to catch the entity of eels within this enclosure square and extrapolate data from sampled areas to a regional eel density.

The monitoring and quantification of the yellow eel stock may be a difficult task potentially biased by stocking and differing monitoring strategies and techniques. However, time series of yellow eel data are of great value and especially for regions with limited or no true glass eel recruitment data such as the Baltic Sea or the Mediterranean Sea can be a very informative tool for stock assessment if certain time ranges are covered (e.g. minimum of 10 years (ICES2018a)).

2.1.5 Stocking of juvenile eels

The translocation of wild-caught eels from donor to recipient areas is a fairly old and widespread management practice intended to locally increase numbers of individuals to support local fisheries or meant as a stock enhancement measure to redistribute eels from areas with higher recruitment to areas with lower recruitment (ICES 2016a). Measures for the recovery of the stock of European eel as presented by the EU (Council Regulation (EC) 1100/2007) proposes stocking of eels besides measures to reduce mortality (e.g. fisheries reduction or restrictions, combating predators, switching off hydropower turbines etc.), as a potential approach to increase the number of escaping silver eels of a water body or Eel Management Unit. Brämick et al. (2016) stated that in some management areas with low natural recruitment numbers, stocking is an essential tool to achieve the 40% escapement target, as obliged by the Eel Regulation. However, stocking of eels in general is controversial, as a debate about the net benefit for the stock is still on-going and of very high relevance among experts (ICES 2018a). Despite glass eels being a very scarce resource, stocking activities are not coordinated at a European level. Depending on Member States, stocking is carried out by regional fisheries managers, commercial and recreational fishing associations and even individual fishers. In three out of the four focus countries of this study (Germany, Greece and Spain) stocking is coordinated at a regional and local level, while for other countries like e.g. France, Sweden and Poland it is coordinated at a national level. Apart from single case studies, implications and potential benefits and losses caused by stocking are not scientifically monitored or evaluated and a European strategy for the use of stocking as a measure for stock recovery is lacking.

Up to date there is no clear scientific proof how stocking measures, besides benefits for local fisheries, contribute to overall higher numbers of escaping spawners and thus potentially pose an enhancement of the entire stock. As mentioned above, stocking is still entirely based on wild-caught seeds, as the artificial production of juvenile eels is still not possible. The whole process of stocking usually involves multiple steps that are connected to a certain mortality, which in this form naturally would not occur. Glass eels meant for stocking are caught in the wild, transported to farms or collecting facilities, pre-grown or directly transported further to their future habitats and then released. Each of the mentioned steps includes and may cause additional mortality, which in most cases, have yet never been properly quantified. As a result, ICES notes that internationally coordinated research is required to determine any net benefit of stocking on the overall population, including carrying capacity estimates of glass eel source estuaries, detailed mortality estimates at each step of the stocking process, and performance estimates of stocked vs. non-stocked eels.

Revision of recent scientific publications mirrors the broad scientific interest on the performance and practicability of juvenile eels as seed in stock enhancement programs. To distinguish stocked individuals from natural recruits, it is of great importance to mark one of the groups. Since external markings such as elastomer tags or T-bar tags are mostly unsuitable for small eels, marking of stocking material is often done by staining of the otoliths (calcified microstructures that are found in the inner ears of vertebrates, which are also often used for age determination). In a study by Kullmann et al. (2018a), the authors present an experimental dataset on a new chemical double-marking technique for otoliths of European glass eels that resulted in low mortalities and was proven practicable for large-scale stocking programmes. A number of publications in the past (e.g. Simon et al. 2013; Simon and Dörner 2014) have already dealt with growth and survivability of wild caught and translocated glass eels in comparison to "bootlace eels", that have been cultured and pre-grown in aquaculture facilities before stocking. In a more recent study, Kullmann et al. (2018b) compared the most commonly used stocking forms (glass and farmed eels) in terms of their growth performance, body condition, and benefit-cost ratio to test whether stocking efficiency can be increased by the form of stocking material. Their results indicated an advantage of farmed recruits, as they showed higher total length and body weight than stocked glass eels. Recapture data revealed a lower mortality rate of farmed eels compared to recruits stocked as glass eels at age 2. In summary, farmed eels showed to have a higher benefit-cost ratio to refill local eel populations more efficiently. These findings however, stand in direct contrast to a number of previous studies, in which smaller stocking material indicated higher yields per recruit, but also an advantageous growth performance over larger eels (Simon and Dörner 2014; Pedersen and Rasmussen 2016; Pedersen et al. 2017). In another paper published by Dainys et al. (2017a), the authors studied the growth and survival performance of pre-grown farm eels in comparison to glass eels from the same cohort following their transition to a natural prey diet (*Chironomus* spp. larvae) in the laboratory. Pre-grown groups did not show higher survival than glass eel groups, challenging the hypothesis of presumed benefits of releasing ongrown recruits for population restoration measures.

But not only performance in terms of growth and survival are of concern in stocking measures. Besides additional occurring mortalities in the process of stocking, the EMPs but also common sense postulate that stocking, if thought as a management measure, shall only be performed in "appropriate" habitats. Barriers and hydropower plants in habitats are among the few properties of management units that are under discussion in context of appropriate habitat. Yet, other factors are also of importance in terms of habitat suitability for stocking programs. In a number of connected studies by Sühring et al. (2013, 2015) and Freese et al. (2016, 2017), the authors show that pollution by certain contaminants is habitat-driven and can strongly affect the contaminant burden of stocked eels growing up in these waters. The authors discuss that the proven maternal transfer of certain compounds may have severe effects on the eels' reproductive capability. This may conflict the general contribution of eels from highly polluted areas to the spawning stock in some cases and thus generally negates the conservational approach of stocking in polluted waters. Another example illustrating possible effects of mismanagement related to stocking and lack of knowledge concerning recruitment mechanisms was recently illustrated in a study on the closely related American eel. In this study, Stacey et al. (2014) found that glass eels, deported from their catch sites and released into the more than 2000 km distant St Lawrence River showed significantly faster annual growth, smaller sizes as well as lower age at maturation and differences in sex ratio compared to their naturally recruited counterparts in the stocked area. As a result, the authors concluded that stocking meant for conservation should always be applied with caution, as stocked eels appear to follow life-history patterns comparable with conspecifics in the geographic range of their donor streams, where they were collected. But these are not the only known possible issues associated with stocking. Kullmann et al. (2018c) showed with Alizarin-red-S-marked eels from stocking experiments, that stocked juvenile eels often develop false annuli (e.g. due to stress) during their pre-growing phase in eel farms. The authors concluded that this may influence and bias age readings for biological data collection and stock management. For several management-related and scientific reasons, it is of utmost interest to be able to distinguish stocked and naturally immigrated recruits in local eel populations. Also, the transport and redistribution of fish can generally be seen as a possible vector of parasites and diseases. The swimbladder nematode *Anguillicola crassus* for instance is thought to have been introduced with Asian stocking material and thus is often referred to as an example of an anthropogenic introduced stressor to European eel ecology. In addition to that, Kullmann et al. (2017)

reported that stocking activities in a former anguillid herpesvirus 1 (AngHV 1) - free waterbody (0 % virus positive samples, see Jakob et al. 2009a) led to high infection rates (68% virus positive) in all investigated subsequent year classes due to infected stocking material.

Due to many uncertainties and problems connected to stocking as a stock enhancement measure meant for a sustainable future management of the eel stock, it is crucial to find a final conclusion concerning the validity of stocking as a tool for European eel stock recovery. Further, ICES (2018b) advises that an estimation of the prospective net benefit should be made prior to any stocking activity. Stocking should take place only where survival to silver eel escapement is high and where quality of spawners is likely not to be affected by pollution or diseases and should not be used as an alternative to the attempt to reduce anthropogenic mortality. Where eels are translocated and stocked, measures should be taken to evaluate their fate and their contribution to silver eel escapement and spawning success. Such measures should include a regionally coordinated selection of suitable habitats and scientific monitoring and evaluation. Mass marking of juvenile eels designated for stocking is an appropriate tool to assess potentially differential growth, quality parameters and survival of stocked eels versus natural recruits, prerequisites for a full evaluation of any net benefit of stocking.

2.1.6 Silver eel escapement

Once eels have grown to the necessary size and reached the necessary fat content they develop into a pre-mature migratory life stage (Larsson et al. 1990). The European eel life cycle tends to be shorter for southern populations of their range compared to the northern populations. Age-at-maturity may vary according to annual average temperatures, habitat characteristics, density-dependent processes and ecological factors. As a last step, yellow eels transform into the migrating silver eel life stage and start their final spawning migration back to the 5000-7000 km far away Sargasso Sea and spawn before the cycle starts again. The amount of silver eels leaving a water body at the beginning of their spawning migration is referred to as silver eel escapement. MS use silver eel escapement data to fulfil management goals (reaching a silver eel escapement rate of 40% of those numbers that would have escaped the respective water body at a pristine state without any anthropogenic mortality) as defined in Council Regulation (EC) 1100/2007 (EU 2007).

However, no comprehensive and conclusive dataset on spawning stock biomass or total silver eel escapement in the entire distribution range of the European eel has yet been established or made available. Currently, total commercial landings are an available estimate of population and thus indirectly describe the size of the spawning stock (Westerberg et al. 2018b). Also ICES (2013) attempted to calculate silver eel escapement from catch statistics by including an intermediate step via exploitation rates and the outcome confirmed the stock decline scenario as numbers showed a decrease in the range of about 20% compared to the 1950’s. In the years since the implementation of the Eel Regulation in 2007, fishing restrictions in many countries appear to have reduced the catches considerably. Care should hence be taken with the interpretation of the landings as indicators of the stock as such, since the catch statistics will now underestimate the status of the stock by including the effect of fishing restrictions. As an example, Andersson et al. (2012) documented a strong reduction of fishing effort in the coastal waters of the Swedish west coast, with the most rapid decline occurring in the 1960s and early 1970s, but also in recent years. Also, in other countries in the distribution range of the European eel, stronger restrictions for eel fisheries have been established such as in Ireland or Norway. In contrast, Aalto et al. (2016) assume that fishing effort in many Mediterranean lagoons did not change strongly during the past years. In the frame of the implementation of the above-mentioned Regulation (EC) 1100/2007, MS had to prepare EMPs including a quantification of recent silver eel escapement in comparison to a "pristine" state. As a consequence, scientific efforts to estimate spawner escapement have increased and estimates have been presented in the frame of the implementation of the EMPs but also in scientific publications.

According to the data available for 59 River Basin Districts (RBDs) in 2013, recent silver eel escapement was 19% compared to the pristine state (ICES 2013b). However, some assessments of the estimates from the EMPs or the consecutive implementation reports by mark-recapture studies or total assessments revealed considerably lower escapement values than estimated in the EMPs (MacNamara and McCarthy 2014; Marohn et al. 2014; Brämick et al. 2016). This clearly indicates that the estimations of spawner escapement are challenging and that the results may be afflicted with uncertainties. On the other hand, Prigge et al. (2013) showed that, e. g., the German Eel Model has the potential to provide rather exact estimates of escapement if the input parameters have a good quality.

For the Mediterranean region, including southern European and North African countries, Aalto et al. (2016) conducted a first approach to assess the silver eel escapement based on data from 86 lagoon fisheries. The authors estimated an escapement level of 35% of the pristine value. A similar approach was conducted in the frame of the General Fisheries Commission for the Mediterranean (GFCM) and WGEEL (ICES 2016a). Whereas current escapement was estimated to be 11% of pristine escapement, compared to the value for 1951 (already down to 55% of pristine conditions) the 2014 value was 20.7%. Bilotta et al. (2011) estimated eel escapement from the River Huntspill, UK, to 6 kg/ha, reflecting slightly less the 40% of pristine conditions. Similarly, Amilhat et al. (2008) calculated escapement from a lagoon in southwest France by a mark-recapture study and concluded that escapement was in the range of or slightly below 40% of pristine conditions. It has to be stressed again here that for calculating such a percentage not only the present or recent escapement has to be known but also an estimate for the pristine conditions. As these values have not been calculated on the same basis throughout Europe, the relation between present and "pristine" escapement has to be considered with care. The estimates for silver eel escapement from the EMPs are based on very different methodological approaches in the different countries and there has not been a very strict evaluation of the different approaches. In most cases, the estimation includes some kind of modeling. In some cases, the results have been compared to estimates from tagging studies but in the majority of the cases, the estimates should be considered unverified. Whereas this might be in accordance with the requirements of the Regulation (EC) 1100/2007, which asks for a "best estimate" of eel escapement, for a further scientific use the data have to be considered with care. Regional and thus continental silver eel escapement is affected by a variety of factors, including natural and stocked recruitment, fishing pressure, migration obstacles, fish health and predation. Just recently a seasonal closure of coastal silver eel fisheries was put in place by the EU (Council Regulation (EU) 2019/124), with the option for MS to select 3 months in a time-frame between beginning of August and end of February. The mode that countries can choose months is obviously problematic as then often the peak escapement is not protected with a questionable effectiveness concerning the recovery approach for the stock. Also, definitions of coastal areas that are affected by the measures can be defines on a regional level, leading to disparities among the affected areas.

Even though all these factors are subject to possible management measures intended to enhance population numbers and/or escapement goals, a general lack of data and knowledge gaps leave assessment in this regard on a slippery slope. Brämick et al. (2016) published an article about the situation in Germany, where a modelled calculation of escapement numbers indicated that target values, due to very low natural recruitment, could not be reached without stocking and translocation of glass eels from other areas. The proposed example is likely representative for a number of Eel Management Units (EMUs) with low natural immigration across Europe. Some other, more locally focussed studies investigated silver eel escapement and migration patterns with a wide outcome of results. Dainys et al. (2017b) for instance have studied migration timing, speed and escapement success of silver eels in three natural rivers and one lagoon in Lithuania. Their data revealed a large proportion of downstream migrating eels already in spring, with peak migration to the Baltic Sea was found to happen in late fall. The overall escapement success of all tagged eels was relatively low with 35% of monitored individuals. Despite all these uncertainties, it is obvious that most of these proxies and estimates point towards the same order of magnitude – a reduction in silver eel escapement and hence probably spawning stock to about 15-20% recently in comparison to the values of the 1950s.

2.2 Impact of influential factors on the continental life phase

The European eel is rated "critically endangered" by the IUCN (Jacoby and Gollock 2014) and according to ICES, the European eel stock is outside safe biological limits. Due to the lack of a reliable stock assessment, ICES since 2001 advises every year to reduce anthropogenic mortalities to or as close to zero as possible to allow for recovery of the stock (ICES 2018b). In their latest report from 2018, the WGEEL points toward the spatially adjusted approach in terms of measures for the management of the species (ICES 2018a). While several impacts are discussed to have caused or contributed to the decline of the stock and further prevented the recovery, there is a general consensus that no cause can be singled out, but a combination of several factors has led to the situation today (e.g. Miller et al. 2016). An overview of factors that are currently discussed to (potentially) have an impact on the European eel stock is presented in Table 1 and each factor is described in more detail below.

2.2.1 Climate change

Climate change is a superordinate phenomenon with extensive effects on ecosystems across the globe. While the full scope of the complex mechanisms affecting the European eel stock are not yet entirely understood, some authors consider that the worldwide synchrony in the decline of abundances of temperate eel species suggests that common factors such as ocean climate may have influenced eel population dynamics (Knights 2003; Friedland et al. 2007; Bonhommeau et al. 2008; Kettle et al. 2008). Potential causes for the decline are thus limited food availability in the spawning area of the European eel due to the warming of surface water, as well as changes in oceanic currents resulting in a slowed transport towards the European continent, increasing the risk of starvation (e.g. Castonguay et al. 1994; Knights 2003; Friedland et al. 2007; Baltazar-Soares et al. 2014). However, several studies suggest that the latter is of minor relevance (Bonhommeau et al. 2008; Pacariz et al. 2014). While oceanic factors are generally considered well in line with the simultaneous decline of the European and American eel (which share the same spawning area, but inhabit different continents), Kettle et al. (2011) highlighted further continental impacts of climate change, particularly concerning habitat loss, associated with drought and dam constructions due to changes in hydrological conditions.

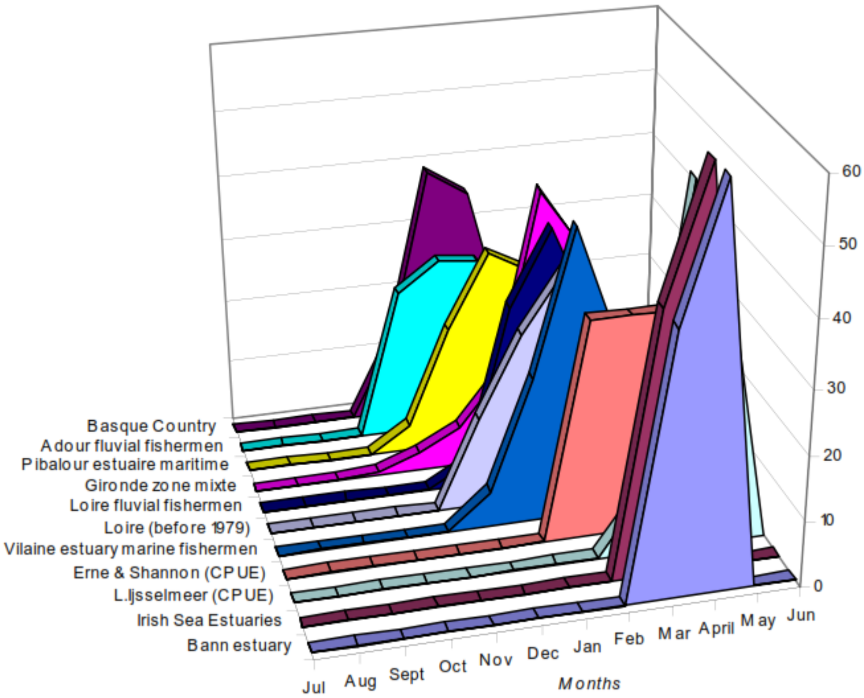
2.2.2 Glass eel fisheries

Glass eel fisheries all around Europe show a temporal distribution from October till May (ICES 2005). The catch distribution follows a south to north gradient. ICES (2005) made an analysis about the glass eel fishery temporal pattern before the implementation of the EMP, when many fisheries stopped or shortened their fishing season. At that time, the studied fishing seasons started in October (Basque country) whereas only in March, in northern areas (Northern Ireland). It ended around February in the south, while in May in the north. All the intermediary areas follow a regular progressive evolution of the season from these two extreme patterns. Modes in catch quantities (Fig. 4) usually occurred in a single month, in which more than 30% of the total catch was taken (exception in the Adour: 27.4%). This month is December in the south (Basque Country and Adour), January in the Gironde estuary and February in the Gironde, in the Loire and in the Vilaine. Last December MS ministries have agreed to prohibit glass eel fisheries in Union waters of the ICES area, brackish waters such as estuaries, coastal lagoons and transitional waters for a consecutive three-month period to be determined by each MS between 1 August 2019 and 29 February 2020. In this way, if the chosen months are August, September and October the effect of the closure will be almost null. It is therefore recommended that in order to render the seasonal closures effective, they should include only those months where fishery currently takes place in each country.

Commercial glass eel fisheries are reported in 5 out of 20 countries providing data for the WGEEL (ICES 2018a). During the 2015-2017 period, 193 million glass eels were caught annually compared to roughly 6.1 million yellow and silver eels (ICES 2018a). However, those numbers do not directly reflect the effect in the stock of each fishery targeting different stages, since natural mortality occurs between the glass eel and silver eel stages. To achieve better comparability, it is necessary to convert glass and yellow eel into Silver Eel Equivalents considering the natural mortality. When doing so, we observe that for the 2015-2017 period the contribution of the glass eel fishery, in terms of Silver Eel Equivalents, to the total catch is 64%. Since this calculation relies on many assumptions (i.e. mortality, mean age/weight of the catch, the percentage of silver eels in the mixed silver and yellow eel catch), we have considered different scenarios, obtaining the lowest (47%) glass eel contribution to the total fishery mortality when a high settlement mortality was used and the highest one (70%) when a shorter lifetime was included (ANNEX IV.1).

In 2017, 86% of the glass eels were caught in the Bay of Biscay (mostly France, 72% Bay of Biscay, 2% Channel) (ICES 2018a). However, exploitation rates differ among estuaries: In the Vilaine estuary (France), Briand (2003) estimated an exploitation rate of 95% before the implementation of the management plan measures, while for the Adour River, Bru et al. (2009) estimated that the overall rate of exploitation of the marine and continental fisheries, on average, was 15.7%, ranging between 8 and 25% during the 1998 and 2005 fishing seasons. In Spain, the exploitation rates have been only calculated in the Oria (Aranburu et al. 2016) ranging between 6.2–48.7% with a mean of 31.1% for the 2003-2013 period. Though it is difficult to quantify the overall fraction of glass eels being caught, Bevacqua et al. (2015) estimated that roughly 55% of all arriving glass eels were removed from the stock (not including catches for stocking) between 1950 and 2010. In contrast, the exploitation rate calculated from recruitment estimates derived by Bornarel et al. (2017) would be lower (11%). In both cases, there is large uncertainty on the size of recruitment, particularly in the Mediterranean where recruitments series are few. While recreational glass eel fisheries used to exist, they are prohibited today in France and only of minor importance in most regions of Spain, except in the Basque Country, where annual catches are above 1500 kg since 2013.

Figure 4: Seasonal glass eel catches before the implementation of the EMP



Source: ICES 2005

According to EUROPOL the total illegal export even reached 100 t during the 2017-2018 season (https://www.europol.europa.eu/newsroom/news/glass-eel-traffickers-earned-more-eur-37-millionillegal-exports-to-asia). Stein and Dekker (in press) calculated the potential Chinese eel farm production based on the reported glass eel input and put that in relation to the reported eel farm production. According to their estimations, the farm production cannot be met by the reported legal glass eel input and the glass eel demand exceeds the annual 100 t estimate for the 2010-2016 periods. However, authors stated that their estimations are indicative only and should be used with caution since the conversion of grown-out eel production into Glass Eel Equivalent relies on simplified parameters (e.g. eel size/weight, farming period, mortality) that need to be further refined.

Table 2: Glass eel catches and exports to Asia according to different sources

	Period	Exports to Asia (t)	Stocking (t)	Others (t)	Legal catches (t)	Exports to Asia (% of legal catches)
Dekker 2003b	1990s	300	53	342	695	43.2
Crook 2010	1997-2007	77.6	ND	ND	169	45.9
Briand et al. 2008	1996-2006	123	23		189	65.1
SEG 2017	2017	30	13		66.5	45.11
Europol 2018	2018	100	28		60	166.67

Source: ICES 2018

In the 1990s, buyers of live glass eels entered the market for fattening in Asian fish farming facilities, offering higher prices than those reached in the domestic consumer market. The listing of the European eel in CITES Appendix II restricted the eel export and by 2011 MS implemented a zero-export quota. The aim of this measure was to decrease the price of the glass eel driven by the Asian market and this way decrease the incentives to go fishing. However, some criminal networks, still illegally transport glass eels to Asia. The increased incentive for an illegal trade brought by high prices is a concern, because it will undermine the management effort made by the legal fishery. On the other hand, it should not distract from the importance of managing glass eel mortality at a level allowing a restoration of the stock and the fulfilment of the Regulation 40% objective in the long term.

On the other hand, taking into account that the declared catches during this season were 60 t, and that the MS declared that they have stocked 28 t, this would mean that the remaining 32 t of legal catches plus 68 t of illegal catches were exported illegally to China. This would mean that illegal catches of glass eel are 113% of the legal catches. Current estimates of illegal fishery are not available to assess whether these numbers are realistic. The volume of illegal fishery was estimated by a trader to have ranged from 20 to 40% in France between the years 1996-2006 (Briand et al. 2008). Thus the 68 t figure of illegal fishery would imply a severe shift in the fishery.

The largest amount of legal trade to Asia was registered in the 1990s (Briand et al. 2008). According to Dekker (2003b), 43.2% of the catches were legally exported to Asia at that time (Tab. 2). However, there was a great variability in the exported percentage among years (Briand et al. 2008). According to national/territorial Customs data, China, Hong Kong, Taiwan, Japan and Korea imported on average 77.6 t of live eel fry (i.e. glass eels) during the 1997/8 and 2007/8 period (before the CITES implementation) (Crook 2010). During that period average landings were 169 (ICES 2018a) so 46% of the live eel fry eels were supposed to be exported to Asia at that time. However, Briand et al. (2008) made a more precise analysis of the export quantities re-attributing the amount of glass eel when the export was possibly a mixture of glass and yellow eel. They concluded that from 1996 to 2006 the export/dispatch routes for live glass eels from the EU to Asia were annually (on average) 123 t, 65% of the total average 189 t landings during that period (ICES 2018a). After the CITES implementation, SEG (2017) estimated that in 2017 21% of the reported glass eel catch was used for stocking and 30% were supplied to aquaculture while 49% were not traceable with a presumed illegal export of 30 t (45.1% of legal catches). According to EUROPOL estimates, the % of exported glass eel comparing to legal landings would be much higher than before the CITES implementation, when exporting was still legal. Thus, the real figures of illegal trade volume remain unclear. One of the main problems to quantify the illegal trade and fishery is the lack of traceability at both domestic and international level. The fate of many of the legal glass eel catches is unknown in some countries, which makes it easier for smugglers to send those glass eels to Asia. In addition, there is not any international traceability system. Thus, once the glass eels leave a given country, the recipient EU country cannot know for sure the origin of these glass eels. An international traceability system for glass eel should be implemented to follow the movement of the legal catches among countries and detect the illegal catches.

It is also important that regional and national enforcement agencies control illegal eel fishery. Finally, coordinated actions between Member States' enforcement agencies, such as the EUROPOL "LAKE" operation (https://bit.ly/2DYzWR4), should be promoted.

Table 1: Factors affecting the European eel stock at different life stages and habitats

<table>
<tr><th></th><th>Habitat</th><th>Climate change</th><th>Pollution</th><th>Predation</th><th>Parasitation & Pathogens</th><th>Commercial Fisheries</th><th>Recreational Fisheries</th><th>Hydropower</th><th>Habitat loss</th></tr>
<tr><td>Larvae</td><td>Open ocean</td><td>Potential impact on food availability and larval transport by oceanic currents</td><td rowspan="8">Contamination with organic and inorganic pollutants, e.g. PCBs and Metals, causing adverse health effects. Recent evidence for maternal transfer of contaminants indicates that even the youngest life stages are possibly affected.</td><td rowspan="8">Though part of the natural mortality through all life stages, it is discussed whether anthropogenic influences lead to an increase of predation above normal levels, particularly in case of the Greater Cormorant.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Glass eel</td><td>Inland waters</td><td rowspan="6">Secondary effects, e.g. due to habitat loss through aridification</td><td rowspan="7">The most commonly discussed impacts are the infestation with the swimbladder nematode Anguillicola crassus, as well as the Viruses HVA, EVE and EVEX - all of which evidently cause adverse health effects. Stocking with infected eels has been demonstrated to further spread both parasites and pathogens.</td><td rowspan="6">All continental life stages of the European eel are commercially exploited. The largest glass eel fishery is located in France, whereas fisheries for adult life stages are highly diverse and vary with time and geographic region. Illegal fisheries and underreporting are issues.</td><td rowspan="6">Recreational fisheries target all continental life stages and though detailed data is not available throughout Europe, the impact is supposedly comparable to commercial fisheries in some areas.</td><td rowspan="2">Direct mortality by pumps and cooling stations. Impeded upstream migration.</td><td rowspan="4">Mostly due to obstruction of inland waters (e.g. by dams and weirs), with varying degrees across Europe.</td></tr>
<tr><td>Coastal</td></tr>
<tr><td rowspan="2">Yellow eel</td><td>Inland waters</td><td rowspan="4">Direct mortality by pumps, cooling stations and turbines. Impeded migration. Turbine mortality mostly affects the silver stage.</td></tr>
<tr><td>Coastal</td></tr>
<tr><td rowspan="3">Silver eel</td><td>Inland waters</td><td></td></tr>
<tr><td>Coastal</td><td></td></tr>
<tr><td>Open Ocean</td><td>Potentially affecting silver eel migration</td><td></td><td></td><td></td><td></td></tr>
</table>

2.2.3 Commercial fisheries

All adult life stages of the European eel (i.e. yellow and silver eels) are exploited in various habitats (marine, coastal and freshwater) across Europe and North Africa. Eel fisheries have existed for *centuries* and thus precede the observed decline in the stock since the 1970s (ICES 2018a; Dekker and Beaulaton 2016). Quantitative data on the eel stock is only available since 1950 (Dekker 2004), however, and it is thus difficult to assess the impact of fisheries on the stock. While catches are estimated to be as high as 20,000 t in the 1950s, they dropped to approximately 2,500 t in 2017. As stated by Dekker (2003a), landings declined before the observed recruitment decline indicating that continental factors, such as fisheries, contributed to the decline due to a lack of spawners.

Despite the lack of a quantified assessment of the impact of fisheries on the whole stock, it is obvious that any mortality caused by fisheries further reduces the spawner output from continental waters since the European eel is a semelparous species (i.e. it spawns only once and then dies). Thus, fisheries are considered an impact on local eel populations and spawner escapement by 15 out of 20 countries reporting to the WGEEL (ICES 2017), while eel fishery is not reported in two countries and prohibited in the remaining countries. In total, fisheries make up for more than 50% of anthropogenic mortality in 29 of 62 EMUs, where data for fishing and hydropower mortality was reported (ICES 2017).

2.2.4 Recreational fisheries

There are considerable data deficiencies for recreational landings across Europe. Data has not been reported from all countries and the available estimates are subject to large uncertainty. It is thus difficult to assess the impact of recreational fisheries, but it is thought to be of the same order of magnitude as commercial fisheries (ICES 2017).

2.2.5 Hydropower & Habitat loss

Estimations of MS suggest, that hydropower mortality accounts for more than 50% of anthropogenic mortality in 33 of 62 EMUs, where data for fishing and hydropower mortality was reported (ICES 2017). Hydropower and habitat loss impact the eel stock in several ways: i) direct mortality of eels e.g. in pumping stations for cooling water, ii) direct mortality of mostly migrating silver eels in turbines and iii) habitat loss due to river obstruction rendering upstream areas inaccessible for immigrating eels. A detailed description of the impact of water constructions and hydropower is given in Chapter 4.

2.2.6 Pollution

European eels are exposed to numerous toxic organic and inorganic chemicals, such as heavy metals, Polycyclic Aromatic Hydrocarbons (PAHs), Polychlorinated Biphenyls (PCBs) or Polybrominated Diphenyl Ethers (PBDEs) (Belpaire et al. 2016). As a long-lived predatory fish species, with a high fat content, living in close association with sediments, eels are particularly prone to the accumulation of persistent organic pollutants and various degrees of contamination have been found across different life stages and habitats (e.g. Belpaire et al. 2008; Sühring et al. 2013; Freese et al. 2016). In these studies it has been shown that the yellow eel growth habitat is highly decisive for the corresponding silver eel contaminant burden, which finally decides upon the eel's specific spawning potential. Eel habitats in European countries are nationally subdivided in Eel Management Units, which often follow the spatial management model of River Basin Districts, as introduced by the Water Framework Directive 2000/60/EC. This directive commits EU Member States to achieve good status of all water bodies and includes chemical quality status assessments, which bear the potential to be a basis for a selection and evaluation of suitable habitats for enhanced eel protection measures (e.g. through stocking).

Though little information is available on direct adverse health effects specifically for the European eel, some of the detected substances are known to cause e.g. organ failure, cancer and negatively affect reproduction (Safe 1994; Robinet and Feunteun 2002; Corsi et al. 2005). Recent studies also provided evidence that several contaminants are maternally transferred to the eggs of European eels (Pierron et al. 2008; Sühring et al. 2015; Freese et al. 2017; Nowosad et al. 2018) evidently causing damage to eel embryos (Palstra et al. 2006). In addition, the remobilization of fat stores during their spawning migration might result in high blood concentrations of previously accumulated contaminants potentially causing acute toxic effects (e.g. Brinkmann et al. 2015). A broad range of different contaminants have been associated to declining populations or stocks of various animals including mammals (Atkinson et al. 2008), birds (Koemann et al. 1972) and fish (Hamilton et al. 2015). In a paper by Jepson and Law (2016), the authors summarized how various species around the globe have suffered from persistent pollution and how problems even with nowadays banned substances prevail.

This is a major problem, as even decades after their ban, several contaminants persist in the environment and can be detected in biota (e.g. PCBs and Dioxins). But even a ban of specific hazardous substances is not always enough, as sometimes substitutes are introduced, which share similar chemical properties due to the nature of their application (e.g. chlorinated flame retardants substituted by brominated flame retardants), presumably cause similar issues.

2.2.7 Predation

Predation is usually considered a source of natural mortality and thus of limited interest in the frame of this report. However, predation by the Great Cormorant (*Phalacrocorax carbo*) is frequently discussed as an additional or specific source of elevated mortality for the European eel. It is argued that the increase in cormorant populations across Europe during the past decades (van Erden et al. 2012; Bregnballe et al. 2014) led to mortality levels that pose a threat to local fish populations (e.g. Steffens 2010). Generally, an opportunistic feeding behaviour of cormorants is well documented in several studies (ICES 2011). The 2011 report of the WGEEL (ICES 2011) contains a short review chapter on predation by cormorants. According to this overview, the biomass percentage of eel in the diet of cormorants in several studies varied between 0% and 46.6%. However, it was noted that there was no standard protocol for studying the diet of cormorants and that the results could have been influenced by spatial and temporal aspects (e. g. habitat characteristics and the respective fish communities, seasonal aspects). The review also noticed that no time series and data on (potentially) changing diet composition of cormorants and their impact on the eel stock were available.

The only pan-European assessment of predation by cormorants was done by Carss (2006) concluding that in the 19 countries covered by the study, approximately 2,000 – 5,000 t of eel are consumed by cormorants each year, constituting 15-40% of the commercial catch in 1993/94 (excluding glass eel fishery). Though a negative impact of predation by cormorants was also shown for local sub-populations (e.g. Carss and Ekins 2002; Brämick and Fladung 2006), the value of this information is effectively unknown and has to be interpreted with extreme caution. According to ICES (2011), in the light of the eel stock decline it is questionable whether diet estimates prior to 2005 should be used to estimate the current impact of cormorants.

Since it is unknown which levels of natural mortality can be sustained by the eel stock, it is consequently not possible to put the recent levels of predation by cormorant into perspective. Furthermore, there is conflicting information in scientific literature with other studies concluding that predation by cormorants is only a minor aspect compared to other mortalities (e.g. Carpentier 2009). Despite a temporal overlap in the increase of cormorants and the decrease of the eel stock it therefore remains elusive if and to which degree predation contributed to the decline or hampers the recovery of the stock.

2.2.8 Parasites & Pathogens

Infestation with the swim bladder nematode *Anguillicola crassus* as well as the infection with the *Herpesvirus anguillae* (HVA), *Eel Virus European* (EVE) and *Eel Virus European X* (EVEX) are amongst the most notable health risks for the European eel. Though the overall impact on the European eel stock is hardly quantifiable, farming and stocking of live eels has evidently aggravated the spreading of parasites and diseases (Peters and Hartmann 1986; van Ginneken et al. 2004; Kullmann et al. 2017).
Anguillicola crassus is an alien species, which was probably introduced with live eels from Asia (Hartmann 1993) and is nowadays found across European and North African inland waters (e.g. Jakob

et al. 2009b; Becerra-Jurado et al. 2014; Wariaghli and Yahyaoui 2018). It has been documented that the parasite causes functional damage to the swim bladder of eels (Barry et al. 2014), which likely impedes swimming performance during spawning migration and thus has an effect on migration and thus spawning success (Palstra et al. 2007; Clevestam et al. 2011). Similarly, the above-named viruses cause several pathological symptoms (e.g. renal pathology, haemorrhages, skin and gill erythema, necrosis) resulting in reduced migration capabilities and increased mortalities (e.g. van Ginneken et al. 2004, 2005).

3 SUMMARY OF PUBLIC MEASURES TAKEN TO AID RECOVERY STOCK AND INDICATING THE RELEVANT COMPETENT AUTHORITIES

Key findings

- The European eel stock is currently managed in a framework consisting of EU regulations, international conventions, national law and several scientific, advisory and management bodies. The main instrument is the EU Regulation No 1100/2007, "establishing measures for the recovery of the stock of European eel".
- In the frame of this Regulation, the EU Member States have produced Eel Management Plans (EMPs) for their waters. Most measures in these plans are directed towards commercial and recreational fisheries, reduction of mortalities at technical installations like hydropower turbines or pumping stations, and habitat improvements in general. Meanwhile, the degree of implementation of the measures is high.
- Within the EU, there is a great diversity of measures and restrictions.
- The structure of competences and responsibilities is often scattered, sometimes hindering effective management and protection.
- The effect of the measures is often difficult to assess, as in most of the river systems, multiple factors are affecting the eel stock. An evaluation of the measures is therefore difficult.
- There is a clear need for a better evaluation of the effects of measures on the development of the eel stock, including controversial measures like stocking of juvenile eels.

3.1 The current management framework for the European eel

European eel management is affected by several laws and regulations and further influenced by international conventions as well as advisory and management bodies in the fields of nature conservation and fisheries, which support politics and authorities in eel management and protection. In the following section, these drivers of eel management will be shortly described.

3.1.1 Regulation (EC) No 1100/2007, "establishing measures for the recovery of the stock of European eel" ("Eel Regulation")

The Eel Regulation was adopted in 2007 and obliges MS to establish EMPs for their waters. It forms the main instrument for the management of European eel in the MS and provides a framework aiming at the protection, recovery and sustainable use of this species.

In Article 2 (4) of the Regulation, the objective of an EMP is defined 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"*. This target shall be achieved in the long-term, but the Regulation does neither specify an order of magnitude for this period nor an additional short-term mortality limit. If a MS does not produce an EMP or if the EMP cannot be approved by the European Commission, this MS "*shall either reduce fishing effort by at least 50 % relative to the average effort deployed from 2004 to 2006 or reduce fishing effort to ensure a reduction in eel catches by at least 50%*

relative to the average catch from 2004 to 2006, either by shortening the fishing season for eel or by other means".

During the scientific and political discussions about the content of the Eel Regulation, it became clear that management of the stock by uniform measures all over the EU (e.g. a common minimum landing size, a common closed season or a shared catch quota etc.) were not feasible. Due to large variations in eel life history over its distribution range, uniform measures could not be designed in a way that would be effective all over the EU, but rather on regional level. Therefore, the Eel Regulation (Article 2 (8)) offers a broad range of measures, which could be applied by MS:

"An Eel Management Plan may contain but is not limited to, the following measures:

- *Reducing commercial fishing activity.*
- *Restricting recreational fishing.*
- *Stocking measures.*
- *Structural measures to make rivers passable and improve river habitats, together with other environmental measures.*
- *Transportation of silver eel from inland waters to waters from which they can escape freely to the Sargasso Sea.*
- *Combating predators.*
- *Temporary switching off hydro-electric power turbines.*
- *Measures related to aquaculture."*

The Regulation explicitly notes that factors outside the fishery should be addressed to reduce anthropogenic mortalities, if this is necessary to achieve the targets (Article 2 (10)): *"In the Eel Management Plan, each Member State shall implement appropriate measures as soon as possible to reduce the eel mortality caused by factors outside the fishery, including hydroelectric turbines, pumps or predators, unless this is not necessary to attain the objective of the plan."*

In Article 9 of the Regulation MS are obliged to report to the European Commission in 2012, 2015 and 2018 and subsequently every six years. Yet, in conjunction with the Council Regulation (EU) 2018/120 of 23 January 2018 (see below), the EU Commission and the MS published a "Joint Declaration on strengthening the recovery for European eel", in which, among other points, it is stated that "*Member States will, within the limits of their institutional set-up, endeavour to provide Progress Reports on the implementation of their Eel Management Plans every three years, until there is a strong scientific evidence of recovery signs for the eel population across Europe*." These reports ("Progress Reports") should contain best estimates of present spawner escapement in relation to "pristine" conditions (spawner escapement without anthropogenic impacts and a full recruitment), information on fishing effort, the level of non-fisheries anthropogenic mortality factors and the amount of eels less than 12 cm caught and the proportion used for different purposes.

It has to be noted, however, that the Eel Regulation as a political-administrative instrument has not been evaluated critically against conformity with the Precautionary Approach. ICES supported the implementation of the Eel Regulation and the reporting in this frame by developing several biomass indicators, which could be used for post-evaluation of measures and for an international stock assessment. These indicators have been described several times by ICES (e.g. 2016a). However, multiple different approaches and models are used in the different countries to calculate eel populations and spawner escapement and there was so far no critical evaluation of these models.

ICES supported the European Commission during the evaluation process of the EMPs and conducted a workshop for the evaluation of the first reports on their implementation in 2013. However, the 2015 reports have not been evaluated scientifically at all and the 2018 reports were only evaluated for the biomass indicators.

In order to reinforce the efforts for the recovery of the eel stock, the Council Regulation (EU) 2018/120 of 23 January 2018 states that "*fixing for 2018 the fishing opportunities for certain fish stocks and groups of fish stocks, applicable in Union waters and, for Union fishing vessels, in certain non-Union waters, and amending Regulation (EU) 2017/127*" established further measures regarding the marine and coastal fishery in parts of Europe. In addition, Article 10 of this Regulation states: "*It shall be prohibited for Union fishing vessels and third country vessels, as well as for any commercial fisheries from shore, to fish for European eel of an overall length of 12 cm or longer in Union waters of ICES area, including in the Baltic Sea, for a consecutive three-month period to be determined by each Member State between 1 September 2018 and 31 January 2019. Member States shall communicate the determined period to the Commission not later than 1 June 2018.*"

In December 2018, the potential time-period for the consecutive three-month closures in Union waters of ICES area was extended to between 1 August 2019 and 29 February 2020 (Article 11 of Council Regulation (EU) 2019/124 of 30 January 2019 fixing for 2019 the fishing opportunities for certain fish stocks and groups of fish stocks, applicable in Union waters and, for Union fishing vessels, in certain non-Union waters). It was also clarified that this temporal closure should apply also for brackish waters such as estuaries, coastal lagoons and transitional waters. Furthermore, the following provisions were introduced for the Mediterranean Sea (Art. 42): "*It shall be prohibited to fish for European eel in EU and international waters of the Mediterranean Sea, for a consecutive three-month period to be determined by each Member State. The fishing closure period shall be consistent with the conservation objectives set out in Regulation (EC) No 1100/2007, with national management plans in place and with the temporal migration patterns of European eel in the Member States concerned. Member States shall communicate the determined period to the Commission no later than one month before the entry into force of the closure and in any case no later than 31 January 2019.*"

Non-EU states: Whereas the Eel Regulation is legally binding only for MS, the distribution area of the species extends much further. In particular, northern Africa is thought to be of importance. Thus, for a whole-stock assessment, data from such non-EU eel habitats are required. Some non-EU countries, e.g. Norway, provide such data and the situation has improved further, since in recent years, the GFCM started to get involved to a greater degree in the work on eel.

3.1.2 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

In 2007, European eel was listed in Appendix II of CITES. This appendix contains species '*which although not necessarily now threatened with extinction may become so unless trade in specimens of such species is subject to strict regulation in order to avoid utilization incompatible with their survival*'. The listing came into force 18 months after the adoption of the decision (13th March 2009) and was transferred into EU law by the inclusion of European eel in Annex B of the EC Regulation 338/97 "*on the protection of species of wild fauna and flora by regulating the trade therein"* (EU 1996).

The listing in Appendix II of CITES and Annex B of the EU Regulation 338/97 only relate to international trade, i.e. trade from and into the EU. Eel fisheries and trade within the EU continue legally, on the basis of national legislation (ICES 2015a). Further, the listing in Appendix II of CITES does not mean that international trade is strictly prohibited, but for any international trade of the respective species, a permit is needed. Such a permit "*shall only be granted when the following condition has been met: a Scientific Authority of the State of export has advised that such export will not be detrimental to the survival of that species." (*Article IV.2 of the CITES Convention). The decision on this so-called Non-Detriment Finding (NDF) lies in the responsibility of the national CITES authorities but for the EU a uniform EU-wide decision has been made. In 2015, ICES conducted a dedicated workshop (WKEELCITES; ICES 2015a), which aimed to develop criteria for a NDF for European eel under conditions of a potential recovery of the stock. The results of the workshop were then transferred into a formal advice of ICES (2015b). So far, the status of the eel stock did not allow the CITES Scientific Review Group to provide a NDF for eel, and hence, any trade of eel from or into the EU has been banned in the recent years. Yet, trade between non-EU States could still be permitted provided those countries have demonstrated NDFs (ICES 2015a).

It should be noted here that the listing of the European eel in Appendix II of CITES could become important in relation to the BREXIT. Beside France and Spain, UK is among the most important countries fishing and trading glass eels to other MS. So far this is legally possible, as it is trade within the EU. The responsible authorities of the UK have already applied for a NDF under the present conditions. This proposal is presently under evaluation by ICES.

3.1.3 Convention on Conservation of Migratory Species of Wild Animals (CMS, "Bonn Convention")

CMS is an environmental treaty under the auspices of the United Nations Environment Programme. It provides a global platform for the conservation and sustainable use of migratory animals and their habitats. CMS brings together States through which migratory animals pass, the Range States, and lays the legal foundation for internationally coordinated conservation measures throughout a migratory range. CMS represents the only global convention specializing in the conservation of migratory species, their habitats and migration routes (https://www.cms.int).
In 2014, the European eel has been listed in Appendix II of CMS. This means that contracting parties to the Convention (covering almost the entire distribution of European eel) call for cooperative conservation actions to be developed among Range States.

3.1.4 The International Union for Conservation of Nature (IUCN)

IUCN is a membership union composed of both government and civil society organisations. Its main goal is to provide public, private and non-governmental organisations with the knowledge and tools that enable human progress, economic development and nature conservation to take place together. IUCN is the world's largest and most diverse environmental network and represents the global authority on the status of the natural world and the measures needed to safeguard it. IUCN is the only environmental organisation with official United Nations Observer Status (https://www.iucn.org).

IUCN has assessed the European eel as 'critically endangered' on its Red List, in 2009 and again in 2014. Yet, it was also noted 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".

Furthermore, by approving motion 005 "Promotion of Anguillid eels as flagship species for aquatic conservation" in September 2016, the IUCN Conservation Congress moved eels stronger in the focus of conservation (IUCN 2016).

3.1.5 International Council for the Exploration of the Sea (ICES)

ICES is a global organization that develops science and advice to support the sustainable use of the oceans. It represents a network of more than 5,000 scientists from over 690 marine institutes in 20 member countries and beyond (http://www.ices.dk/explore-us/who-we-are/Pages/Who-we-are.aspx). ICES has many different expert groups, which are specialized on several issues and which conduct the relevant scientific analyses. These results are then peer-reviewed during the advisory process. The advice itself is then solely in the responsibility of the Advisory Committee (ACOM) and is not further modified by any other ICES entity. For eel, the group conducting the underlying scientific analyses is the joint EIFAAC/ICES/GFCM Working Group on Eel (WGEEL).

3.1.6 European Inland Fisheries and Aquaculture Advisory Commission (EIFAAC)

EIFAAC is a regional fishery body working under the auspices of the Fisheries and Aquaculture Department of the Food and Agriculture Organization of the United Nations (FAO). Its mission is to "*promote the long-term sustainable development, utilization, conservation, restoration and responsible management of European inland fisheries and aquaculture, consistent with the objectives and principles of the FAO Code of Conduct for Responsible Fisheries and other relevant international instruments, and to support sustainable economic, social, and recreational activities towards these goals through:*

- *providing advice, information and coordination;*
- *encouraging enhanced stakeholder participation and communication; and*
- *the delivery of effective research."* (http://www.fao.org/fishery/rfb/eifaac/en#Org-Issues)

The area of competence covers all of Europe, with the exception of parts of the Balkan, together with Turkey and Israel, and has membership from most of the countries including the EU. (See http://www.fao.org/fishery/rfb/eifaac/en#Org-GeoCoverage).
Among many other issues and projects, EIFAAC has contributed to WGEEL for many years.

3.1.7 General Fisheries Commission for the Mediterranean (GFCM)

GFCM is a regional fisheries management organization established under the provisions of Article XIV of the FAO Constitution. The GFCM initially started its activities as a Council in 1952, when the Agreement for its establishment came into force, and became a Commission in 1997 (http://www.fao.org/gfcm/background/about/en).

The main objective of the GFCM is to ensure the conservation and the sustainable use, at the biological, social, economic and environmental level, of living marine resources as well as the sustainable development of aquaculture in the Mediterranean and in the Black Sea. At present, GFCM has 24 members – 23 countries and the EU (http://www.fao.org/gfcm/background/area-of-application/en/). In addition, there are three Cooperating non-Contracting Parties (Bosnia and Herzegovina, Georgia and Ukraine).

GFCM has the authority to adopt binding recommendations for fisheries conservation and management in its area of application and plays a critical role in fisheries governance in the region. In particular, its measures can relate for instance to the regulation of fishing methods, fishing gear and minimum landing size, the establishment of open and closed fishing seasons and areas and fishing effort control. Recently, GFCM integrated the WGEEL into its work, establishing it now as the joint EIFAAC/ICES/GFCM Working Group on Eel.

3.2 Overview of management and protection measures and their effectiveness

According to ICES (2015a), 19 MS established EMPs, 6 have been exempt and 3 have abstained from producing plans, for various reasons. Most EMPs were approved in 2009 or 2010 and all submitted plans were approved by 2014 (ICES 2015a) without proper scientific evaluation.

The MS, which had established EMPs, had to report on the progress of the implementation of their EMPs as well as the stock development in relation to their targets in 2012, 2015 and 2018. Following the submission of the first Progress Reports, an ICES Workshop (Workshop on Evaluation Progress in Eel Management Plans, WKEPEMP) evaluated these reports in terms of the technical implementation of actions in May 2013 (ICES 2013). However, it is noted in the WKEPEMP report that time constraints limited the depth of investigation and as a consequence much of the data and information available to the workshop was accepted in good faith. In addition, since the 2012 Progress Reports were often written in native languages, some of which were not available to the workshop, and no translations were available, final crosschecks of the preparatory work provided by WGEEL with the original EMPs and Progress Reports were not possible in all cases (ICES 2013).

According to the WKEPEMP report (ICES 2013) 1,188 management actions were documented in the first Progress Reports of MS in 2012. 1,140 of these measures had been planned in the original EMPs, whereas the remaining 48 actions were not foreseen originally. The workshop noted that of the actions planned in the EMPs, 756 were implemented fully, 259 partially and 107 were declared as not implemented at all. Information for the remaining 18 actions was missing. The information is summarised in Tables 3 and 4, for the planned and additional actions, respectively.
The single actions were then categorized into the following types of measures:

- commercial fisheries
- recreational fisheries
- habitat improvement
- hydropower and obstacles (and pumping stations)
- measures against predators
- stocking
- others

ICES noted that "*Though listed in the Eel Regulation as a possible feature of management measures no Member States reported any direct actions related to aquaculture.*" (ICES 2014).

In 2018, ICES organized a new workshop (WKEMP) for the review of the 2018 Progress Reports. This workshop focused on the methods and results for biomass and mortality estimates in single Eel Management Units (EMUs) and discussed reporting requirements for international stock assessment. The effects and effectiveness of management measures were not evaluated.

In 2014, based on the results of WKEPEMP and new information provided by MS in their Country Reports (CR), WGEEL (ICES 2014) gave an updated analysis of eel management measures. The results are given in the following section.

With a total of 1,362 individual measures reported from 81 EMUs, the number was higher than in the WKEPEMP report (ICES 2013). The measures were categorized to the same groups as by WKEPEMP, except for "Measures against predators", which were not included anymore. However, according to WKEPEMP, only 10 measures (5 fully and 5 partly implemented) had been established in this group by 2012. Hence, the number was much lower than in all other categories.

WGEEL (ICES 2014) does not distinguish between "planned" and "additional measures" and does not provide the absolute number in each category, but a graph with the share of each category. Yet, this graph (Fig. 9.1 in ICES 2014) indicates a very similar distribution of the actions compared to the results of WKEPEMP.

Overall, WKEPEMP (ICES 2013) and WGEEL (ICES 2014) found that about two-third of the planned measures were related to fisheries (commercial and recreational), improved passage at hydropower installations and other obstacles and habitat improvement in general.

The most recent information on measures implemented for eel can be found in the CRs provided to WGEEL in 2017 (ICES 2018a). According to these reports, there are no major changes in management practices for eel throughout Europe in the recent years. However, it became obvious that the CRs are not always consistent and comprehensive. As an example, in the Danish CR, there are no measures against predators indicated. Yet, Denmark has established a management plan for cormorants and definitely has conducted measures to reduce the impact of the birds on fish stocks. The reason is probably that the cormorant measures are not strictly related to eel management and are hence not reported to WGEEL. Similar cases of not reporting measures in the CR may possibly also occur in other countries and thus a sound analysis is difficult due to incomplete information.

Table 3: Overview about the implementation status of measures planned in the frame of the EMPs in EU countries by action type

Implementation level / Action type	Fully	Partly	Not	Information missing	Total	% of all planned measures
Commercial fishery	204 (71.6%)	63 (22.1%)	13 (4.6%)	5 (1.8%)	285	25.1
Recreational fishery	78 (63.9%)	24 (19.7%)	18 (14.8%)	2 (1.6%)	122	10.7
Fishery total	282 (69.3%)	87 (21.4%)	31 (7.6%)	7 (1.7%)	407	35.8
Habitat improvement	53 (49.1%)	49 (45.4%)	5 (4.6%)	1 (0.9%)	108	9.5
Hydropower and	158 (62.5%)	68 (26.9%)	25 (9.9%)	2 (0.8%)	253	22.3
Habitat improvement and obstacles total	211 (58.4%)	117 (32.4%)	30 (8.3%)	3 (0.8%)	361	31.8%
Predator reduction	5 (35.7%)	5 (35.7%)	4 (28.6%)	0	14	1.2
Stocking	53 (59.6%)	23 (25.8%)	11 (12.4%)	2 (2.2%)	89	7.8
Others	205 (77.4%)	27 (10.2%)	31 (11.7%)	2 (0.8%)	265	23.3
Total	**756 (66.5%)**	**259 (22.8%)**	**107 (9.4%)**	**14 (1.2%)**	**1136**	

Source: ICES 2013

Table 4: Overview about the implementation status of additional measures in EU countries by action type

Implementation level / Action type	Fully	Partly	Not	Total
Commercial fishery	3	4	0	7
Recreational fishery	5	1	0	6
Fishery total	8	5	0	13
Habitat improvement	1	11	0	12
Hydropower and	1	2	0	3
Habitat improvement and obstacles total	2	13	0	15
Predator reduction	0	0	0	0
Stocking	3	1	0	4
Others	14	1	1	16
Total	**27**	**20**	**1**	**48**

Source: ICES 2013

When discussing the success of eel management, it should be noted that the effectiveness of single measures for eel is often difficult to assess due to multiple factors acting on the eel stock even within one river system. For example, if the fishery is closed in a river section above one or more hydropower plants, the hydropower turbines will kill a certain part of the "saved" eels when these eels migrate downstream. This may illustrate that effects cannot be simply added, at least not in absolute terms. However, some general conclusions may be possible.

ICES (2013) stated that most direct management actions were related to fisheries (commercial and recreational), followed by hydropower and obstacles, then measures on habitat, stocking, and predator control. Other actions, which only will have indirect effects, such as implementing monitoring programmes and scientific studies, were almost as common as controls on commercial fisheries.

In 2013, ICES WKEPEMP noted that measures related to fisheries have mostly been fully implemented, while other measures had often been postponed or only partially implemented (ICES 2013). At that time, most increases in silver eel escapement since the implementation of management plans had been achieved by measures addressing commercial and recreational fisheries on silver eels.

In many cases, WKEPEMP assessed the outcome of management actions as "unsure" due to the absence of (quantitative) information on the action taken and/or the absence of post-evaluation of the actions at EMU level (ICES 2013). As mentioned before, the impact of individual actions will often be difficult to quantify, because of the simultaneous and synergistic effects of the various actions applied in the respective EMU. In addition, the effects on silver eel escapement may occur at different time-scales, depending on the life stage that is addressed by the action. For these reasons, ICES (2013) noted that it would be more pragmatic to consider the impact of the whole package of actions applied in each EMU rather than focusing on single actions. In the following section, the groups of actions are discussed in more detail.

3.2.1 Fisheries

In most countries, eel fisheries have already been regulated by national and regional laws and regulations before the Eel Regulation came into force. The measures described in the following sections are therefore limited to modifications of existing rules or adoption of additional actions.

3.2.1.1 Commercial fishery

Management measures for the commercial fishery were adopted by almost all countries. Until 2013 the great majority of the planned actions had been implemented fully (72%) or partly (22%). ICES (2013, 2014) noted a great diversity of measures, reflecting the great variety and the scattered nature of eel fisheries across the distribution area of the species. Despite the great variety of measures, the main goals could be described as:

- reducing fishing effort
- improving documentation and administration, e.g. by national registers (ICES 2014).

The approaches to reduce fishing effort include:

- a total closure of commercial fisheries for eel (e.g. Ireland and Norway)
- the introduction or extension of closed seasons
- the introduction or increasing of minimum landing sizes (MLS), with differences between and sometimes even within the countries
- limitations for special gears, sometimes only in certain areas
- licence systems for eel fisheries
- introduction of quota
- the obligation to release certain part of the catch

These different approaches result in a great variety of measures and intensities of restrictions, making it difficult to provide general conclusions. While it is obvious that commercial fisheries have been addressed in most countries and therefore the fishing pressure on the overall eel stock has decreased in Europe, the extent of this decrease is still unclear.

ICES (2013) noted that no general answer was possible on whether and when the individual measures will have a significant effect on silver eel escapement. Considering the life cycle of eel, it is clear that actions on silver eel fisheries will have an immediate effect on spawner escapement, if they are designed properly, whereas measures targeting glass and yellow eels will have a delayed effect.

ICES (2013) also stated that some measures were designed in a way that a real effect is questionable, e.g. in cases when closed seasons were established in periods when fishing effort has already been very low. Similarly, Pohlmann et al. (2016) demonstrated that simply increasing MLS does not guarantee reduced fishing pressure on eel, if it is not flanked by accompanying measures, such as quotas or catch effort restrictions. Consequently, ICES (2013) concluded that the effects of individual measures could only be assessed by considering case specific conditions. Such an assessment was neither possible during the WKEPEMP Workshop nor is it in this study. Therefore, the conclusion of WKEPEMP (ICES 2013) is reiterated that an improved monitoring and assessment of the effectiveness of measures is needed.

3.2.1.2 Recreational fishery

Measures regarding recreational fisheries were also established in most of the countries. Until 2013 the majority of the planned actions had been implemented fully (64%) or partly (20%). The degree of successful implementation was, however, slightly lower than for commercial fisheries. As for commercial fisheries, there was a broad range of actions implemented, including the following main types of measures (ICES 2013):

- a complete ban on targeting or capturing eel
- restricting the fishery at certain periods or life stages (e.g. implementing closed seasons)
- increasing MLS (different between countries)
- introduction of bag limits (allowed number of eels per day)
- catch and release for eel
- introducing of quotas
- adjusting gears and hours of fishing thereby reducing their efficiency (e. g., ban of night angling for eel)
- regulating the fisheries by implementing systems to report catches

As for commercial fishery, there is a considerable variety of approaches to limit the effects of recreational fishery on eel. Yet, the issue has been addressed clearly in the majority of countries.
The availability of data on recreational fisheries is much lower than for commercial fisheries. Hence, an assessment of the effects of the measures is difficult and uncertain. As recreational fisheries are typically directed towards yellow eels, it is, however, very likely that the effects of these measures on silver eel escapement will be delayed. Generally, effects can only be expected if the measures result in a reduction of fishing mortality of eel. As for commercial fisheries, no general assessment of the effectiveness of individual measures can be provided.

3.2.2 Industrial river installations

The introduction of barriers into rivers represents one of the major factors affecting riverine fish stocks, in particular migratory species. Such barriers include culverts, weirs, bridge aprons, dams, hydropower stations, pumping stations, tidal flaps, sluices (ICES 2011). In relation to eel, different types of obstacles and barriers can adversely affect all continental life stages of eel during their migrations. Typical negative effects of barriers include the loss of habitat due to an impassability of the structures, delays in migration and mortality at turbines, pumping stations or water intakes. The impacts of hydropower turbines, pumping stations and water intakes have been reviewed by WGEEL several times (e.g. ICES 2011, 2016a) and are presented in Chapter 4. Below, different problems and approaches to their solution in the frame of the EMPs are summarized.

3.2.2.1 Improvement of upstream migration

Negative effects during upstream migration are typically related to glass eels or small yellow eels. Management measures related to upstream barriers were planned in several countries. ICES (2014) noted that facilitation of natural upstream migration in hydropower-impacted eel populations had been proposed by 8 countries in respect of glass eel and 9 countries in respect of small yellow eel. This involves either removal of barriers or installation of appropriate eel pass structures. Yet, the measures were often vaguely defined and only partly fulfilled. As these measures mainly address young stages, their effect on spawner escapement will be delayed. Due to that delay and the frequent lack of post-evaluation, ICES noted difficulties in evaluating the effect of these actions on silver eel escapement (ICES 2013).

3.2.2.2 Improvement of downstream migration

Measures aiming at the reduction of mortality of silver eels at hydropower turbines or pumping stations were intended in many EMPs, but the degree of "full implementation" was slightly lower than for the fisheries measures (ICES 2013). Furthermore, ICES (2013) also noted that such measures were often not strictly related to the EMP but were conducted in the frame of implementing the European Water Framework Directive (WFD).

Typical options to reduce mortality at hydropower installations, pumping stations or water intakes include:

- deflection screens / rakes and bypass solutions
- the temporary switching off of turbines in relation to migration peaks ("adapted turbine management")
- the use of fish-friendly turbines or pumps
- "Trap-and-transport"-solutions (catching of fish upstream from obstacles and transport to free flowing river sections or the sea).

According to ICES (2013, 2014), the removal of obstacles and/or the provision of eel pass facilities has been proposed by 9 countries for larger yellow eels and by 5 countries for silver eel migrating downstream. Management measures involving "adapted turbine management" or design features were proposed measures in 11 MS, though specific details remain unclear or are subject to future technology developments.

Trap-and-transport measures were planned and implemented in several countries. In some cases, existing projects were incorporated into EMPs. This measure was often implemented in time. As a positive side effect, trap-and-transport measures provide in-come for eel fishers as their skills are required for these fisheries. A further advantage is that an exact quantification of the effect is possible. However, typically, the overall amount of safeguarded eels is relatively low (e.g. in Germany approximately 12 t per year between 2013 and 2016 (Fladung and Brämick 2018), but at least 60 t in 2017 in Ireland (Poole 2018). The efficiency of trap-and-transport actions (i.e. the proportion of eels upstream of the barrier, which is safely transported to downstream river sections without hydropower mortalities) depends on several factors, including fishing effort and gear efficiency, river discharge and timing and duration of migration events. Since trap-and-transport is directed to silver eel, an immediate effect is realized (ICES 2013).

By analysing Progress Reports, ICES noted that the implementation of many measures was often delayed, which was probably attributed to the high costs associated with actions in this field. Furthermore, the legal situation may be difficult or sometimes unclear. Authorities responsible for the EMPs have often no or only restricted legal competence for hydropower issues. In some cases, there may be no legal basis to require improvements at technical installations. Generally, legal competences may be distributed vertically (national or regional level) and horizontally (fisheries authorities or environmental authorities), thus resulting in complex and diverse responsibilities and management structures. As these measures have their greatest effects on downstream migrating silver eels, their effect is expected to be immediate. The magnitude of the effect depends on the number of other obstacles further downstream, and is hence site specific. However, MS are requested to estimate the effects of their measures in their Progress Reports. However, as noted above, the authorities responsible for the EMP are not necessarily involved in the implementation of other EU regulations, such as the Water Framework Directive (WFD).

Technical measures at turbines to reduce mortality of eels (and other fish) can be challenging, in particular at large hydropower installations. Where many hydropower plants exist in the same river, multiple actions are necessary, resulting in high efforts and costs. Often, measures are not foreseen at existing installations, but only for newly planned ones.

It is not possible to conclude, if the situation has improved or deteriorated in recent years, as there may be improvements (installation of deflection screens, rake systems and bypasses or trap-and-transport actions), while at the same time new hydropower installations may have been built.

3.2.2.3 Habitat improvement

According to WKEPEMP (ICES 2013), only about 10% of all measures planned in the EMPs were directed to habitat improvement. Most of these actions aim at the improvement of river connectivity and passability of obstacles and hence are not only targeting eel but will also improve the situation for other species. In general, there are two main approaches in this category:

- improving river connectivity and passability of barriers
- assisted migration for eel (transporting eels over unpassable barriers)

The progress in the implementation of these measures is often unclear (ICES 2013). There is a considerable variety of measures and the descriptions as well as the general approach are often rather vague.

From a general view, the measures typically aim at increasing connectivity of waters, improving water quality or establishing aquatic protected areas. They are often related to the implementation of the WFD, from which benefits also for the eel stock are expected. The potential effects of these measures were often considered unspecific and are difficult to quantify. All life stages could potentially be affected and the effects could range from immediate to long-term.

3.2.2.4 Stocking

Stocking has been planned and at least partly implemented in the great majority of MS (ICES 2013). However, there are considerable differences in the intensity of the measure (numbers stocked). It is typically performed either with glass eels or with small pre-grown eels of roughly 2-10 gram. Whereas in the past, eel stocking was typically done only in freshwaters, in the last years stocking has also been conducted in coastal waters of some Baltic countries.

Yet, according to ICES (2014), in only 6 cases all targets were fully achieved. Based on information from the countries reporting to WGEEL, the main reason for not reaching the stocking targets was the lack of funding (ICES 2014).

On EMU-level, stocking could potentially have a great effect on production and escapement of spawners (ICES 2011, 2016b), of course depending on the number of eels stocked and the level of mortalities in the respective EMU. However, these effects will be delayed as it may take roughly between 6 (southern Europe) and 10 to 20 years (central and northern Europe) before eels start their spawning migration.

Among all planned groups of measures, stocking probably represents the most controversial action. It has been reviewed and discussed several times by WGEEL (ICES 2006, 2011, 2016a) and during a dedicated ICES workshop (WKSTOCKEEL, ICES 2016b). Stocking is typically seen as one part of the fisheries management, but in contrast to the other actions listed here under "commercial/recreational fisheries", it does not lead to a reduction of fishing mortality. In fact, in the past and also in the frame of the EMPs, stocking has often been conducted as a measure to sustain the eel fishery in times of decreasing overall recruitment or to compensate for reduced immigration into upstream areas due to an increasing number of barriers in the rivers. However, in relation to the Eel Regulation, stocking may also help to achieve the 40% escapement target on EMU level. Brämick et al. (2016) exemplarily demonstrated that achieving this target in the EMU Elbe in the midterm would not be possible without stocking, since natural recruitment is too low at present. On the other hand, it has been stated clearly that under the conditions of a long lasting, dramatic decline in recruitment the main goal of stocking should be the recovery of the stock and not the sustainment of fisheries. At this point, the discrepancy between the EU Eel Regulation as a political-administrative instrument and the scientific advice becomes obvious: whereas the scientific advice relates to the whole, panmictic eel stock, the Eel Regulation puts the responsibility to the MS and tries to solve the problem at the regional level. For MS this offers the possibility to establish measures, which potentially help to achieve the escapement target on a regional level (EMU level), but which could even have a detrimental effect on the whole stock. Whereas the Eel Regulation requires that MS document the contribution of stocking as a measure within an EMP to the silver eel escapement from single EMUs, the scientific advice states that there should be a surplus of silver eel escapement on the whole stock level. Such a net benefit has not been demonstrated so far and, as there are mortalities related to catching and transporting of glass eels, which can be substantial (Briand et al. 2009), a net benefit of stocking measures for the whole stock may be rather unlikely. So far, there are no serious data or calculations available on this issue, but a first rough attempt to approach this problem with the TranslocEel-model during the WGEEL meeting in 2011. This attempt provided some evidence that stocking with glass eels from France would not result in a net benefit for the stock in terms of silver eel escapement (ICES 2011).

As a general conclusion, ICES (2011, 2016b) stated that (translocated and) stocked eel can contribute to yellow and silver eel production in recipient waters, but that evidence of further contribution to actual spawning is limited.

It has also to be noted that the Eel Regulation requires that 60% of all caught glass eels have to be reserved for stocking in EU waters (Article 7) and only 40% can be used for other purposes including human consumption.

ICES (2011, 2016b) noted some problems, which could be associated with stocking:

- The risk of altering genetic aspects of the eel stock.
- The risk of spreading of disease and parasites.
- Potential effects on sex ratio in recipient waters.
- Potential problems in homing ability of eels translocated to distant water bodies (Westin 1998, 2003). Yet, recent work indicates that stocked eels behave in the same way as natural recruits (Westerberg et al. 2014).

In order to better understand and quantify the contribution of stocked eels to spawner escapement, a coordinated marking programme of stocked eel has been repeatedly recommended by WGEEL (e.g. ICES 2016a) to distinguish stocked individuals from wild eel in subsequent sampling.

3.2.2.5 Other management options

Under this category, ICES (2014) summarized a wide range of actions, which had been listed by MS in their EMPs and in the 2012 Progress Reports. These measures do not affect the stock directly, but mainly refer to monitoring, reporting structures and the legal frameworks of the management in a wider sense. ICES (2014) categorized those actions under 8 subgroups and provided the following list of actions:

1. Strengthening of the management framework, including
   - Reinforcement of legal framework (national and regional);
   - Reinforcement of co-ordination among agencies and interested parties;
   - Dissemination, raising of awareness;
   - Stakeholders' involvement.
2. Reinforcement of fishery reporting structures, including
   - Setting up of fisheries reporting systems (other than DCF);
   - Use of import/export data to monitor commercial fisheries;
   - Use of catch/return logbooks to monitor commercial fisheries;
   - Improvement of fisheries control (enforcement);
   - Control and contrast of illegal fisheries (enforcement).
3. Reinforcement of monitoring frameworks, including
   - Catchment surveys, by fyke net or electrofishing (both multi-specific or eel-specific) in defined catchments;
   - Establishment of new, or the continuation of existing recruitment monitoring, most specific for glass eel and many aiming at investigating potential new sites;
   - Assessment of sites for silver eel monitoring, the implementation of or continuation of escapement monitoring;
   - Continuation of monitoring of Index Rivers.
4. Assessment of efficacy of technical actions, to
   - Enhance accessibility and migration routes;
   - Reduce impacts and losses on eel populations.
5. Actions related to stocking, including
   - Identification of areas for stocking;
   - Implementation of stocking plans;
   - Investigations of contribution of stocking to the eel stock;
   - Pilot studies for stocking actions.
6. Actions related to eel quality issues and fish health, such as
   - Monitoring of *Anguillicola crassus*;
   - Investigations on pathogens and contamination;
   - Implementation of sanitary agreements specific for dealers;
   - Assurance of compliance to Fish Health Directive.
7. Inclusion of eel within specific conservation or species protection programmes.

8. Research actions, generic or specifically aimed at
    - Development of models for the assessment of stock indicators;
    - Development of models to assess compliance with targets;
    - Development of indices for assessing management effectiveness;
    - Setting up of river or basin indexes for recruitment and escapement quantification;
    - Development of ecosystem-based models specific for eel;
    - Retrieving and analysing historical data.

3.3 Detailed description of eel management measures in focus countries

In the following section, eel management under the Eel Regulation and the respective national EMPs is exemplarily described for the four focus countries of this study: France, Germany, Greece and Spain. These countries are of importance for the eel stock and fishery in the EU, but also reflect the great variety of conditions and eel fisheries found in Europe (e.g. different levels of glass eel recruitment, fisheries targeting different life stages of eel).

3.3.1 France

France is of great importance for the European eel. Together with the Iberian Peninsula, the country receives a very high share of total eel recruitment in the whole distribution area (see Bornarel et al. 2017). Consequently, France is also important for the production of spawners, what is reflected in the high estimates of spawner biomass under undisturbed conditions, compared to all other European countries (Beaulaton and Briand 2018). All life stages of eel are fished in France but the greatest importance can probably be attributed to the glass eel fishery. France realises the highest glass eel catches in Europe. Hence, the country is of great importance for eel stocking programs and aquaculture operations in many European countries.

The administrative saline limit separates two different fishery regulations: marine and fluvial (freshwater). The marine fisheries are located in coastal water, brackish estuaries and in the Mediterranean lagoons. The freshwater fisheries are located upstream from the saline limit and comprise rivers, lakes, ponds, ditches and canals. In large estuaries, there is a special zone, called the "tidal freshwater reach", located between the saline limit and the tidal limit, where some fishers that carry out commercial fisheries in marine waters can fish along with river fishers, while these are not allowed to go down-stream the saline limit.

In brackish and coastal waters within EMUs, recreational fishers do not need licences to fish with authorized fishing gears (rods). Upstream from that limit, anglers do not require any special authorization for eel fishing. They just need to have a general fishing licence and a logbook system has been set up, but is not really monitored in practise. A system of licences is set up for marine commercial fisheries and for commercial and recreational fisheries using gears in freshwaters. The glass eel fishery is limited with glass eel stamps and the silver eel fishery is limited by personal authorizations. Fishers that carry out commercial and recreational fisheries with gears must have a special authorization to target eels. In the Mediterranean lagoons, where glass eel fishing is forbidden, there are also limitations in the number of marine fishers that carry out commercial fisheries and in fishing capacities. In the French EMP there is also a system of stamps: one for yellow and one for silver eel fishing. Outside EMUs, at sea, eel fishing is forbidden.

In rivers under fluvial regulation, the fishing rights are delivered to fishers by the local Fluvial Fisheries Administrations. The regulation systems in brackish estuaries and Mediterranean lagoons are the result of a negotiation between fishery organizations (respectively "Commission des poissons migrateurs et des estuaires" and "Prud'homies") and Marine Fisheries Administrations.

The marine commercial fisheries in Atlantic coastal areas, estuaries and tidal part of rivers in France has been monitored by the "Direction des Pêches Maritimes et de l'Aquaculture" (DPMA) of the Ministry of Agriculture and fisheries through the Centre National de Traitement Statistiques (CNTS, ex-CRTS) from 1993 to 2008 and is now by FranceAgrimer. This system is evolving and is supposed to include marine fishers that carry out commercial fisheries in Mediterranean lagoons. In this system, glass eels are distinguished from yellow and silver eels, but yellow and silver eels could not be separated until recently.

Fishers that carry out commercial or recreational fisheries in rivers above marine estuaries (and in lakes) have been monitored since 1999 by the AFB[1] in the frame of the «Suivi National de la Pêche aux Engins et aux filets» (SNPE).

These two monitoring systems are based on mandatory reports of captures and effort (logbooks) using similar fishing forms collected monthly (or daily for glass eel).

For the management of the migratory species and their fisheries all along the watershed (under marine and fluvial regulation), special organizations, called "Comités de Gestion des Poissons Migrateurs" (COGEPOMI), have been created in 1994. There are eight COGEPOMI (management units, grouping basins), one for each important group of basins: Rhine-Meuse, Artois-Picardie, Seine-Normandie, Bretagne, Loire, Garonne, Adour and Rhone-Méditerranée-Corse. They gather representatives of fishery organizations, administrations, civil society and scientific and technical structures. Each COGEPOMI proposes a management plan and funding every five years and has to monitor them. The plan determines conservation and management actions, stocking operations, proposes fishing regulations for both recreational and commercial fisheries.

Since 2009, French EMUs as defined by the European Eel Regulation are more or less COGEPOMI. One should notice that Corse is a separate management unit and that EMUs are extended to coastal waters. A national EMP has been build that gives national instructions that can for some measures be adapted by EMUs through COGEPOMI or other local institutions.

The French EMP was approved on February 2010 and is publicly available (http://www.onema.fr/le-plan-de-gestion-de-l-anguille-en-france). It is one plan, but contains nine River Basin Districts (RBDs) (according to WFD) (Fig. 5) two of which are internationally shared RBDs (Rhine and Meuse). In some cases, the RBDs are further divided for the purpose of the EMP. E.g., there is one RBD for Loire–Britany, but two EMUs as there were initially two regional migratory fish management committees (COGEPOMI) and plans (PLAGEPOMI).

After several discussions, the following measures were planned in the EMP:

- Shorten the fishing seasons for yellow eel fisheries

[1] Previously this administration was known as ONEMA (2006-2017) and CSP (prior to 2006)

- Glass eel quota reduction of 60%
- Yellow eel fishery reduction of 60%
- A special area (close to the sea) where all dams have to be equipped in priority. This applies mostly for upstream migration
- Reduction of turbine mortality by turbines seasonal closures and a research plan
- 10% quota of glass eel transported in France
- Set up monitoring of silver eel escapement (index rivers and modelling program)
- Interdiction of fishing in marine area (outside from EMU perimeters), in some cases marine or estuarine areas are included in the EMUs (estuaries and bays: Golfe du Morbihan, Bassin d'Arcachon, Mediterranean lagoons).
- Reduction of 75% of other mortality causes, but these other causes relate mostly to habitat and pollution problems, which are currently hard to translate into escapement of silver eels.

Since the entry into force of the European eel Regulation, the majority of regulation regarding eel fisheries is taken in conformity with the French EMP. The main bylaw is thus the "Décret n° 2010-1110 du 22 Septembre 2010 relatif à la gestion et à la pêche de l'anguille" which translate the French EMPs into the French regulations. Regulations regarding other impacts are mainly derived from the European Water Framework Directive.

The French 2015 Progress Report lists 36 actions to be done under the French EMP: 26 of which are fully completed, nine are partially been completed and one is not done at all.

Among the actions related to monitoring and evaluation the most significant achievements are: development of an evaluation model (Eel density analysis, EDA), a census of migration obstacle, establishment of an eel specific electrofishing network and establishment of a river index system, monitoring of recreational fisheries (only done in some regions).

Main management actions for fisheries are:

- a quota system for glass eel fisheries,
- recreational glass and silver eel fisheries ban,
- stage-specific licencing system,
- fishing season for all fisheries,
- a buy-out programme.

Main management actions for other anthropogenic mortalities are:

- improve eel migration,
- R&D program on evaluation and improvement of upstream and downstream eel migration,
- a stocking program and its evaluation.

As a result of the implementation of the measures, the fishing effort for glass eel has diminished. This diminution was achieved in 2013-2014 but effort has risen again since then (only 50% reduction in 2016-2017). The reason is that glass eel quotas are set before knowing the extent of the next year fishery. The main ways to achieve the reduction were the establishing of the quota system and a reduction in fishing capacity. The closure of Asian market has had a high impact on the fleet. The post-evaluation of management measures is based on the comparison of recruitment trend and catch level.

The glass eel fishing season has been limited to five months. However, the fishing season had been limited in practice already before this legal rule, corresponding to the main peak of glass eel arrival. Consequently, the major reduction in glass eel fishing effort has probably been achieved through quota and reduction of fishing capacity, whereas the limited season is probably of little effect on the glass eel fishery. The access to the fishery is limited to fishers having access to a licence. This licence system is probably the most effective mean of dimensioning of the fishery. The number of licences delivered to marine fishers has been cut in half; the number of licences delivered to fluvial fishers has been diminished by 71%. The recreational glass eel fishery has been stopped effectively.

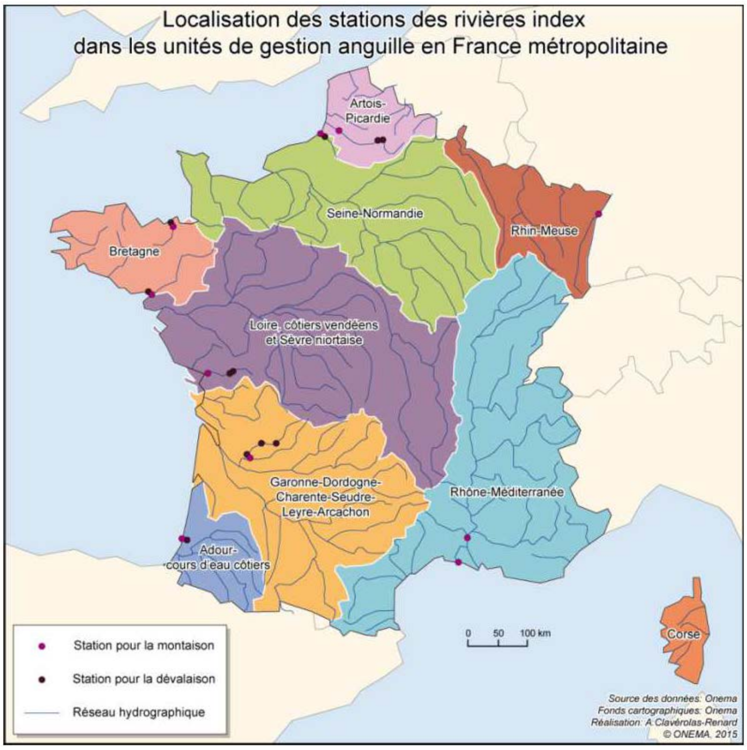
Enforcement of controls is detailed in the latest eel management report (Rapport PGA 2018). The setting up of a monitoring system of glass eel catch and trade ensures that the glass eel fished are reserved for consumption or stocking purpose. A large effort has been set up by the administration to control the trade chain and put up quite restrictive penalty for illegal trade or fishing. But the system fails when glass eels are sent to foreign countries because of the absence of a monitoring scheme orchestrated at the European level. Glass eel can be sent as stocked material but later be found in other circuits.

In France, stocking is part of the National Management Plan, which aims at reserving 5 to 10% of the national catch to transport operations, and in practise has led to the annual transport of 0.5% to 16% of the national catches in French waters. The objective is to transport glass eel in places where they are at low density and lifetime mortality is reduced. A public call is opened by the ministry to the organisations willing to conduct restocking operations. The maximum amount possible is EUR 2 million per year. The projects are evaluated by a selection committee including experts from MNHN (French Museum of Natural History) and AFB (French biodiversity agency). A national association is grouping the project holders (ARA France). In practise, the largest share is done by commercial fisheries organisations. All projects must abide by national rule in term of protocol and monitoring. The net benefit or net loss from those operations has not been demonstrated scientifically, but valuable insights in term of growth rate and post fishing survival have been enabled by the long-term monitoring of stocking operations.

In addition to the measures originally planned in the EMP, a few more actions have been implemented. Some of them are not mentioned in the Progress Report, especially local measures focusing on habitat restoration. Silver eel trap-and-transport in the Mediterranean region has been set up since 2013/2014. They amount to 1.08 million silver eels (163,907 kg) since 2011 (Rapport PGA, tableau 46 p 160). A large effort has been carried out by the fisheries organisations to ameliorate the quality of glass eel and limit post fishing mortalities.

The French EMP is accompanied by several scientific studies and evaluations. The most important is EDA, which as further evolved from its first version. The model still seems to underestimate the real eel production, likely because the habitat surface is under-evaluated in the underlying river network model. EDA only covers freshwater areas and a part of the stock, so there is still an uncertainty about the production in estuarine area. Yet, the inclusion of all kind of electrofishing (including deep habitat electrofishing), the use of a size structured model and a model for silvering has probably lifted a part of the uncertainty regarding eel production in deep habitat. The Mediterranean and marshes have been included in the post-evaluation but with data that are certain. The French model measures real silver eel output, and when back calculating the number of glass eel after adding mortalities the results were not far from the evaluation of recruitment by GEREM model (Drouineau et al. 2015). There were also studies on mortality at turbines, resulting in a considerable progress for this issue. Furthermore, on a local basis some work on the impact of small weirs on silver escapement habitat impact have been done in index rivers (Dronne, Frémur) and in the Grand Lieu lake (Trancart et al. 2018).

Figure 5: French EMUs and location of upstream and downstream eel monitoring stations for index rivers



Source: Agence Française de Biodiversité

3.3.2 Germany

In Germany, the European eel is an important species for both commercial and recreational fisheries. Commercial fisheries in Germany usually are mixed fisheries, which catch different species and also both stages, yellow and silver eel (though some gears primarily target one of the stages). The inland fishery is under the legal competence and responsibility of the federal states ("Bundesländer").

In December 2008, Germany submitted EMPs for its RBDs as required by the EU Council Regulation 1100/2007. The relevant German river systems belong to the ICES Ecoregions North Sea (Rhine, Elbe, Weser, Ems, Eider) and Baltic Sea (Oder, Warnow/Peene, Schlei/Trave). The plans had been prepared for nine RBDs (Eider, Elbe, Ems, Meuse, Oder, Rhine, Schlei/Trave, Warnow/Peene and Weser) (Fig. 6). No plan was prepared for the river Danube, since according to a decision of the European Commission the Danube does not constitute a natural distribution area for eel in the sense of the Council Regulation 1100/2007. The EMPs have a common structure and where submitted to the European Commission together with a German "frame" providing a short summary of the results of the estimates for escapement. Yet, the measures for the stock management were decided for each RBD and consequently differ between the rivers.

The new rules regarding eel in the EMPs have become part of the fisheries laws or fisheries regulations in the respective states.

The main measures proposed in the EMPs are:

• to increase minimum size limits to 45 cm or 50 cm (different between the states and EMUs, not distinguished between yellow and silver eels);

• to maintain and, if possible, increase stocking of eels (not all RBDs);

• closed seasons (different periods);

• attempts to reduce mortality by hydropower use (e.g. at turbines, water intakes etc.);

• actions to reduce mortality by cormorants.

In April 2010, the German EMPs were approved by the European Commission. Following this approval, the states started the implementation of the plans. Some of them established special eel regulations, whereas others only changed some aspects of existing legal frameworks. During the implementation process of the EMPs, the authorities in the "Bundesländer" in cooperation with the Federal Ministry for Food and Agriculture established a dedicated permanent working group, which mainly focuses on the requirements of the implementation reports (i.e. reports in three-year intervals). These Progress Reports were submitted to the European Commission in 2012, 2015 and 2018 as required by the Eel Regulation.

Meanwhile, some further restrictions have been established, e.g. in parts of the river Rhine commercial fishing for eel was forbidden since 2010. However, eels in considerable parts of the river Rhine are known to exceed PCB thresholds for human consumption. The fishing ban mainly applies to these riverine regions although the contaminant load of the fish is not explicitly mentioned as a reason for the ban. Additionally, in some RBDs there are special restrictions, which are limited to one or two states, e.g. removal of stationary eel traps, if possible. These were not included into the list of "main measures" (see above).

In response to the Council Regulation (EU) 2018/120 and the "*Joint Declaration on strengthening the recovery for European eel (Commission and Member States)*" from the 16th January 2018 (No. 5382/18), further measures were adopted in Germany. In the German coastal and waters, a closed season for the eel fishery was established from November 2018 to January 2019. For the period 2019/2020, the exact dates are discussed at present. In the transitional and freshwater parts of the relevant EMUs, further measures were adopted:

- Introduction of a closed season for the commercial fishery (Lower Saxony: November to January (estuary of the River Elbe), Schleswig-Holstein: October to January for silver eels, Thuringia: November to February)
- Introduction of a closed season for recreational fisheries (Schleswig-Holstein: October to January for silver eels, Thuringia: November to February)
- Increased minimum size limit of 52 cm (Berlin, Saxony, Saxony-Anhalt, Thuringia)
- Introduction of a "catch window" of 45-75 cm (Hamburg)
- Introduction of bag limits for anglers (Hamburg: 3 eels per day, Thuringia: 2 eels per day)
- Reduction of allowed effort of the recreational fishery (Hamburg: reduction from 10 to 2 fykes per person)

- Increased amount of stocking above the originally planned amounts, beginning in 2019 (Brandenburg and Saxony-Anhalt: increase by 10%, Lower Saxony: increase by 30%)
- Minimum mesh size for fyke nets of 14 mm (Hamburg)
- No stocking in closed water bodies (Hamburg)

Meanwhile most of the measures have been implemented, but in some cases, the targets were only achieved partially. This is particularly true for stocking, where the planned numbers could not be achieved in all RBDs and years. The present state of the implementation of the planned measures in the German EMUs is presented in ANNEX II.1.

Figure 6: River Basin Districts of Germany

Source: Umweltbundesamt. RBDs: Eider, Schlei/Trave, Elbe, Warnow/Peene, Oder, Weser, Ems, Rhine, Meuse and Danube

3.3.3 Greece

In Greece, there is a long-time effort to protect freshwater fish species. It is noteworthy to mention that one of the first laws that came in force towards this subject, was the Royal Decree 142 established in 1971 (RD 142/1941). According to this Decree, the Greek government established specific measures for the protection of six freshwater fish species and one freshwater decapod. The species under protection were *Salmo fario*, *Coregonus* sp., *Cyprinus* sp., *Anguilla* sp., *Tinca tinca* and *Carassius carassius* and the decapod *Astacus astacus.*

The RD specified not only the minimum length of the species (for the species *A. anguilla* was set at 30 cm) but also limited the areas that fisheries was prohibited (i.e. rivers, lakes etc.) as well as the type of gear (nets, long lines, traps etc.) that could be used for fisheries.

Many years later, RD 142/1971, which was still active, was the basis for the development of the Hellenic Eel Management Plan (HEMP), which was the result of the implementation of Council Regulation No 1100/2007/EC. Greece, through the Ministry of Rural Development and Food, Directorate of Aquaculture and Inland Waters submitted the HEMP to EU in 2009.

The HEMP was prepared taking into consideration the obligation stated by the Council Regulation No 1100/2007/EC for MS to take measures and develop national management plans in order to increase the percentage of escapements to the sea of at least 40% of the silver eel that would have been migrate in the absence of anthropogenic influences.

The plan defines four EMUs, based on the main climatic characteristics, on the spatial distribution of lagoons, lakes and rivers, on the existing Ecoregions (Directive 2000/60/EC), on the distribution of the eel fisheries and on the location of the main authorities involved in water and eel management. The management measures concerning fishing restrictions and environmental aspects are applied to all EMUs. The nature and scale of the proposed specific actions, like stocking or pilot studies, respect the relative importance of the EMUs.

- **EMU-01** (7 Prefectures, 3 Regions) is located in Northwestern Greece. It comprises 70% of the total Hellenic lagoons surface and 45% of the lakes surface. Despite the considerable decrease of the EMU-01 landings (180 t in mid-1980, 50 t the recent years), the unit remains the most important eel producer.
- **EMU-02** (5 Prefectures, 2 Regions) is located on the Western Peloponnesus. It comprises 5% of the total Hellenic lagoons surface and 3% of the lakes. The eel landings of this EMU increased since the mid-1980s, contrary to the general pattern and now represents about 40% of the Hellenic lagoon landings (about 40 t).
- **EMU-03** (four Prefectures, one Region) is located on the north-eastern part of the country. It comprises 24% of the total Hellenic lagoon surfaces and 9% of the lake surfaces. The landings dropped from 70 t in early 1980s to less than 10 t.
- **EMU-04** covers the rest of the country, mainly central eastern continental Greece and the islands of the Aegean Sea (35 Prefectures and eight Regions). The landings of the EMU-04 are almost zero.

The main targets of the EMP are:

- Reduce direct fishing mortality
- Establish an efficient recording system
- Reduce natural mortality
- Improve the efficiency of eel migrations

The HEMP proposed various measures, grouped into three categories. These categories were the "Immediate actions" the "Midterm" and the "Longterm Actions".

***Immediate actions*:** In this category, six measures, which could be implemented immediately, were proposed by HEMP. These measures targeted the protection of the stock by minimizing the mortality of the species, while focusing on the increase of the number of spawners that manage to escape during their migration.

One of the first measures proposed by HEMP was the prohibition of eel recreational fisheries in both inland and transitional waters, in an effort to reduce fishing mortality to zero. Moreover, it proposed, in accordance with the Decree No 142/1971, to ban the use of specific fishing gears such as fyke nets, while only hooked fishing gears allowed in rivers.

The HEMP also proposed the implementation of stocking actions as a measure to enhance the abundance of eel in Greek waters and additionally to minimize eel mortality and increase the number of spawners able to escape and continue their migration towards the Sargasso Sea. In an effort to minimize eel mortality due to fisheries and increase the number of spawners that escape, fishing cooperatives that lease and exploit lagoons are obliged to release 30% of their annual landings. Fishing cooperatives are eligible to export eels only if they release this 30% of catches as confirmed by a Committee of representatives from the Regional Fisheries Department, the Coast guard and the Regional Veterinary Office.

Glass eels used for stocking come from two possible sources: gathering glass eels from the wild stock or importing glass eels from other countries. In the first case, the Ministry of Rural Development and Food has the authority to issue special permission for glass eel fisheries. Anglers that were designated by the ministry are allowed to catch glass eels from selected estuaries and release them in estuaries were stocking actions are planned to take place. In the second case, the Management Plan suggested that every fish farm that imports glass eels for rearing (in accordance with present CITES rules exclusively from EU countries) are obliged to release the 10% of the total biomass of glass eels imported. The glass eels are released to rivers designated by the Ministry of Rural Development and Food.

Since the implementation of the HEMP, no glass eel licence has been issued by the ministry. Thus, the only source of glass eels for stocking remains the ones released by the fish farms.

***Mid and Long-Term Actions*:** In the second and third categories (Mid and long-term actions) measures targeting the improvement of the upstream and downstream migration were included. The main goal was to find and implement solutions to overcome the problems raised by the presence of barriers inhibiting the species migration. Also, the “Mid and long-term actions” included stocking actions, which will assist in long-term period the recovery of the stock.

After 2005, more than 100 licences issued for the installation of small-scale hydropower plants. Despite the numerous small-scale hydropower plants designed to be constructed, their installation is situated in areas with high altitude and very steep geomorphology and thus will not affect the upstream migration of the glass eels. However, the main threat in upstream or downstream migration is the presence weirs, culverts, fords and ramps, which are being constructed sometimes without proper design and licencing, fragmenting the rivers prohibiting the migration of all fish species inhabiting the river. For this reason, the HEMP suggests the development of technical interventions that will allow the free moving of the fish species.

In the “long-term” actions, the measures proposed through the HEMP are 1) to minimize eel mortality due to fisheries and 2) stocking actions to increase silver eel escapement. The HEMP set an initial target of releasing the 30% of the annual eel catches by the fishing cooperatives. The implementation of the measure will re-examined and depending of the results, it was suggested the gradual increase of the release from the lagoons to up to 70% of the catches in combination with the transfer of early stages from “death traps” to open to the sea and safe environments.

***Further information*:** Since 2012 there is a data collection in the framework of the DCF/EU Multi-Annual Programme (EU-MAP).

All the available data requested by the ICES WGEEL through the data calls are provided by the country.

Apart from the Ministry of Rural Development, which is responsible for the implementation of the EMP, the Fisheries Research Institute, the Department of Biology in the University of Ioannina and University of Patras, are the other institutions that participate in the eel data collection and stock evaluation. Greece is following the CITES Regulation in recording all the imports of glass eels and exports of silver eels.

3.3.4 Spain

The Ministry of Environment, and Rural and Maritime Environment (MARM), responsible for fisheries and environmental issues, submitted the Spanish EMP in December 2008. After several discussions, consultations between Spain, ICES and the European Commission the revised plan was approved in October 2010. Spain and Portugal jointly produced the Miño international River plan, which was approved in May 2012. All plans are available at http://www.magrama.gob.es/es/pesca/temas/planes-de-gestion-y-recuperacion-de-especies-pesqueras/planes-gestion-anguila-europea/.

The National EMP defines the structure and methodology, the monitoring and evaluation measures and the objectives at national level. It also contains a summary of the 12 specific EMPs. Each participating Autonomous Community – with exclusive competences on eel fisheries - has been defined as an EMU that shall establish an EMP, in accordance with Article 2(1) of Council Regulation (EC) 1100/2007.

There are large differences between the monitoring and evaluation, available data and the capacity for action between the inner regions with no current eel populations and the coastal regions that still have them. Those autonomous regions, where the eel disappeared many years ago and that have no data or criteria for action, cannot put forward effective measures in the short term according to the Spanish EMP. However, a commitment at national level was adopted within the Sectorial Environmental Conference on 7th June 2010 between MARM and the Regional Ministers of Environment of the Autonomous Communities, allowing for effective measures to take place in the medium term to deliver the 40% silver eel escapement target in the Spanish territory.

Spanish rivers flow into both, the Mediterranean Sea and the Atlantic Ocean. There are considerable differences between the rivers, in particular regarding hydrological characteristics like slope, currents or the presence of lagoons (only in the Mediterranean area). There are also climatic differences between the catchments. Some of the large rivers (Duero, Tajo and Guadiana) disembogue in Portugal.

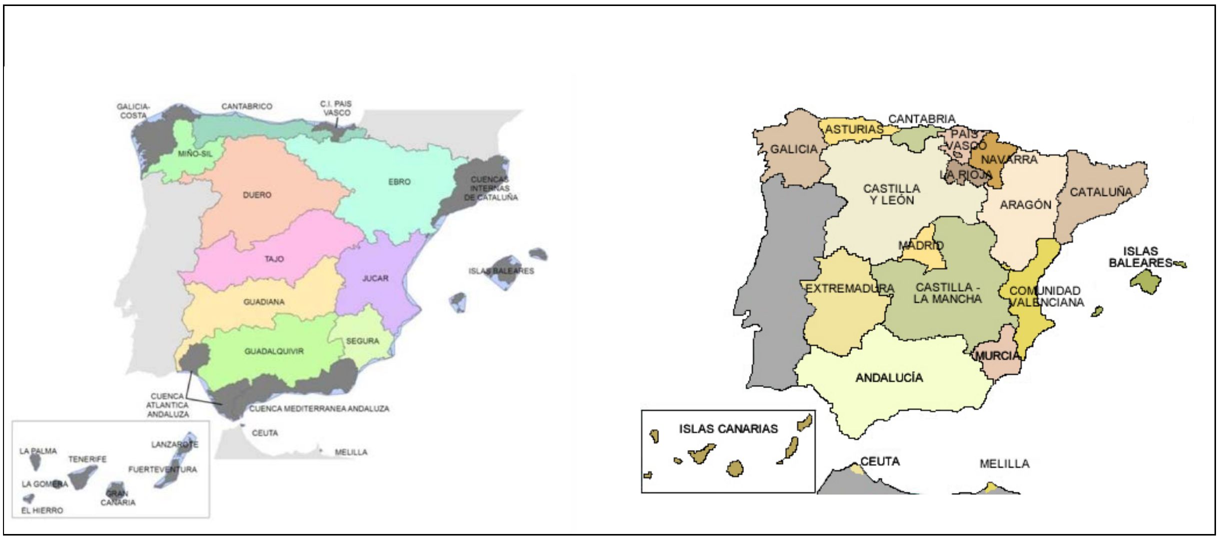
All the territory of the RBDs of Guadalquivir, Galicia Costa, Basque Country Inner basins, Catalonia Inner basins, Canary Islands basins, Balearic Islands basins and Atlantic and Mediterranean basins of Andalucía belongs to a single autonomous region (Fig. 7) and are managed by the autonomous region they belong to. On the contrary, Segura, Júcar, Miño-Sil, Cantábrico, Duero, Tajo, Guadiana, Ebro and Guadalquivir RBDs extend over different autonomous regions and are managed by MARM through eight hydrographical confederations. Additionally, the Miño, Duero, Tajo and Guadiana RBDs are shared with Portugal, whereas the Ebro RBD is shared with France.

Given Spain's national and regional structures, the Spanish management plan is based on a National EMP and other specific EMPs. When the EMP was launched, it included 11 EMPs for the Autonomous Communities, and 1 EMP specific for the Ebro River Basin. The inner basins EMU includes the Autonomous Communities that do not have current eel population (Castilla y León, La Rioja, Madrid, Aragón and Extremadura) except from Navarra and Castilla la Mancha that have their own EMP. However, since the 2012 post-evaluation report the part of the Ebro located in Cataluña, has been included in the Cataluña EMU. This is the only area of the Ebro where eels can still be found and where the eel and glass eel fishery take place.

There is no dedicated national eel working group, but during the implementation of the EMPs and the work on the Progress Reports, many meetings have been held. These meetings are organized by the Secretaría General de Pesca, and managers for each of the EMUs (both fishery and environment related) are invited, as well as scientific advisors and further scientific and administrative authorities.

In Spain, there is no stock assessment at a national level. Each autonomous region has assessed the stock for the management plan in a different way. The management plan of each autonomous region has its own objectives, methodology and structure. Overall, this causes great differences between the autonomous regions and their EMPs. The autonomous governments are responsible for control, regulation and management of eel fishery and population.

Figure 7: RDBs (left) and Autonomous regions (right) of Spain



Source: Díaz and Korta 2016

The Spanish EMP has set up a two-phase approach: In the **first phase (2010-2015)** the coastal Autonomous Communities that had data available and management measures prior to the drafting of the plan should implement their proposed measures. According to this approach, in the inland river basins, a series of commitments and specific measures should be adopted at national level such as the elimination of barriers, habitat improvement, monitoring, study and assessment of the eel population and more accurate definition of pristine habitat in order to develop specific measures. In addition to that, working groups comprising representatives of all the public administrations involved in the eel management and scientific experts should be created. Estimates of the pristine and current situations of the European eel in Spain should be updated on that basis. At the end of this first phase, the new data should allow to reassess the stock situation and to launch the second phase, with from 2016 on, specific regional measures to strengthen and improve the plan's objectives across the potential surface defined. This phase has almost been completed as foreseen. Measures on elimination of barriers and habitat improvement have been adopted in the framework of other regulations (WFD) and programs. Although the foreseen working groups were not created, some of the coastal EMUs have improved their estimations thanks to specific eel samplings. However, some of the EMUs still use reference values and other have not updated or improved their estimations.

The **second phase (2016-2050)** started in 2016 and coincides with the timescale for reviewing the River Basin Management Plans as set out in the Water Framework Directive (WFD) to take account of further measures needed to meet the Directive objectives.

The measures provided for in the National EMP and in the specific EMPs aim to ensure the protection and sustainable exploitation of European eel and to restore the escapement levels of eel at national level, by the year 2050.

A detailed description of the fisheries and the management measures taken in the different EMUs is presented in ANNEX II.2 (also in relation to the measures planned in the EMPs).

Summary for Spain:
Spain is very important for eel recruitment. According to Bornarel et al. (2017), the rivers of the Iberian coast receive between 20-50% of the total eel recruitment in the whole distribution area. Yet, the construction of large dams since the 1960s has led to the disappearance of eel from most of the inland river basins of the Iberian Peninsula. The eel was historically widespread throughout the Iberian Peninsula, but it has lost over 80% of its original range, mainly due to river fragmentation by dams (Clavero and Hermoso 2015).

Taking the distribution of competences into account, the adopted measures greatly differ depending on the EMU as shown by the summary of measures per EMU.

***Commercial Fishery*:** Since the EMP was implemented, the fishing effort has decreased by shortening the fishing season (Asturias, Galicia, Cantabria and Valencia), decreasing the licence number and fishing places (Cantabria, Cataluña and Galicia) and forbidding fishing in some basins (Cantabria and Valencia) or even in all the EMU (Andalucia). In Valencia fishers are obliged to give a percentage of the catches for stocking purposes. The EMUs in the Mediterranean area (Murcia, Valencia and Cataluña) have accepted to cut the fishing season or limit the number of vessels within the General Fisheries Commission for the Mediterranean (GFCM) management plan framework; this will be implemented in the coming season.

***Recreational fishery*:** Recreational yellow and silver eel fisheries have been forbidden in most of the EMUs, where this activity existed before the plan. Recreational glass eel fishery only existed in Cantabria and Basque Country, and both EMUs have decreased the effort by shortening the season and Cantabria has finally forbidden glass eel recreational fishery in 2015.

***Entrainment and mortality at water intakes (including hydropower facilities)*:** Before 2015, up to 100 kg of glass and young yellow eels have been transported upstream at unpassable obstacles in the Valencia region and the Basque Country. From 2015 on, a decree was established obliging electricity companies to transport eels upstream of their facilities (Decree 35/2013), so there has been a significant increase in the amounts of eels transported, ranging between 678 and 1076 kg for the 2015-2017 period.

***Increasing habitat quantity and improving quality*:** Many dams have been removed and passes have been installed; however, available information does not allow estimating the available habitat increase. In addition, different studies to inventory and catalogue the dams have been carried out. The Basque Country, Navarra, Asturias and Valencia have declared some of the territory within the species distribution area as protected.

***Stocking*:** In Spain there is no national stocking programme as the regions are the competent authorities. Thus, it is up to each region to use stocking as a management measure and to implement it. Currently, the only region that stocks on a regular basis is Valencia, where fishers are obliged to donate 10% of their catches that are grown on public farms before being released. In Andalucia, some farms with fishing permits were obliged to reserve 60% of their catch for stocking, but this measure has not been implemented since 2017. Murcia and the inland regions have never stocked. In Cantabria, a 40% of the total landings of the 2010-2011 season of recreational fisheries was used for stocking. In Catalonia, fishers provided approximately 5% of their glass eel catches during the 1998-2010 period for stocking. The Basque Country, Catalonia and Andalusia have stocked punctually using glass eels from the seizures carried out by SEPRONA. Navarra stocked with ongrown eels during the period 2010-2013 that were bought from Basque traders. Regional managers from Asturias purchased 6 kg and 8 kg of glass eel that were released in Sella and Nalón rivers in 2010 and 2011, respectively. In summary, except from Valencia, Spanish regions only stock punctually and in most of the cases using glass eels donated by fishers or SEPRONA.

***Further information*:** In addition to the actions foreseen in the EMPs, a few further measures have been taken. Glass eels coming from seizures have been stocked. Cantabria has forbidden recreational fishery although this was not foreseen initially.

The development and implementation of the EMPs has been and is supported by accompanying scientific studies. In some of the EMUs (Murcia, Asturias, Andalucía and Basque Country), scientific experts have been hired to obtain field data and to provide support in the estimation of the indicators for the management plan. The Spanish Secretaría general de Pesca has been hiring AZTI as scientific advisor since 2010. AZTI also gives support to the different EMUs for the Progress Reports.

Together with scientific institutions and management related actors from France and Portugal, Spanish scientists cooperate in the SUDOANG (https://www.sudoang.eu/) Interreg SUDOE project. Its main objective is to provide tools and joint methods that support the conservation of the European eel and its habitat to managers in the SUDOE area. More specifically, the Eel Density Analysis model (EDA) will be implemented, which allows the prediction of yellow eel densities and silver eel escapement from electrofishing survey networks. In addition, the project will quantify the impacts of hydropower facilities on downstream-migrating silver eels. In addition, SUDOANG will produce recruitment estimates and will create a governance platform to support the proper management of the eel stock in the SUDOE area. All of this will be ready by the end of 2020, so the estimations of the stock indicators for the next post evaluation report will be greatly improved.

During the implementation of DCF/EUMAP (2017-2020), several monitoring tools have been developed in Spain:

- 8 index rivers allowing to estimate eel recruitment
- 14 index rivers allowing to estimate the eel stock and silver eel production. In many of the above-mentioned rivers eel was monitored already before the implementation of the EUMAP.

All required information on the eel stock and eel fishery is provided annually to ICES WGEEL and is publically available in the WGEEL CR.

The European eel is included in the Spanish Red List of endangered species. The Spanish CITES administrative authority participates in the EC Action Plan against trafficking for European Eel (COM/2016/87).

Criminal networks use glass eel coming for both legal and illegal fisheries in Portugal, Spain, UK and France and using different routes they send them to Asia. Since 2012 the SEPRONA (the environmental division of the Spanish Guardia Civil), has led large national and international operations against illegal trade and fishing, of the eel ("Suculenta", "Suculencias", "Black Glass" and "Abaia"). SEPRONA is very active in the ongoing "LAKE" operation against glass eel trafficking led by EUROPOL.

3.4 Conclusions and Recommendations

In the course of the implementation of the EMPs, many measures have been proposed in the EU Member States and the majority of these measures have meanwhile been implemented. The main direct measures are directed to fisheries and other anthropogenic mortality sources like hydropower installations or pumping stations, which have been proposed by nearly all countries. Yet, the real effect on the eel stock is often unsure, since some of the measures seem to be implemented in a less appropriate way (e.g. sometimes closed seasons may not have been established in periods, when fishing pressure was high before, or increased Minimum Landing Size (MLS) which can potentially be compensated by increasing fishing pressure by other means).

The high overall number of measures also includes actions, which will not have direct effects on the stock, such as control and enforcement, scientific studies, improved documentation etc. Particularly in relation to habitat improvement and hydropower issues, the measures are often defined rather vague, probably because of restricted legal competence of the authorities responsible for the EMPs.

Stocking is part of the management strategy in many countries, but this measure is also critically discussed. Whereas it can clearly result in increased European eel abundance on a local basis, the net benefit of this measure for the whole stock is still not proven.

The examples of the four countries illustrate another potential problem of sustainable eel management – the scattered nature not only of the fisheries and the impacts on the eel stock but also of the legal responsibilities. The legal competences may be distributed vertically (national or regional level) and horizontally (e.g. fisheries authorities or environmental authorities). This results in complex management structures and a great diversity of regulations, rules and measures sometimes even within one river system. Authorities responsible for the EMPs have often no or only restricted legal competence for hydropower issues. In some cases, this probably impedes a coordinated management.

Based on the descriptions and evaluations of the management measures established during the implementation of EMPs according to the Eel Regulation, it is recommended that efforts should be made to achieve a full implementation of all measures planned in the EMPs. Furthermore, a better evaluation of the effectiveness of the management actions is needed. Despite being a panmictic species, there is a great complexity of eel management on local, regional, national and international level. Yet, for an effective management and protection of the species, a better coordination of the management on all levels should be strived for. Stocking is conducted in many countries, but is also critically discussed. Therefore, the effects of this measure should be studied scientifically, in particular in relation to effects on the whole European eel population level. Improvements in the field of hydropower, pumping stations, water intakes etc. (reduction of mortality and damage rates) can be challenging. Therefore, short-term approaches like trap-and-transport could possibly be established as interim solutions. However, they should not be used as justification for not taking measures with long-lasting effects. The Eel Regulation defines the management goal as biomass target (spawner biomass 40% compared to undisturbed conditions). Yet, this can result in discrepancies between local or regional and whole-stock approaches to management (e.g. at high stocking level, biomass target can be achieved for an EMU despite high mortalities in this EMU). Hence, it would be highly recommended to move from the current 40% regional level escapement targets to a mortality-based target in a revised version of an EU Regulation, which would also be in better agreement with the current ICES advice for the species ("all anthropogenic mortalities should be reduced to as close to zero as possible").

4 IMPACT OF INDUSTRIAL INSTALLATIONS ON ESCAPEMENT AND MIGRATION OF THE SPAWNING STOCK

Key findings

- 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. At this distance, only 25% of total hydropower plants in the country are found.
- Existing 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.

This chapter discusses in detail the impact of various industrial installations that are major obstacles to the escapement and migration of the spawning stock. Section 4.1 provides an overview of the impact of industrial installations on the upstream migration of eels and potential mitigation measures while section 4.2 discusses the obstacles of industrial installations to downstream migration and potential mitigation measures.

4.1 Upstream migration obstacles and migration progress

This section examines in detail the impact and mitigation measures of industrial installations on the upstream migration of eels. Sub-section 4.1.1 provides an overview of the impact from industrial installations, and sub-section 4.1.2 discusses potential measures that could reduce or mitigate these impacts.

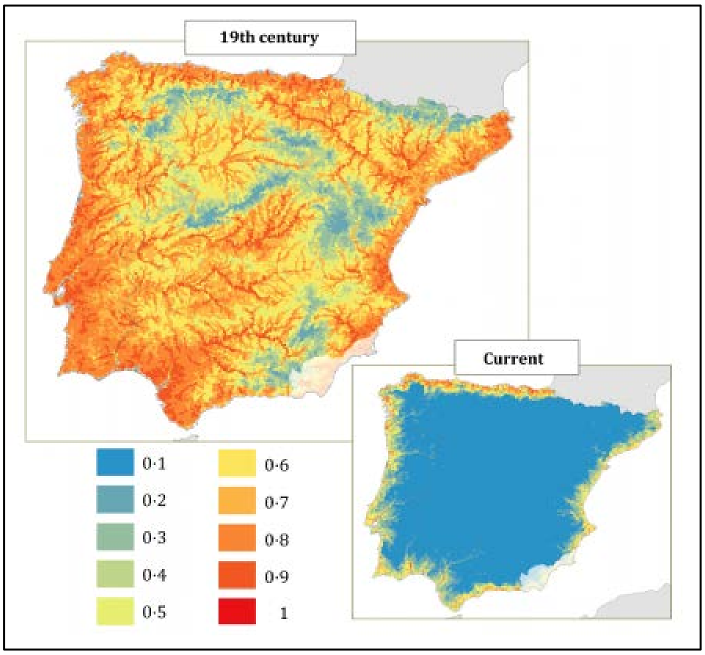
4.1.1 Impact

The presence and increasing number of transverse structures created by humans in rivers (tidal barrages, tidal flaps, mill weirs, gauging weirs, amenity barrages and weirs and navigation weirs) have significantly limited the natural free movement of aquatic living communities. The largest dams, which are used for drinking water, irrigation and energy production, are entirely impassable. Some of these infrastructures are equipped with fishways or eel specific traps to reduce their effect, but those are unlikely to be fully efficient.

According to Knights and White (1998) about 7% (200,000 ha) of still water habitats and 25% (68,000 ha) of riverine habitats in Europe are inaccessible to eels due to man-made barriers. Feunteun (2009) further calculated that 50%–90% of eel habitats were inaccessible by the end of the twentieth century in Europe.

The Iberian Peninsula is one of the areas that has been more affected by large dam construction since the 1950s: it has been estimated that eels have lost more than 80% of their habitat in this region (Fig. 8) (Clavero and Hermoso 2015).

Figure 8: Probability of occurrence of the eel in the Iberian Peninsula in the 19th century and the present



Source: Clavero and Hermoso 2015

While in other places in Europe, the distribution of eels is less severely impacted by the effect of habitat fragmentation, river continuity, as requested by the European Water Framework Directive, is rarely implemented in European river systems. 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 have been transported massively upstream from dams (Dekker et al. 2011). 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.

However, ICES repeatedly requested in its advice on the European Eel that stocking should take place only where survival to silver eel escapement is high and should not be used as an alternative to reduce anthropogenic mortality. Where eels are translocated and stocked, measures should be taken to evaluate their fate and their contribution to silver eel escapement (ICES 2018a). The stocking of eels upstream from migration barriers is clearly inconsistent with this advice.

Although habitat loss undoubtedly affects the eel population, it is difficult to quantify its contribution to population decline. Due to obstacles from industrial installations eels are forced to remain in lowland river sections, estuaries or coastal areas, which, at high natural recruitment, may cause unnaturally high population densities. High densities are reported to increase competition between individuals resulting in lower survival (Bevacqua et al. 2011), increased susceptibility to predation

(Drouineau et al. 2015) and overfishing (Briand et al. 2005). High densities may also affect sex determination (Tesch 2003). However, eel upstream migration is probably a density-driven process, where most eels only migrate far upstream if the ecological niches in estuaries and lower perennial habitats are occupied (Feunteun et al. 2003). To what extent eels at the current low level of recruitment would still migrate into the upper reaches of river systems is largely unknown.

Therefore, stocking juvenile eels to upstream regions cannot per se be considered a measure to help stock recovery. When stocking is undertaken to increase silver eel escapement and thus aid stock recovery, an estimation of the prospective net benefit should be made prior to any stocking activity (ICES 2018a). Stocking upstream of obstacles, like hydropower dams, is highly questionable and urgently needs to be validated in a case by case approach. This validation should assess whether the provision of otherwise inaccessible habitats can compensate for accompanied mortalities, including indirect mortality during glass eel fishing and transport, and turbine passage during downstream migration.

Sections 4.2.1.4 and 4.2.1.5 provide additional details on the impact of hydropower generation on eel migration in France and Spain, respectively.

4.1.2 Mitigation measures

Obstructions to eel upstream migration occur in a variety of forms, functions and sizes. In addition, depending on their location, these installations affect different eel stages. This great diversity in obstacles is an important challenge in identifying the best solution for fish passage. Furthermore, the cost of each solution varies largely. Thus, before adopting any measure, a detailed study of the local eel stock and the obstacles affecting migration should be performed. The United Kingdom's Environment Agency (2004) proposes six Basic Approaches for providing upstream passage:

- Build a fish pass, which incorporates a channel that allows the fish to ascend under controlled conditions that are within its swimming and crawling capabilities. This commonly involves the use of ramps with a crawling or climbing substrate. The effectiveness of passes depends heavily on ensuring, with respect to the main flow over or through the dam, both correct positioning of the pass and enough flow to attract the fish (Baran et al. 2012). In addition, the migrating eel size should be taken considered to choose the most suitable substrate.
- Trap the fish and release them above the obstruction. Again, this commonly involves the use of a pass trap with ramps with crawling substrate.
- Allow the fish to swim through the barrier e.g. through an orifice or pipe; this would normally require some mechanism for restricting water velocity through the aperture.
- Lift the fish either in a fish lock or a fish lift.
- Create conditions at the barrier to allow ascent, for example by roughening the back of a small weir or providing rocks to generate edge effects; in practice, this approach merges with approach No 1 above.
- Removal of the barrier. Whenever possible, it is advocated to remove barriers in the planning documents (SDAGE) in France. This measure ensures the restoration of river continuity and lessens the impact of dams on water compartment. However, the effects of the changes on water usage and hydrology should be considered.
- More detailed information can be found at Environmental Agency (2004) and Baran et al. (2012).

4.2 Downstream migration obstacles

Obstacles significantly impact the distance covered by eels and may lead to stops or delays in migration that impair escapement success when there is a limited suitable time-window for migration (Drouineau et al. 2017). These delays can have a serious impact on eels since their energy resources are limited for a successful trans-Atlantic migration. In addition, delays and exploratory behaviour can also increase predation and disease risk (Verhelst et al. 2018).

This section further examines the impacts of two types of installations on the downstream migration process of eels: subsection 4.2.1 examines the impact of turbines and potential mitigation measures to be implemented and subsection 4.2.2 discusses how pumps can also be detrimental to eel downstream migration and how this could be mitigated.

4.2.1 Turbines

During their downstream migration as silver eels or simply as they migrate to other habitats as yellow eels within freshwater basins, eels are vulnerable to the impact of hydropower installations. When passing through turbines, eels are exposed to sudden pressure change (Duncan and Carlson 2011), shear stress (Neitzel et al. 2004), turbulence, shocks (Deng et al. 2011) and grinding between blades and turbine mantel, and these effects can cause injuries or mortality (Larinier and Travade 2002; Larinier 2008). The eel, considering its size and shape, is one of the species most exposed to mechanical shocks, which can cause fractures, perforations, lacerations or even the individual to be completely sectioned (Feunteun et al. 2008). On top of mortality or injuries occurring during fish passage through turbines, the crossing of a HP dam can result in deleterious effect on trash racks on which eels can be stuck when approach velocities are too high (Marohn et al. 2014), and also during the migration on spillway when the reception area (rocks – shallow bottom) is inadequate.

The mortality caused by hydroelectric power plants is very variable and depends on numerous factors such as the flow, the shape of the obstacle and its derivation, the type of turbine available, etc. For migrating species, including eels, the main problem lies in the succession of hydropower plants along migratory axes, which produces a cumulative impact that can reach very high mortality rates of up to 100% (Dönni et al. 2001; Dumont et al. 2005; Dumont 2006).

During downward migration, eels follow the natural flow of the river (Carton 2001; Jansen et al. 2007). The transversal barriers to the riverbed, commonly known as dams, have the objective of altering the flow of water, slowing down the speed of the water and damming it in order to redirect the excess water towards exploitation, normally a hydroelectric plant, through an intake or diversion channel. The downward movement of the eel, which follows the flow of the water, is diverted to the bypass channels, directly to the turbines or to an alternative step (bypass) if existent.

In these cases, the amount of dead fish depends largely on the percentage of animals that pass through the turbines, a fact that is influenced by the configuration of the intake and proportion of flow in detraction. On the other hand, the percentage of eels that die in turbines or the mortality rate depends on the circulating flow and the type of turbine available in the plant (Larinier and Travade 1998).

When assessing mortality at a given site, two main aspects must be considered: the number of eels entering the plant and the mortality caused by the turbines. However, at the stock level, the location of downstream migrants is by far the most important factor in predicting the overall impact of hydropower in a basin or at the stock level (McCleave 2001).

4.2.1.1 Number of eels entering the plant

A study including six installations (Baran et al. 2012), showed that most passages of eels (65%) took place via the spillways. The turbines were the second most important channel (32%), with the other possibilities (bypasses and fish passes) representing only 3% of passages. However, there was a great variability in the percentage of eels transiting the turbines between the six installations, ranging from 2 to 62%. The significant differences between installations are due to their specific characteristics. The entrance of the eels to a hydroelectric exploitation depends on the shape of the obstacle, the configuration of the water intake or derivation channel with respect to the axis of the river (the eels migrate through the main current), the period of operation of the plants (coincidence with the period of migration of the species), the presence or not of anti-fish barriers (protection grids for example) and the hydrostatic pressure due to the height of the jump or speed of the current (Feunteun et al. 2008).

The most important factor is probably the relationship between the flow that flows through the river and the flow that detracts the use, which determines the presence or operation of alternative routes, if any, to avoid passing through turbines. However, in a study at a complex of water control structures in one location on an English river, Piper et al. (2017) found that the distribution of eels across five potential routes of passage differed from that predicted based on proportion of discharge alone. In their study, certain routes were consistently avoided, even when the majority of flow passed through them. The downstream migration of eels is related to river flow (Deelder 1984; Lowe 1952; Tesch and Rohlf 2003; Bruijs and Durif 2009), but depending on the topological position of the river within the basin there are differences in migration dynamics. In some basins, river flow explains a large part of the migration (Vøllestad and Jonsson 1988; Behrmann-Godel and Eckmann 2003; Winter et al. 2006). However, this relation can be less marked in other context particularly those located downstream from large lakes on in downstream watercourse where eel can migrate from a large distance upstream (Cullen and McCarthy 2003; Allen et al. 2006; Chadwick et al. 2007; Durif and Elie 2008). So, in short rivers, the migration dynamics will be well predicted by the flow peak (Trancart et al. 2013; Marohn et al. 2014). On the other hand, in larger rivers, or in place where river obstacles are hampering the progress of eel, the movement of eels will still be triggered by flow, but this relation is harder to predict, and the migration is likely to span several months.

4.2.1.2 Turbine mortality

The first research papers on European HPP-caused mortality were published by Von Raben (1955; 1957) and Berg (1986). From these studies, it was concluded that the average mortality caused in the European eel population could range between 15 and 38%. However, it is not only turbines that cause mortality, but also the presence of grids to prevent the passage of garbage, which can cause injuries when the speed of the water or approach is greater than the fish's own swimming capacity (Adam and Bruijs 2006).

In terms of types of mortality, turbine mortality can be grouped into four categories:

- Contact of the animal with one of the parts of the turbine, usually the blades of the propeller, causing the bisection of the animal.

- A sudden acceleration or deceleration of the water velocity caused at the trailing edge of the corridor may create a shear force sufficient to kill the fish.
- Changes and variations in pressure can increase by three times the reference pressure, causing the swim bladder to rupture.
- Cavitation, which is the creation of gas bubbles in a liquid by pressures below vapour pressure, can cause internal injury to fish.

Variations in pressure or velocity can occur anywhere during fish passage, but contact with shovels and cavitation occur only in specific areas, on small surfaces, and can be avoided with proper turbine design and adjustment. The most common types of injuries to eels are bisections, spinal breaks and internal bleeding (Fig. 9).

Eels show a higher mortality rate compared to other fishes due to their morphology, with a very large length-weight ratio. Also, larger eels are more likely to be injured than smaller ones (Gomes and Larinier 2008), i.e. large sized female with a high fecundity (MacNamara and McCarthy 2012), and more chance to have the reserves to migrate to the spawning ground. Prignon et al. (1998) estimate that, in the Meuse River, direct mortality on males is between 35-45% and in females, of larger sizes, between 40-63%.

As turbine mortality occurs at the end of the continental phase, these impacts are less likely to be compensated by processes like density-dependent mortality (Mateo et al. 2017).

The percentage of eels that do not survive the passage through the exploitation is very variable according to the circulating flow and the type of turbines available. The mortality rate can vary significantly from one hydroelectric plant to another, even in the same plant depending on the time and conditions of the environment.

Figure 9: Dead silver eel at the outlet of a power plant on the Oria River

Source: © EKOLUR

The types of turbines found in European rivers are Kaplan, Francis, and Pelton. However, the most common of these is the Kaplan. A review of Kaplan mortalities by Bruijs and Durif (2009) found different mortality rates: 38% in Neckarzimmern Germany (Berg 1986), 22% in Dettelbach Germany (Holzner 1999), 20% in Obernau Germany (Von Raben 1957), 16-26% in Meuse (Winter et al. 2006), 24% in Beauharnois Canada (Desrochers 1995) and 37% in Raymondville USA (Franke et al. 1997). Francis turbines, normally used in small rivers, are more dangerous because of their smaller opening width between blades. A study by Holzner (1999) estimated that they cause 2.5 times more mortality than Kaplan turbines. On the other hand, the mortality caused by Kaplan decreases with greater flow, while the opposite is true for Francis (McCleave 2001). Large turbines equipping dams in lowland large stream are expected to have a lesser mortality than in smaller units. Mortalities are expected to increase with dam's head (Eicher et al. 1987; Larinier and Dartiguelongue 1989; Gomes and Larinier 2008) especially in Francis turbines, and they will decrease with turbine diameter in Kaplan (Gomes and Larinier 2008). Pelton reaction turbines are limited to dams with large head most often located in mountain areas, and are expected to induce 100% mortality, mortalities are also expected to be very high in cross flow types (Dainys et al. 2017). It must be further emphasised that injured eels are likely to be lost to the stock as they will have reduced chance to do the very long route (more than 6 month) to the spawning grounds, that only the fittest individuals are likely to survive.

Dönni et al. (2001) estimated that in a stretch with 11 plants in the Rhine, the cumulative mortality rate was 93% very close to that estimated by Behrmann-Godel and Eckmann (2003) during the successive passage through 14 hydroelectric jumps in the Moselle River. In the Rhône (Rhone) river, the mortality rate of eels departing from Lyon would be 90% to the sea (Feunteun et al. 1999). Winter et al. (2006) radio-marked (Nedap-transponders) 150 silver eels in the Meuse River of which 121 migrated to the sea, reaching their target of 37%.

As far as the size of the turbine is concerned, small turbines are more lethal, showing an increase in mortality between 5 and 25% compared to large turbines (Hadderingh 1982; Hadderingh et al. 1992).

In the National EMPs, Member States have adopted disparate approaches in estimating mortality due to turbines (Tab. 5). In Ireland's plan, a mortality rate of 28.5% was taken at the passage of each turbine, a figure derived from the revision of ICES (2002). Therefore, the probability of surviving the passage through "n" turbines is $(0.715)^{*n}$. In the case of The Netherlands, Vriese et al. (2008) determined that the mortality in each plant is around 18% in the Rhine. In the case of Sweden, they determined an average mortality of 70% in each plant. In Poland, based on the same revision of ICES (2002), they determined the following mortalities depending on the power of the plants (Tab. 6).

Table 5: Compilation of studies on mortality related to turbines

For all eel sizes	
Study	**% eels**
Berg (1985)	36.7
Berg (1988)	9.3[1,6]
Berg (1993)	15.4–25
Berg (1994)	30.4–40.5
Kisker (1930)	2.5
Lundbeck (1927)	5.5
Von Raben (1955)	18.4–19.6
Butschek y Hofbauer (1956)	12-40.5
Wondrak (1989)	54–87
Seifert (1989)	42–50
Desrochers (1995) [1]	16–24
Hadderingh and Bakker (1998)	13.5
Holzner (1999)	27
Dönni, Maier and Vicentini (2001)	17–86
AVERAGE	28.5
For the silver/migratory fraction	
Gustavsberg y Mai (1960) [2]	91–100[3]
Langgöl (1960, 1961) [2]	75–80.8[3]
Larinier and Dartiguelongue (1989)	40–63[3]
Larinier and Dartiguelongue (1989)	51–92[3]
Larinier and Dartiguelongue (1989)	81.2[3]
Larinier and Dartiguelongue (1989)	63[4]
Larinier and Dartiguelongue (1989)	100[5]
Monten (1985)*	40–100[3]
AVERAGE	68.8

Source: ICES 2002. [1]Cit. in McCleave (2001); [2]Cit. in Larinier and Dartiguelongue (1989); [3]silver eels 73-90 cm, [4]silver eels 56.5 cm; [5]Francis Turbine, [6]low water flow.

Table 6: Mortality according to turbine power

Power	Mortality
< 100 kW	0.8
100kW - 1 MW	0.6
1 MW y-10 MW	0.4
> 10 MW	0.3

Source: Poland Eel Management Plan

4.2.1.3 Mitigation measures

Recent work provides sufficient knowledge and technology to take the necessary measures to protect fish from turbines by creating alternative routes or safe bypasses (Larinier and Travade 2002; Richkus and Dixon 2003; ATV-DVWK 2004, Dumont et al. 2005). Mitigation measures to reduce the impact of hydropower mortalities include:

- Technical measures to facilitate downstream movement or bypasses. Different bypasses have been tested in France (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

8%. 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 both horizontally or vertically slanted screens can be advised, depending on the configuration of the dam. In Germany, a combination of an inclined 10 mm horizontal rake in combination with a shaft-like by pass at the end of the rake at present 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 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.
- Turbine closure during flood events or migration 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 is 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. A longer migration period is expected in large rivers.
- 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.
- Trap-and-transport of silver eels around hazards such as hydropower stations, applied effectively in rivers in Germany and New Zealand, is recognised as being a practical solution when effective diversion of silver eels to by-pass channels is not possible (Richkus and Didson 2003). However, trap-and-transport programmes are expensive and their efficiency depends on a variety of different factors (e.g. river discharge, fishing effort, timing and duration of migration events, total number of silver eels). Hydropower operators might contribute to the trap-and-transport programmes.

4.2.1.4 Impact on the silver migration of hydropower generation in France

When assessed regionally, the most important factor to calculate the effect of hydropower plants (HPP) is their location relative to the eel stock. This factor is more important than the variation in mortality from site to site. Electric turbines located far up in mountainous areas have no effect on the overall eel mortality, if eels are not stocked further upstream.

In France, the EDA model (Briand et al. 2018) predicts the number of silver eels produced in the rivers. This model is used to calculate the potential number of downstream migrants impacted by the dams. A national database (ROE) references the dams over France and indicates dams used for energy production. Those dams have been selected and joined with the potential downstream migration to assess their potential impact (Fig. 10).

The calculation assumes that assignation to the hydropower usage in the ROE database is correct. Estuarine nuclear power plants have been removed from the dataset, as it was obvious that there was no impact downstream in the Loire and the Gironde. This calculation indicates that hydropower plants (HPP) < 250 kilometres from the sea would affect approximately 60% of the migrating silver eels. In terms of number of plants these only represent 25% of the total number of plants (Tab. 7).

Table 7: Effect of Hydropower plants on eels in relation to their distance from sea

Number of dams	Eel production	Distance
1185	947129	<250 km
3540	680850	>250 km
25%	58%	

4.2.1.5 Impact on the silver migration of hydropower generation in Spain

Information on two aspects is needed to assess silver eel mortality caused by HPP: HPP location and characteristics and silver eel abundance.

Compiling the HPP information is a complicated and onerous task that could not be carried out during the present project framework. The SUDOANG Interreg SUDOE project (https://www.sudoang.eu/) that started in March 2018 will try to assess the silver eel HPP in three years. Here, data on HPP were used that were already compiled in the SUDOANG project.

Regarding silver eel abundance, SUDOANG is currently building an estimate of instream silver eel production using the inspire river network. However, the model is still under development and estimation of the number of eels in rivers is not available yet. So the French model (EDA) was used to estimate eel abundance based in the river network built in SUDOANG, providing an order of magnitude of the potential impact of the main identified HPPs (for methods see ANNEX IV.2).

The cumulated number of eels obtained in the downstream part of the basins is of the same order of magnitude as in France, and as a first expertise, it can be used to assess the relative impact of dams. The main drawback in this approach is that the density of eel in the upstream river course will be overestimated, as the dams currently have a very large impact on upstream migration in Spain, more than in France.

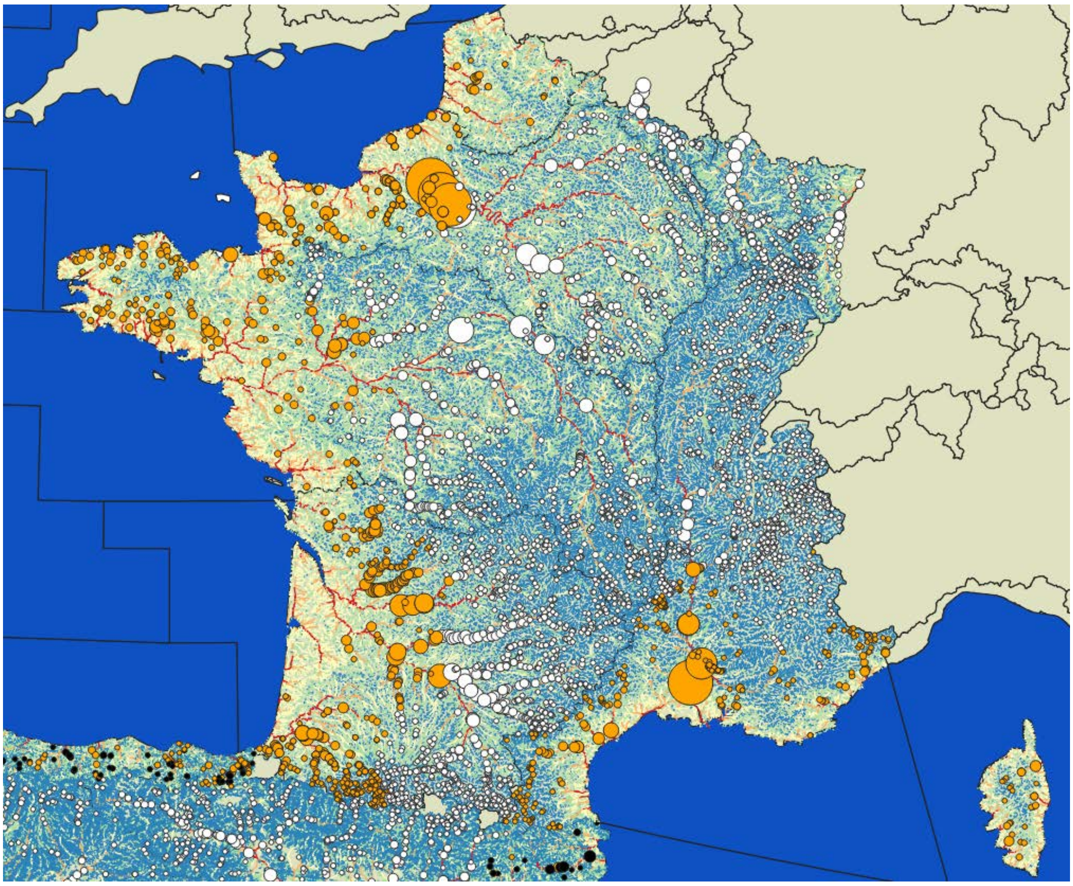
Dam and HPP data were obtained from the Spanish government (Dirección general del Agua). Two layers were provided; the first one contained not updated HPP data including production. The second layer contained data about dams, but HPP information was missing. Thus, the two layers were combined, and geographical information such as river width was used to exclude some upstream reservoirs. Still this information should be considered as partial and possibly flawed.

Some dams, especially in the Mediterranean area are completely impassable and no silver eel migration can occur, as no upstream migration is possible. Thus, all dams >20 m and < 250 km from the sea were considered impassable and included in category 1.

Other dams < 20 m and < 250 km from the sea were considered to have a potential impact on eel and are considered as category 2.

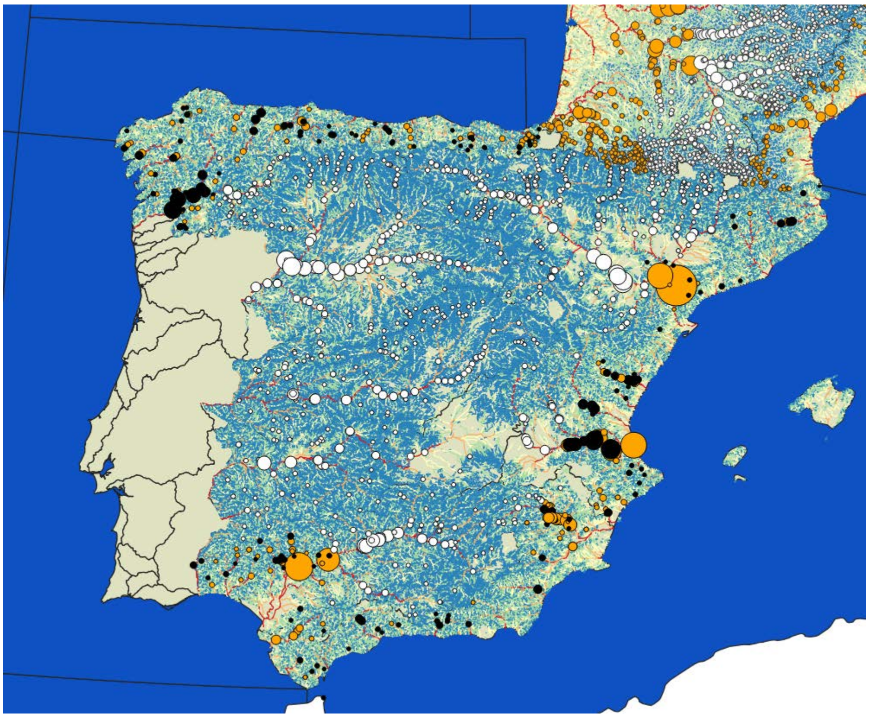
According to our approach (Fig. 11) 28% of the silver eel run is completely removed by category 1 (impassable) dams. Those represent 16% of the total number of HPP dams, assuming that all dams > 20m are HPP dams.

Figure 10: Impact of Hydropower Plants in term of number of eels passing the dams in France



Source: Data from EDA2.2 (Briand et al. 2018) and ROE data.gouv.fr (SIE -version December 2018) . Orange <250 river km from the sea, white > 250 river km. The number presented is not the number of eels killed by the dam, which will vary depending on dam location and turbine type.

Figure 11: Map of silver eel production predicted in Spain



Source: SUDOANG - AZTI, data from Spanish ministry. Impassable dams (category 1: dams >20 m and < 250 km) are in Black, other HPP dams (category 2: < 20 m and < 250 km) are in orange, dams > 250 km from the sea are in white.

When category 1 dams are not considered, the fraction of dams with a potential impact (category 2) is 18% of the total number of dams in Spain according to the total number of HPP in Spain.

The power production from category 2 is 20% of total HPP production in Spain.
The estimation of the total number of silver eels passing through HPP dams located < 250 km from the sea (category 1 and category 2) is the same as in France (58%).

4.2.2 Pumps

In addition to the use of turbines to obtain electricity, the use of water pumps for different uses (consumptive or not) in reservoir areas such as dams can have a significant impact on the migratory eel population, with mortality rates of up to 100% in the most modern pump models. Pumps create a barrier for upstream migration of diadromous fish species. In addition, fish migrating downstream through the pumps are damaged as the working principle of pumps is similar to turbines and a similar effect on eels is assumed.

Pumping stations can roughly be divided in three groups (ICES 2011)
1. water wheels
2. Archimedes screws
3. pumps

Among these, pumps can be further subdivided based on the way the water flows through the pump in following three types:
1. centrifugal pumps (radial water flow)
2. propeller-centrifugal pumps (radial/axial water flow)
3. propeller pumps (axial water flow)

4.2.2.1 Mortality produced by pumps

Germonpre et al. (1994) found low mortality rates for screw pumps (3.5%) and centrifugal pumps (no mortality). However, a more recent study (Buysse et al. 2014) showed high mortalities ranging from 97±5% for the propeller pump to 17 ± 7% for the large Archimedes screw pump and 19 ± 11% for the small Archimedes screw pump. Most injuries were caused by striking or grinding. In a short review section on this issue, WGEEL in its 2011 report (ICES 2011) stated that that in general propeller pumps with axial or axial/radial water flow caused the highest mortality rates. Regrettably, at least in the Netherlands, this is the most common type used to regulate water levels. It should also be noted that although Archimedes screws are less harmful than propeller pumps, contrary to popular believe, they are not by definition harmless and can still cause significant mortality (ICES 2011).

4.2.2.2 Mitigation measures for pumps

Mitigation measures are similar to the turbine mitigation measures and they include:

- Technical measures to facilitate downstream movement or bypasses. Protection measures, i.e. deflection screens, in front of the turbines may prevent eels being entrained into the turbines or pumps. Generally, gap widths ≤ 15 mm are necessary to stop silver eels entering a turbine or pump (ICES 2002). An inclined screen ending with a bypass at the downstream end of the turbine is necessary to protect the silver eel from jamming against the screen. A screen inclination angle against the current direction of 15° is sufficient for the deflection and protection of the eels (Adam 2000, Adam et al. 2002).
- Safe passage at pumps could be achieved by installing fish-friendly pumps. However, it is important to check that the pump is efficient since a recent study showed that innovative pumps such as the de Wit Archimedes screw pump adaptations did not substantially minimise grinding injuries and overall mortality of eels (Buysse et al. 2015). Further research to find effective fish-friendly pump designs for eels is needed.
- Trap-and-transport (see section 4.2.1.3)

4.3 Discussion and Recommendations

Industrial installations in freshwater streams and rivers in Europe have been found to significantly impact eel migratory patterns, both upstream and downstream. In upstream migration, hydropower dams are important obstacles that force eels to remain in lowland river sections, estuaries or coastal areas, where eels may accumulate in higher densities than they would if they could follow regular migration flows. Several mitigation measures have been suggested, e.g. by the UK Environmental Agency, which require significant testing to establish in which circumstances and for which obstacles they can be implemented. These potential mitigation measures mainly include bypasses, fish lift or barrier removal. In contrast, the stocking juvenile eels upstream of obstacles, like hydropower dams cannot per se be considered a measure to help stock recovery. It requires true validation that should assess whether the provision of otherwise inaccessible habitats can compensate for accompanied mortalities, including indirect mortality during glass eel fishing and transport, and turbine passage during downstream migration.

During downstream migration, turbines and pumps are responsible for significant mortalities. A regional assessment of the relation between eel population and hydropower plants demonstrated that eels are significantly concentrated in streams within 250 km from the sea. Dams lying within that distance from the sea are less numerous than in mountainous ranges, but have much more potential to injure a large fraction of the eel stock when as are located downstream in large rivers. Management measures should be focused on hydropower plants potentially killing the largest number of eels and could include: bypasses, rake systems, fish friendly turbines and pumps, trap-and-transport, undershot gate management and temporary turbine closures.

5 CLASSIFICATON OF MAIN ECONOMIC ACTORS IN THE EU IMPACTING THE EEL STOCK

Key findings

- Eels are primarily fished by individual fishers, both in fresh and marine water.
- Eel aquaculture is not a widely diversified market, where between two and five companies are involved in this sector for each selected country.
- Eel processing and trading is slightly more diversified, especially in Germany where eighteen companies were identified.
- Eel aquaculture tends to be more vertically integrated, including processing and marketing activities.
- Hydropower in the selected countries is dominated by globally active companies, with between two and five companies identified for each country.

This chapter presents the main economic actors in the EU impacting the eel stock at its different stages of life (glass eel, yellow eel and silver eel). This chapter is divided as follows: section 5.1 describes the main companies involved in eel capture, section 5.2 presents the companies with activities in eel aquaculture, section 5.3 describes the identified companies active in processing of eel, including trading and marketing, and section 5.4 provides an overview of companies involved in hydropower infrastructures. Each section is further divided between the focus countries: France, Germany, Greece and Spain (for methods see ANNEX IV.3.1 & 2).

5.1 Fish capture

In Europe, due to the low stock, professional fishing on freshwater yellow and silver eel is primarily a small-scale business. Most often, this type of fishing is performed by individual fishers. Aside from fishers that carry out commercial fisheries, eel fishing is performed by recreational fishers. Both commercial and recreational fisheries capture wild eel in coastal, transitional and inland waters. Additionally, many freshwaters are stocked with young eels in order to comply with management obligations (increase of silver eel escapement) and to sustain fisheries. Glass eel fishing, which occurs in marine, transitional and freshwater, is done by small vessels, but the glass eels are collected by larger trading companies.

Within this research, no companies were identified with activities in eel fishing. In France, Germany, Greece and Spain, small-scale fishers that carry out commercial fisheries, sometimes working under producer organizations, were found to be the main economic actors engaged in eel catching.

The sections below provide a description of the fish capture sector in each of the selected countries. Section 5.1.1 provides a description of eel fishing in France, section 5.1.2 provides an overview of eel capture in Germany, section 5.1.3 explains how eel is captured in Greece and section 5.1.4 provides an overview of eel fishing in Spain.

5.1.1 France

Small-scale fishers that carry out commercial glass eel, yellow eel and silver eel fisheries. Generally, these fishers are not organized under an official organization. However, recently in the Loire a cooperative for eel fishers that carry out commercial fisheries was established. In the Mediterranean, fishers have organized themselves in informal 'brotherhoods'.

In the last 5 years, French fishers harvested on average 75% of the total glass eel catch in Europe. As such they are an important source for glass eel used in aquaculture in other countries in Europe.

5.1.2 Germany

The bulk of German eel catches is landed in inland waters compared to coastal waters. In 2017, total eel landings from inland waters accounted for 143.1 t, while coastal eel catches reached only 51.6 t. However, in Germany, information on the level of individual fishers catching eel cannot be provided, due to data protection reasons. Therefore, no economic information on inland eel fisheries is available. From the coastal eel fishery, however, some basic information is provided by Producers Organisations (PO) that report eel catches from coastal areas. Three of these POs are only active on the coast of the Baltic Sea while the fourth is registered in Cuxhaven on the coast of the North Sea. However, as stated above, these numbers do not include inland eel fishery, which account for the major share of eel landings in Germany.

Wismarbucht e.G.: Wismarbucht e.G. is located in Wismar at the southern Baltic Sea coast. A number of small and middle-sized vessels are marketing their fish via this PO. Eel landings in 2016 were 3.4 t with revenues of EUR 44,862. Total revenues amounted to EUR 245,020. This implies that eels accounted for 18% of the total revenues of the Wismarburcht PO.

Zentrale Absatzgenossenschaft Ruegenfang e.G.: Zentrale Absatzgenossenschaft Ruegenfang e.G. is headquartered in Sassnitz on the Island of Ruegen. It combines the POs of the island of Ruegen in a centralised organisation. It is not clear how many fishers are marketing their landings via this PO but in 2016 12.9 t of eel were reported with revenue of EUR 141,199. Total revenues amounted to EUR 1,908,557. This implies that eels accounted for 7% of the total revenues of the Zentrale Absatzgenossenschaft Ruegenfang PO.

Usedomfisch e.G.: Usedomfisch e.G. combines 24 fishing companies with 26 fishers operating 54 vessels. These vessels are mainly located in the harbour of Freest at the southern Baltic Sea near the Polish border. This PO also processes fish and sells fresh fish in an own shop. Although this PO does not list eel as one of their main species for catching or processing, Usedomfisch reported landings of 6.5 t with revenues of EUR 66,589 in 2016. Total revenues amounted to EUR 2,414,355. This implies that eels accounted for 3% of the total revenues of the Usedomfisch PO.

Erzeugergemeinschaft der Hochsee- und Kutterfischer GmbH: Erzeugergemeinschaft der Hochsee- und Kutterfischer GmbH consists of a wide variety of small to middle-sized vessels. The primary company within this PO is Kutterfisch with 10 middle-sized fishing vessels between 20 and 40 m. Four of the vessels are based in Sassnitz (Ruegen Island, Baltic Sea) and the other six vessels are registered in Cuxhaven. A number of smaller vessels on Fehmarn Island (Baltic Sea) are also part of this PO. In 2016, Erzeugergemeinschaft der Hochsee- und Kutterfischer reported eel landings of 2.7 t with revenues of EUR 15,176. Total revenues amounted to EUR 28,855,466. This implies that eels accounted for 0.05% of the total revenues of the Erzeugergemeinschaft der Hochsee- und Kutterfischer.

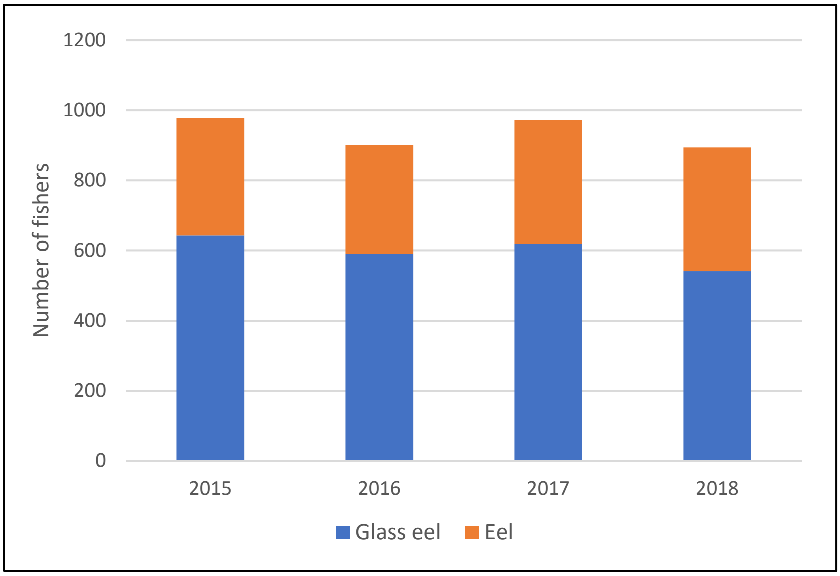
5.1.3 Greece

Silver eel capture in Greece occurs primarily through fishing cooperatives, undertaken in coastal waters. These cooperatives are led by a membership of between 50 and 75 fishers that carry out commercial fisheries. Together the cooperatives identified to be active in Greece produced less than 50 t per year. The two cooperatives identified are Alieftikós Synetairismós Vistonídas Ágios Nikólaos and Alieftikós Synetairismós Koronisías – Kalogerikoú.

5.1.4 Spain

In Spain, eel capture is primarily led by individual fishers. Fishers are predominantly self-employed within the Special Scheme for Sea Workers, with few retired persons also involved in recreational eel fishing. There are approximately 550 and 350 fishers involved in commercial glass eel and yellow and silver eel fisheries, respectively, with total numbers of fishers capturing glass eel or eel ranging between 800 and 1000 (not full time equivalent) (Fig. 12).

Figure 12: Number of fishers that carry out commercial eel fisheries in Spain (estimate)



Source: AZTI, own elaboration from the surveys sent to the autonomous communities with eel fishery.

Revenues of fishers vary between regions and between the fishing gear (land or boat). Only data for three regions is available: Andalucía, Galicia and Murcia. Without an overview of costs, revenue dependency from eel is approximated to range from 1-7% in Andalucía, where land fishing is predominant, to 20-80% in Galicia and 8-14% in Murcia, where vessels are primarily used. Fishers in Spain and Portugal harvested on average 9% of the total glass eel catch in Europe.

See ANNEX IV.3.3 for details about data gathering an analysis of the Spanish eel fishery.

5.2 Aquaculture

Eel aquaculture is generally integrated within the following process: glass eels are caught in the wild and transported to farming locations, where they are grown between one and one and a half years. Some companies additionally sell ongrown eels for stocking.

This section presents the main companies with activities in aquaculture in each of the focus countries: section 5.2.1 discusses eel aquaculture in France; section 5.2.2 describes the main companies involved in aquaculture in Germany, section 5.2.3 provides an overview of aquaculture companies in Greece and section 5.2.4 presents aquaculture companies in Spain. This research identified that, for the large part, companies involved in aquaculture are vertically integrated: they are involved in farming, processing, trading and marketing. Where the companies identified in this section are additionally active in processing, they are described in this section and referred to in section 5.3.

5.2.1 France

There is no eel farming through aquaculture in France (Via Aqua and FranceAgrimer 2014). However, Nijvis Group, one of the most important and largest aquaculture companies in Europe has established a subsidiary in France. This company's activities could not be confirmed, as no financial statements or other corporate documentation could be identified in company registers and further databases. Below is a description of Nijvis Group's activities.

Nijvis: Nijvis Group is one of the largest eel production companies in Europe, with activities in farming, processing and trading and marketing in the Netherlands, Germany and France (Kamer van Koophandel, n.d.). Although the group has a subsidiary in France, no further details concerning this subsidiary could be identified (Kerr 2018). Nijvis Group produces around 2,400 t of eel annually (Vishandel Klooster 2017). Additionally, the group is directly involved in the Dutch initiative Stichting Duurzame Palingsector Nederland (Foundation for a Dutch sustainable eel sector, Dupan) (Vishandel Klooster 2017). Nijvis Holding B.V. is the ultimate holding company of the group. In 2016, the company had EUR 30.8 million in assets (2015: EUR 32.1 million) and EUR 11.2 million in turnover (2015: EUR 11.7 million). As of 2016, Nijvis Group had 118 employees (2015: 114) and held 10 consolidated subsidiaries (2015: 11), including Nijvis B.V., which holds in turn: Palingkwekerij Koolen B.V., Gebr. Kraan Palingrokerij B.V., G. Kramer Holding B.V. and Vishandel Klooster B.V. (Kamer van Koophandel 2017). Nijvis Holding B.V. is managed by W.S. Fish B.V., Gerrit Klooster Jr. Holding B.V., HG. Broers B.V. and Hermann Bentlage Beteilingung GmbH (Kamer van Koophandel, n.d.).

5.2.2 Germany

Three eel-aquaculture companies were identified to be active in Germany: Aal-Hof Götting, Albe Fischfarm and Emsland Fischzucht. Together, these companies raise eels in intensive recirculation systems amounting to more than 1,200 t of eel production annually. This section provides more details on each company's activities.

Aal-Hof Götting: Aal-Hof Götting (Aal-Hof Götting GmbH & Co. KG) is an eel-farming company based in Cloppenburg, Germany. The company was founded in 1985 and since 2006, the farm comprises two aquaculture facilities and a water-treatment plant to reduce dependency on fresh water. Aal-Hof Götting is a member of the German Initiative zur Förderung des Europäischen Aals (Initiative for the promotion of the European Eel; IFEA, 2018), for which it produces around 600,000 ongrown eels for stocking each year (Aal-Hof Götting, n.d.a). Aal-Hof Götting's further raises eels to be sold live or slaughtered directly from its farm (Aal-Hof Götting, n.d.b). In 2017, Aal-Hof Götting's total assets amounted to EUR 2.1 million (2016: EUR 1.8 million). The company has a team of four employees and is owned by Gerhard Götting (Aal-Hof Götting, n.d.b and Orbis, 2018t).

Albe Fischfarm: Albe Fischfarm (Albe Fischfarm Gmbh & Co. KG) is a family-owned eel farming company founded in 1989. The company is based in Haren, Germany, and is active in breeding, processing, as well as selling and marketing of eel to the European market. Committed to sustainable eel farming, Albe Fischfarm raises around six million young eels per year for stocking. The company breeds and raises around 1.5 million eels in more than 60 basins, which results in a yearly production of 320 t of eel. In addition to farming and producing of eels, Albe Fischfarm is also active in purchasing and trading of up to 600 t of eel per year (Albe Fischfarm, n.d.). Albe Fischfarm is owned by Bernhard Albers (50%), Elisabeth Albers (25%) and Liesel Albers (25%) and was previously owned by Nijvis Group (Orbis, 2018i). The company employs 9 people. As of 2017, the company's total assets EUR 3.3 million, with total revenues amounting to EUR 10.9 million (Bundesanzeiger, 2018, Orbis, 2018j). In 2017, Albe Fischfarm's revenues related entirely to eel aquaculture.

Emsland Fischzucht: Emsland Fischzucht (Emsland Fischzucht GmbH & Co. KG) catches, farms and processes eels, with a total production of 900 t per year (Osnabruecker Zeitung, 2014). The company is a subsidiary of Nijvis Group, one of the most important eel farming and production company in the Netherlands (Vishandel Klooster, 2017). Emsland Fischzucht is also part of the stocking initiative of Germany, through which Emsland Fischzucht stocks European streams with around six million young eels every spring. Every year, the company buys 4000 kilograms of glass eels caught in France. The glass eels are transported to Haren, Germany, where the company is based, where they are raised until they reach weights between 100 to 800 grams (Osnabruecker Zeitung, 2014). The company had total assets of EUR 10.9 million in 2017 (2016: EUR 8.3 million) (Orbis, 2018k and Unternehmens Register, 2018). Emsland Fischzucht currently employs 9 people and is owned by Nijvis (75%), Mr. Bentlage (20%), and W.S. Fish Bruinisse (5%) (Orbis, 2018l).

5.2.3 Greece

Two companies based in Greece were identified to include eel aquaculture companies: Geitonas and Simoni Brothers ("Simonis").

This section provides an overview of these companies' activities.

Geitonas: Geitonas (V. GEITONAS & Co Ltd) is an eel-producing company based in Arta, Greece, specialised in eel rearing in aquaculture. The company produces and processes between 170 and 220 t of eel per year, which is sold under their own label to the Greek and European markets either alive, fresh or smoked (Geitonas n.d.a/b). The company farms eels from a size of 150 grams to 1300 grams. In addition, Geitonas produces and markets other smoked products, such as salmon, trout, mackerel, tilapia and mullets (Geitonas n.d.a). Further company information such as their financial statements and corporate structure could not be identified, as they were not made available in the Greek Official Gazette or in Orbis.

Simoni Brothers ("Simonis"): Simonis (Simoni Brothers S.A.) farms, processes and distributes eels in Galatista, in Northern Greece. The company uses underground water for aqua farming of eels (0.2 grams up to 2 kg) (Simoni Brothers n.d.). In addition, the company provides a variety of smoked fish products for the European market, including eel, salmon, mackerel, octopus, trout and fish pastrami. Simonis sells directly to supermarkets, hotels, restaurants and delicatessen stores in Greece and in other European countries (Simoni Brothers n.d.). Further company information such as their financial statements and corporate structure could not be identified for 2017 or 2016, as they were not made available in the Greek Official Gazette or in Orbis.

5.2.4 Spain

Two companies were identified to be active/have been active in eel aquaculture in Spain: Marina Eel Acuicultura and Valenciana de Acuicultura ("Valaqua"). Marina Eel Acuicultura closed at the beginning of 2018.

Marina Eel Acuicultura: Marina Eel Acuicultura was a small eel-farming company based in Grado, Spain (Orbis, 2018r; Ministry of Agriculture and fisheries, 2018). No information could be identified as to the company's product portfolio, or if it is additionally active in processing or sales of eels. At the end of 2017, Marina Eel Acuicultura had total assets amounting to EUR 1.5 million (2016: 1.7 million), a turnover of EUR 2,235 (2016: 729) and 3 employees (2016: n.a.) (Orbis, 2018r).

Valenciana de Acuicultura ("Valaqua"): Valaqua (Valenciana de Acuicultura S.A.) focuses on fish farming in Puçol, Spain. Valaqua was founded in 1984 and produces eel and tilapia (Valaqua, n.d.a). The company is primarily involved in farming of eels and tilapia, although it is likely that it also processes and packs resulting products. Valaqua's production capacity is 300 t of eels per year, with sizes ranging from 100 to 500 grams (Valaqua, n.d.b). At the end of 2015, Valenciana de Acuicultura had total assets of EUR 7.2 million (2014: 7.5 million), and a turnover of EUR 3.5 million (2014: EUR 3.3 million), of which approximately EUR 2.3 million were related to eels (2014: EUR 2.2 million) (Ministry of Agriculture and Fisheries, 2018; Orbis, 2018s). Over the year 2015, Valaqua's profit amounted to EUR 84,000 (2014: 82,000) and the company had 13 employees (2014: 13). Valaqua is co-owned by four companies: Las Anadas de Espana, Dibaq Diproteg, Cuaternia Nexotej and Fabatmar Mareny (Orbis, 2018m), all active in food processing and distribution.

5.3 Processing

This section provides an overview of the companies with activities in eel processing, trading and/or marketing, per focus country: section 5.3.1 examines processing companies in France, section 5.3.2 provides an overview of processing companies in Germany, section 5.3.3 describes processing companies in Greece, and section 5.3.4 presents processing companies in Spain. Each section provides a maximum of three examples of companies involved in processing activities in the respective focus country.

5.3.1 France

In France, six companies with eel processing and/or trading activities were identified: Aguirrebarrena, Dom Petroff, Gurruchaga Maree, J. Barthouil, Jérôme Micheau, and Margain Maree. This section discusses Aguirrebarrena, J. Barthouil and Margain Maree in more detail.

Aguirrebarrena: Aguirrebarrena is a French eel processing company founded in 1984, with operations in France, Spain and Portugal, mainly concentrated around the Bay of Biscay. Aguirrebarrena is active in processing, wholesale trading and marketing, and catering. Wild eel is the company's flagship product, with a production of 130 t annually. The company is also involved in catching, distributing and stocking glass eel, amounting to 10 t each year (Aguirrebarrena, n.d.). At the end of 2017, the company had total assets of EUR 5.2 million (2016: EUR 5.3 million), and a turnover of EUR 6.7 million (2016: EUR 6.6 million), with estimated eel-related revenues of EUR 3.4 million. The company has 9 employees (Orbis, 2018e).

Margain Maree: Margain Maree is active in wholesale trade (business-to-business) in fish, crustaceans and molluscs, and also produces processed fish products under 3 brands: Le fumet des dombes, Desmaris and Saint Jean. Within the fresh products group there are three fish segments. Within the freshwater fish segment eel is 1 of about 10 species (Margain Maree, n.d.). In 2017, the company had an annual turnover of EUR 27.2 million (2016: 26.6 million) and estimated eel-related revenues of EUR 300,000 (Infogreffe, 2018a).

J. Barthouil: J. Barthouil or Maison Barthouil is specialised in smoked salmon and eel, caviar, foie gras and regional products. The company has six product groups. Smoked eel is one of the three products in the product group 'Saumons et Autre poissons' (Barthouil n.d.). Total assets in 2017 amounted EUR 6.8 million (2016: 4.0 million). In 2015, the company's annual turnover was EUR 4.7 million (2014: 4.5 million), with estimated eel-related revenues of EUR 263,000. The company is owned by Mr. J. Barthouil (Orbis, 2018f).

5.3.2 Germany

Eighteen eel processing companies were identified to be active in Germany: Aal-Hof Götting, Aalräucherei Baade, Aalräucherei Friedrich Bruns, Albe Fischfarm, Brauer's Fischräucherei, Emsland Fischzucht, Eyka Feinkost Vertriebsgesellschaft, Fisch Hagenah, Fischerei- und Verarbeitungsbetrieb Dehmel, Fish4Me - Siebrands Fischereibetrieb GmbH & Co. KG, Gosch Verarbeitungsbetrieb, H.-J. Fiedler Meeresdelikatessen, Hans Fiedler und Söhne Lachs- und Aalräucherei, Max & Moritz Feinkost, Möller & Reichenbach, Rassau Seafood, Transgourmet Seafood, and Wechsler Feinfisch.

The largest eel processing company in Germany is Albe Fischfarm, with a turnover of EUR 10.9 million in 2017. This section describes the activities of Möller & Reichenbach, H.-J. Fiedler Meeresdelikatessen and Transgourmet Seafood. Information about Aal-Hof Götting, Albe Fischfarm and Emsland Fischzucht can be found in the section on aquaculture companies (see subsection 5.2.2). All six companies are members of the German Initiative zur Förderung des Europäischen Aals (Initiative for the Promotion of the European Eel; IFEA, 2018).

Möller & Reichenbach: Möller & Reichenbach is a fish processor, wholesale trader and retailer, with six main fish species in their product portfolio (Möller & Reichenbach, 2018a). At the technical core of the production line is an eel slaughtering machine (Möller & Reichenbach, 2018b). In 2017, Möller & Reichenbach employed 21 people, with total assets of EUR 1.4 million (2016: 1.8 million). No revenue data was reported for 2016 and 2017 financial years. In 2015, the company's annual turnover amounted to EUR 7.0 million, with estimated eel-related revenues of EUR 1.2 million. The company is owned by Mr. J. Schrader (Orbis, 2018a).

H.-J. Fiedler Meeresdelikatessen: H.-J. Fiedler Meeresdelikatessen is the company behind the Fiedler Fischmarkt brand. The company is a fish processor, with a smoke house, two restaurants, retail and webshop. Eel is among the 12 product groups made available by Fiedlers Fischmarkt (Fiedlers Fischmarkt, n.d.). H.-J. Fiedler Meeresdelikatessen is owned by H.J. Fiedler. In 2017 the company had total assets of EUR 3.6 million (2016: 4.8 million), a turnover of EUR 12.0 million (2016: 11.9 million), with estimated eel-related revenues of EUR 1.0 million (EUR 992,000). In the same year, the company had 64 employees (2016: 61) (Orbis, 2018b).

Transgourmet Seafood: Transgourmet Seafood is an operational division of Transgourmet Central & Eastern Europe GmbH, ultimately owned by the Swiss COOP group. Transgourmet Central & Eastern

Europe is a large general food processing company with total assets of EUR 1,960 million in 2016 (2015: 1,819 million), an annual turnover of EUR 4,871 million (2015: 4,381 million), and nearly 18,000 employees (Orbis, 2018c). The last available financial data for Transgourmet Seafood are from 2012. In that year, Transgourmet Seafood had total assets of EUR 5.6 million (2011: 4.3 million), an annual turnover of EUR 41.5 million (2011: 34.1 million), and 56 employees (Orbis, 2018d). Eel is 1 of approximately 1,500 products in the company's product portfolio. Eel-related revenues in 2012 are estimated at EUR 28,000 (2011: 22,000) (Transgourmet Seafood, 2018). It is not confirmed whether this company has been merged within Transgourmet Central & Eastern Europe, or whether it is still active.

5.3.3 Greece

Three eel processing companies were identified in Greece: Geitonas, Simoni Brothers ('Simonis'), and Pitenis. Geitonas and Simonis are also aquaculture companies, which are described in subsection 5.2.3. Pitenis, which is a fish processing and wholesale trading company, is described below.

Pitenis: Pitenis produces a variety of delicacy products, including salads, seafood, stuffed pickles, dairy products and olive oils. Export sales extend from European Union countries to the United States, Canada and Russia. Pitenis markets eight product brands, which include a variety of fresh and canned products, such as salads, cheeses, olive oil, pickles, as well as seafood and gourmet fish. The Okeanos Exclusive gourmet fish brand comprises five products, including smoked eel (Pitenis, n.d.). In 2016, the company had total assets of EUR 2.3 million (2015: 2.8 million), with an annual turnover of 4.0 million (2015: 3.5 million). Eel-related revenues are estimated to have a value of EUR 100,000. The company is family-owned by five Pitenis family members Orbis (2018ag).

5.3.4 Spain

Seven companies were identified to have operations in eel-processing and trading in Spain: Angulas Mayoz, Angulas Manterola SL, Comercial Ibaitz SL, El Angulero de Aguinaga, Maribel Santianez, Roset and Valenciana de Acuicultura ("Valaqua"). The majority of these companies are based in the Basque country. This section provides a description of Angulas Mayoz, El Angulero de Aguinaga and Roset. Valaqua is also an aquaculture company and described in subsection 5.2.4. For many of these processing companies, the trading of glass eels accounts for a significant proportion of their income. Some glass eel traders also boil glass eels to be sold for human consumption.

***Angulas Mayoz**:* Angulas Mayoz is a family-owned business founded in the 1950s in Aguinaga and presently based also in Bilbao, Spain. Angulas Mayoz specialises in the processing and trading of glass eels, either fresh or frozen, and in selling of surimi eels, also fresh or frozen. The company sources its glass eels from the North coast of Spain and the Atlantic French coast. Eels are then kept live in basins, until they are to be processed and sold. At the end of 2017, Angulas Mayoz had EUR 4.2 million in assets (2016: EUR 3.0 million) and a turnover of EUR 2.1 million (2016: EUR 2.3 million). In the same year, the company had a loss of EUR 62,000 (2016: loss of EUR 70,000). As of 2017, Angulas Mayoz had 11 employees (2016: 11) and was led by Juan Carlos Eizmendi Zabala.

***El Angulero de Aguinaga**:* El Angulero de Aguinaga ("El Angulero") is an eel-catching and processing company originating from Aguinaga in Spain. The Otamendi family started with eel capture at the end of the 19th century and has been active in this sector for four generations. El Angulero is directly active in glass-eel fishing, processing and selling. In addition, the company is also active in the wholesale of surimi eel, made from fish from the Bering Sea and Patagonia. At the end of 2017, El Angulero had EUR 2.3 million in assets (2016: EUR 2.5 million) and a turnover of EUR 4.2 million (2016: EUR 3.7 million). In the same year, El Angulero's profits amounted to EUR 268,000 (2016: EUR 166,000). As of 2017, El Angulero had 14 employees (2016: 15) and was owned by the Otamendi family: Jose Maria Otamendi Aspiroz (through Angulas y Mariscos Boulevard SL) and Santiago Otamendi Aspiroz each hold 50% of the shares of the company.

Roset - Agulas del Delta del Ebro: Roset is located in the heart of the Ebro Delta in Spain and specializes in the farming, live transporting, and marketing of eels (Roset, n.d.). The company's activities primarily include glass eel catching and aquaculture. Roset then sells eel and glass eel in various product types: live, fresh, cooked, smoked or processed (Roset, 2018). At the end of 2016, Roset had EUR 2.4 million in assets (2015: EUR 1.3 million), with a turnover of EUR 3.3 million (2015: EUR 2.5 million), all related to eels (Orbis, 2018p). In the same year, Roset's profits were EUR 332,000 (2015: 233,000). As of 2016, the company had 13 employees (2015: 13). Roset is owned by three people from the Bonet family (Orbis, 2018q).

5.4 Hydropower

By the end of 2016, hydropower was Europe's largest renewable energy resource accounting for more than 14% of total primary energy production of renewable energy in the EU-28 (Eurostat, 2016a). The total installed hydropower capacity in Europe amounted to 223 Gigawatt (GW) (IHAa, 2017). Norway has the largest installed capacity, with 31.8 GW, followed by Turkey (26.1 GW) and France (25.4 GW) (Eurostat, 2016b). Spain is ranked fifth (20 GW), followed by Germany that is ranked eighth (11.3 GW) and Greece in 13^{th} place (3.4 GW) (Eurostat, 2016b).

This section provides an overview of hydropower installations and related economic actors in the four focus countries (France, Germany, Greece and Spain). Each section provides a general overview of the energy sector, with a specific focus on hydropower. Moreover, it describes in further details the main economic actors involved in the hydropower sector in each focus country. Section 5.4.1 provides an overview of hydropower in France, 5.4.2 discusses the hydropower sector in Germany, 5.4.3 examines hydropower in Greece, and finally section 5.4.4 looks at the hydropower sector in Spain.

5.4.1 France

Hydropower accounted for almost 20% of installed capacity in France in 2016, second only to its nuclear capacity, with 63.1 GW installed capacity (World Energy Council, 2016a). With 25.4 GW of hydropower capacity currently installed, France is seeking to increase hydropower capacity by at least three GW by 2020 (World Energy Council, 2016b). Without pumped storage capacity, installed capacity was 18.4 GW (World Energy Council, 2016c). Hydropower production stood at 4.93 Million Tonnes of Oil Equivalent (Mtoe) per year, which leads it to pay an essential role in balancing the nation's nuclear baseload. More than half of the hydropower supply in France is flexible and allows for adjustment of production to meet fluctuating demand. For eel migration, especially the first four dams on the Seine and Rhône inland from the sea are important.

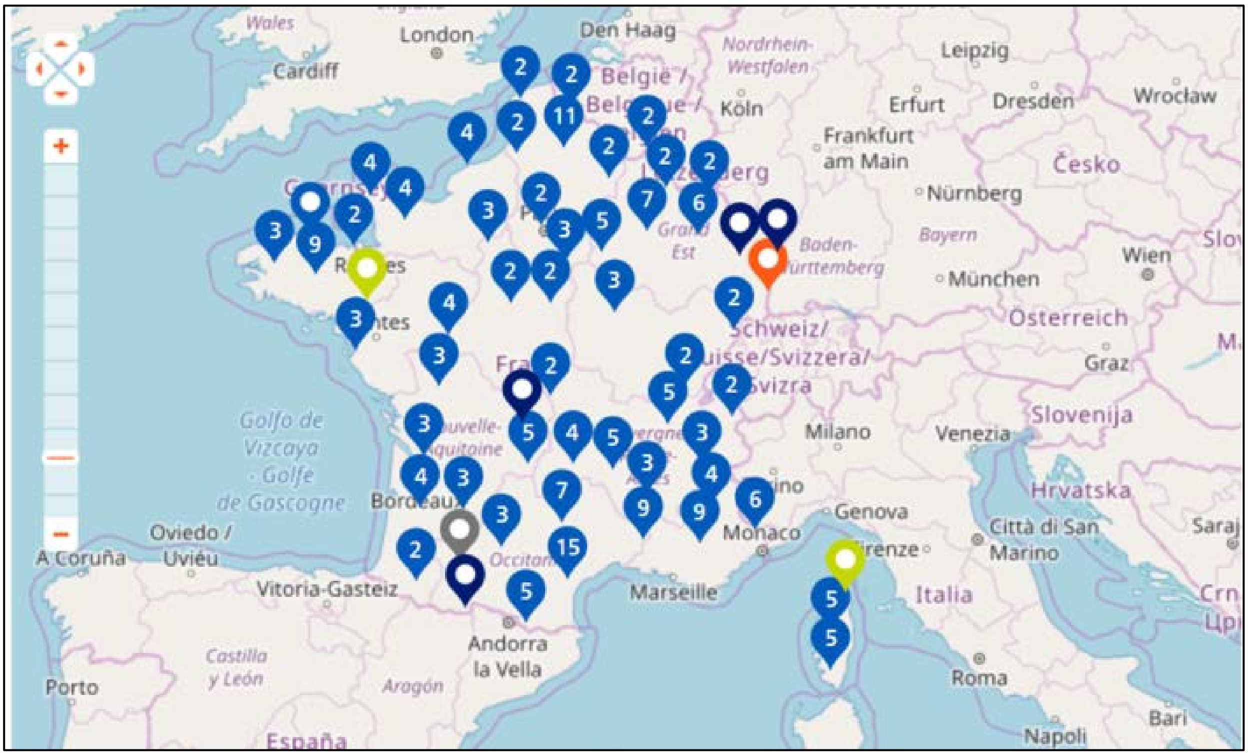
Four companies were identified to have activities related to hydropower in France: CNR, DirectEnergie, Électricité de France ("EDF") and Engie. This section details each of these companies' activities in hydropower in France.

CNR: CNR is France's leading producer of exclusively renewable energy and the concessionary of the Rhone for hydroelectricity production, river transport and irrigation for agricultural use, and it produces approximately 25% of French hydroelectricity (CNR, n.d.a). CNR has two hydropower production sites on the Rhône, one at Bollène, and one at Génissiat. The company owns and operates 19 dams and hydropower plants on the river (CNR, n.d.b). Their total installed capacity was 3.5 GW in France, with a hydropower capacity of 3.0 GW. The total power generation was 15.4 Terawatt-hour (TWh). CNR had a turnover of EUR 1.1 billion in 2016, with profits of EUR 93 million (CNR, 2017). The company has 1,355 employees. Although the majority of CNR's shares are publicly owned (Groupe Caisse des Dépôts and local authorities own 50.03% of them), CNR's reference shareholder is ENGIE, which entered its capital in 2003, and currently owning 49.97% of the shares (CNR, 2018).

DirectEnergie: Direct Energie supplies electricity and natural gas to more than 2.5 million customers - individuals, companies and local authorities in France and Belgium (Direct Energie, n.d.a). The company had total assets of EUR 2.4 billion at the end of 2017, a turnover of EUR 2.0 billion, of which EUR 52 million in profits (Direct Energie, 2018a, 2018b). Their total installed capacity was 112.7 GW, of which 4.5 Megawatt (MW) was installed hydropower capacity in France. In 2017, their power generation amounted to 3,773 TWh. Direct Energie serves over 2.5 million customers in France. Direct Energie's majority shareholder is Total (owning 73% of shareholdings) (Total, 2018). In France, Direct Energie manages and uses the hydropower generated by power plants located in the Belledonne mountain range (Isère) owned by the Compagnie des hautes Chutes de Rocques (CHCR) Group (Direct Energie, n.d.b).

Électricité de France ("EDF"): EDF is one of the largest electricity producers in France. EDF has over 150,000 employees, of which more than 125,000 in France, and serves over 30 million customers (EDF, 2018a). In 2017, EDF produced 623.5 TWh of energy, mainly stemming from nuclear power plants (77%), but with a substantial amount in thermal fossil (8%), hydroelectric (7%), and combined-cycle gas (6%) (EDF, 2017). Other renewable energies accounted for 2%. In 2017, EDF's total assets were EUR 280.8 billion. Turnover stood at EUR 69.6 billion, with a profit of EUR 3.3 billion. In France, EDF's installed capacity was 97.9 GW, of which 20.3 GW was represented by hydropower, generating a total of 42 TWh (EDF, 2018ba). EDF is listed on the Euronext Paris, with 83.5% of the shares owned by the French state (EDF, n.d.a).With 433 hydroelectric plants currently located in France, approximately 10% of EDF's electricity production is generated by hydropower facilities (EDF, n.d.b). Figure 13 shows a map of all EDF's hydropower plants.

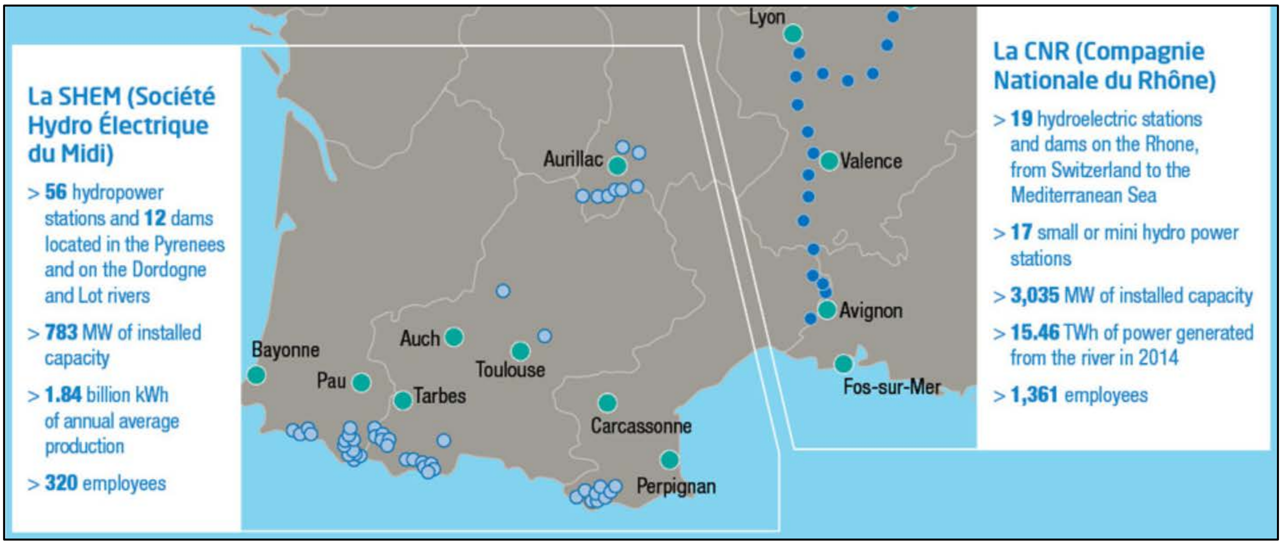
Figure 13: Map of EDF's hydropower installations in France



Source: EDF (n.d.), "Carte de nos implantations industrielles en France", online: https://www.edf.fr/groupe-edf/nos-energies/carte-de-nos-implantations-industrielles-en-france#!field_poi_type_1=363|id=rzr-poi-behavior-filter-form, viewed in November 2018.

Engie: Engie is a global energy and services group, focused on three core activities: low-carbon power generation, mainly based on natural gas and renewable energy, global networks and customer solutions. Installed capacity consists of 56% natural gas, 26% renewables (excluding pumped storage for hydro), 6% nuclear, 7% coal, and 5% other (Engie, n.d.a, n.d.b)). Total installed capacity was 112.7 GW, of which 19.5 GW was hydropower. Of this installed hydropower capacity, 3.8 GW was installed in France, which generated 17.3 TWh of energy in 2017 (Engie, 2018a, 2018b, n.d.a). Engie had total assets at the end of 2017 of EUR 150.3 billion, a turnover of 64.8 billion, of which EUR 163 in profits (Engie, 2018c, n.d.b). It employed over 155,000 people, approximately half of which in France. Engie is listed at the stock exchanges of Paris and Brussels. As per 31 August 2018, 24% of the shares were owned by the state, the rest in public hands (Engie, n.d.c, n.d.d). Figure 14 shows the map of Engie's hydropower locations, including CNR.

Figure 14: Engie hydropower presence in France



Source: Engie (n.d.), "Hydropower", online: https://www.engie.com/en/businesses/electricity/hydropower/, viewed in November 2018.

5.4.2 Germany

Under the German Energiewende (energy transition), the country aims to generate 35 per cent of electricity from renewables by 2020, and 80 per cent by 2050 (IHA, 2017b).

Hydropower installations (including pumped storage) account for a share of around 6 per cent of installed capacity in Germany at roughly 11.3 GW (including 1.2 GW of shared storage hydropower with Austria), and with approximately 22,000 GWh for about 3 per cent of the net electricity generation (IHA, 2017b).

Without pumping storage capacity, however, installed capacity was only 4.4 GW (World Energy Council, 2016c). With respect to renewable energies, this lacks behind wind power (44.9 GW) and solar power (39.6 GW). Installed nuclear capacity is slightly smaller with 10.8 GW (World Energy Council, 2016d). On a yearly basis, hydropower is responsible for 2.1 Mtoe per year, which is small compared to the production from coal (25,400 Mtoe), the largest provider of energy (World Energy Council, 2016e).

Currently, several new hydropower projects totalling approximately 2,770 MW are under development and are expected to come online by 2020 (IHA, 2017b).

Additionally, utility companies with only pumped storage hydropower facilities are not included as pumped storage facilities have not been proven to have a significant impact on the eel stock. These excluded companies are: RWE (excluding its subsidiary Innogy) and Vattenfall.

In Germany, four companies were identified to have hydropower-related activities along eel migratory routes: EnBW, Innogy, Statkraft, and Uniper. This section details each of these companies' hydropower activities in Germany.

***EnBW*:** EnBW is active in four business segments, namely sales of electricity and gas, transmission and distribution of electricity and gas, power generation from renewable energy sources (installed capacity of 1.7 GW) and the generation and trading of gas and electricity (11.2 GW) (EnBW (n.d.a)). Total installed capacity in 2017 was 13.1 GW of which 1.0 GW in run-of-the-river hydropower, generating 5 TWh of hydropower energy. EnBW operates two hydroelectric power plants, one at Rheinfelden and one at Iffezheim (both on the Rhine) (EnBW, n.d.b). EnBW's total assets were EUR 38.8 billion at the end of 2017, with a turnover of EUR 22.6 billion and profits of EUR 2.1 billion (EnBW, 2018). EnBW has over 21,000 employees and the company is listed on the stock exchanges of Frankfurt and Stuttgart. Approximately 47% of the shares is owned by the federal state of Baden-Württemberg and approximately 47% by OEW (EnBW (n.d.c)).

Innogy: Innogy engages in the distribution and supply of electricity and gas and is active in 16 countries across Europe, serving 23 million customers. At the end of 2017, Innogy had total assets of EUR 46.8 billion, with a turnover of 43.1 billion and total profits of EUR 1.1 billion. The company employed almost 22,000 people in Germany, serving over 6.6 million German customers. Innogy is listed on the Frankfurt Stock Exchange with RWE as a majority shareholder (76.8%). Total installed capacity was 4.2 GW in 2016, of which 1.3 GW was located in Germany. Installed hydropower capacity was 727 MW, 380 MW of which in Germany, generating 1.5 TWh of German hydropower energy.

Statkraft: Statkraft is Europe's largest supplier of renewable energy. The Group operates 353 power plants, with hydropower being the dominant technology, followed by natural gas and wind power. Most of the installed capacity is in Norway. Statkraft's total assets were EUR 17.2 billion at the end of 2017, with a turnover of EUR 6.4 billion and profits of EUR 1.2 billion (Statkraft, 2018). Statkraft employs 3,593 employees and is owned by the Norwegian state (Statkraft, n.d.a). Statkraft's total installed capacity was 17.5 GW, of which 2.7 MW in Germany. (Statkraft, n.d.b, n.d.c, n.d.d, n.d.e, n.d.f, n.d.g, n.d.h, n.d.i and n.d.j). Their total installed hydro capacity was 14.1 GW, of which 41.9 MW in Germany. The total generation of energy coming from hydropower was 57.4 TWh. Of this, 0.2 TWh was produced by run-of-the-river hydropower plants in Germany. They are located along the Eder, the Weser, the Fulda, and the Werra rivers (Statkraft, n.d.k). Figure 15 shows the locations of the hydropower plants in Germany.

Figure 15: Statkraft's hydropower plants in Germany

Source: Statkraft (n.d.), "Power Plants", online: https://www.statkraft.com/energy-sources/Power-plants/?un=Norway,Sweden,UnitedKingdom,India,Nepal,Peru,Chile,Turkey,Brazil,Albania,TheNetherlands,UnitedStates,Bulgaria,France,Serbia,windpower,gaspower,districtheating,solarpower,biopower, viewed in November 2018

Uniper: Germany is Uniper's home market, with activities that include power generation, energy trading, energy storage, wholesale energy sales, and technology services. Uniper owns more than 100 hydroelectric plants in Germany, which are organised in the river groups Isar, Lech, and Rhine-Main-Danube (RMD), as well as a group of pumped storage plants (Uniper, n.d.a). Uniper had total assets of EUR 43.2 billion, a turnover of EUR 72.2 billion and profits of EUR 538 million at the end of 2017 (Uniper, 2018). Uniper employed 4,689 people in Germany and is listed on the Frankfurt Stock Exchange, with 47% of the shares owned by Fortum (they bought EOn's shares in June 2018) (Uniper, n.d.b). The total installed capacity was 25.7 GW, of which 10.5 GW was based in Germany (Uniper, 2017). Total installed hydro capacity was 3.6 GW, with 119 MW installed on the Main. Hydropower capacity installed on the Danube was not included in this report. Total power generation in Germany was 20.5 TWh, of which 0.77 TWh was generated from the Main River.

5.4.3 Greece

Total energy production in Greece in 2016 was 22.9 Mtoe (of which oil provided 50%, coal 19%, natural gas 15.2%, biofuels and waste 6.1%, hydro 2.1%, solar 2.3%, wind 1.9%, and electricity imports 3.3%. Installed capacity of hydropower was 3.4 GW in Greece in 2016, which is slightly larger than both solar (2.6 GW) and wind (2.2 GW). Without pumped storage capacity however, this was only 0.7 GW (World Energy council, 2016f).

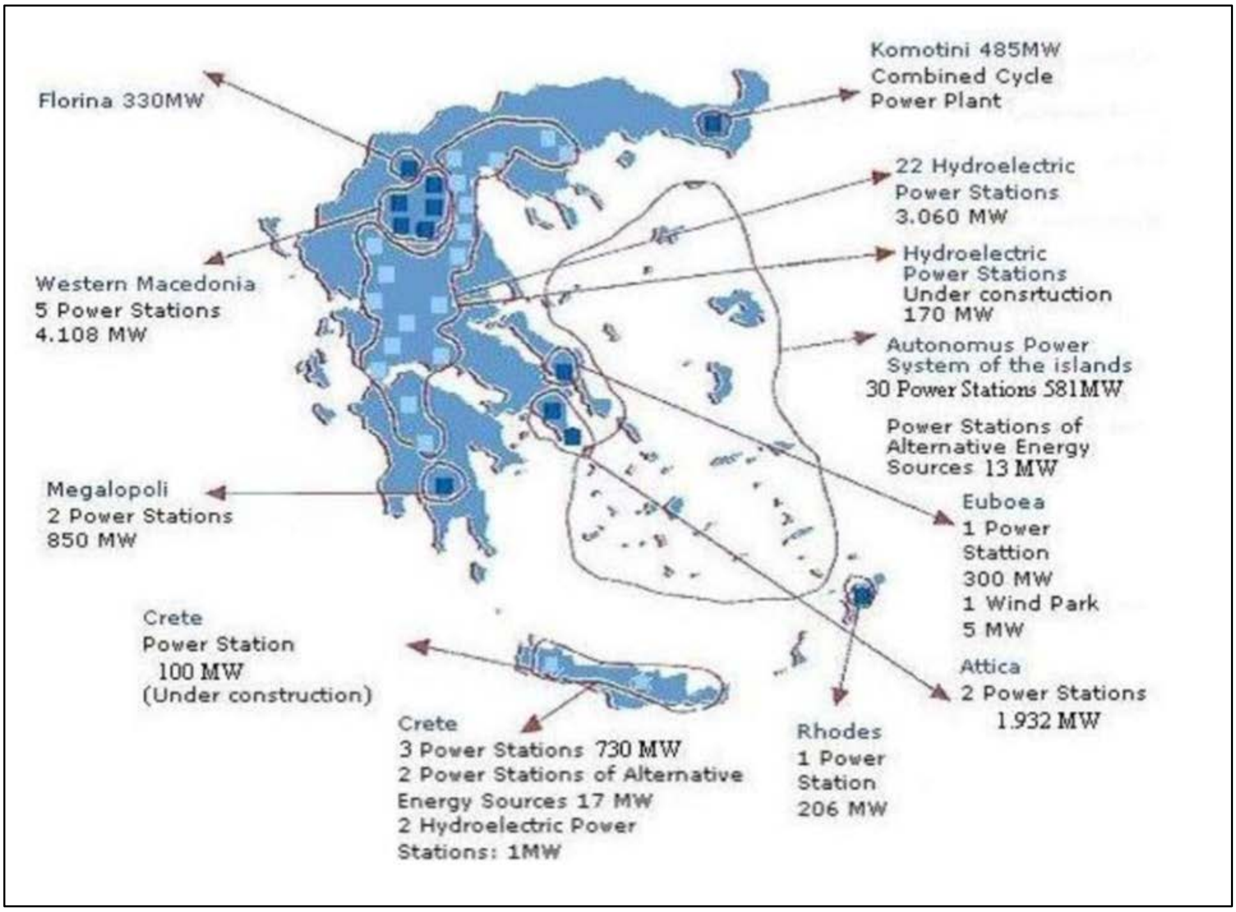
In Greece, three companies were identified to have hydropower-related activities: GEK Terna, Public Power Corporation ("PPC") and Protergia. This section details each of these companies' hydropower activities in Greece.

***GEK Terna*:** Terna Energy is a listed subsidiary of GEK Terna Group. The Group is successfully involved in several industries, such as constructions, energy, concessions, mining and real estate (GEK Terna Group - Terna Energy, n.d.a, b, c and d). Terna Energy has a pipeline of around 6,000 MW of renewable projects in operation, under construction or in an advanced stage of development, which gives them a leading position in Greece, with additional footprint in Central and South East Europe, as well as in the USA (GEK Terna Group - Terna Energy, n.d.e). Terna Energy's total assets were EUR 1.6 billion at the end of 2017, with EUR 277 million in turnover and EUR 38 million of profits (GEK Terna Group - Terna Energy, 2018). GEK Terna employed 4,034 people in Greece. Terna Energy's total installed capacity was 1 GW, with 579 MW based in Greece (GEK Terna Group - Terna Energy, n.d.a, b, c and d). Of this, 17.8 MW was in hydropower, with 183 MW further in the pipeline for development. Terna Energy operates two small hydroelectric projects in Greece, 6.6 MW in Eleousa, and 11.2 MW in Dafnozonara (GEK Terna Group - Terna Energy, n.d.b).

***Public Power Corporation ("PPC")*:** PPC owns 34 thermal and hydroelectric power plants and 3 aeolic parks of the interconnected power grid of the mainland, as well as 61 autonomous power plants located on Crete, Rhodes and other Greek islands (39 thermal, 2 hydroelectric, 15 aeolic and 5 photovoltaic parks) (PPC, n.d.). Hydropower in Greece is dominated by PPC. PPC's total installed capacity was 12.1 GW, all in Greece (PPC, 2018a and b). Of these, 1.3 GW is in hydropower. PPC owns and operates the Kastraki Dam (installed capacity of 320 MW), Kremasta Dam (437 MW), Mesochora Dam (162 MW), Plastiras Dam (130 MW), and Stratos Dam (157 MW). The rest is coming from small-scale hydro. Total power generation in 2017 was 32.6 TWh, of which 3.5 came from hydropower. Figure 16 shows the PPC power plants in Greece. PPC had total assets of EUR 15.4 billion at the end of 2017, with a turnover of EUR 4.9 billion and total profits of EUR 89 million (PPC, 2018c). PPC employed 17,519 people in Greece, serving 7.2 million customers. PPC is majority owned by the Greek state (51%), the rest by institutional investors and the general public (PPC, 2018d).

***Protergia*:** Protergia is the energy unit of Mytilineos, the largest independent electricity producer in Greece. Protergia operates and manages all of Mytilineos' power plants, which comprise gas driven thermal plants and renewable energy plants (wind farms, photovoltaic parks and small hydropower plants). The company's portfolio of energy assets, with a total installed capacity of 1.2 GW of thermal capacity and 200 MW of renewable energy covers more than 10% of the country's active installed capacity (Protergia (n.d.a). At the end of 2017, Mytilineos had total assets of EUR 3.2 billion, with EUR 1.5 billion in turnover and profits of EUR 158 million Mytilineos (2018). Mytilineos had 2,071 employees. Total installed capacity of Protergia was 1.4 GW in 2017, all in Greece, of which 6 MW was in hydropower, spread over four small hydropower plants in the regions of Aitoloakarnania and Fthiotida (Protergia (n.d.b, c).

Figure 16: Map of PPC Power Plants in Greece

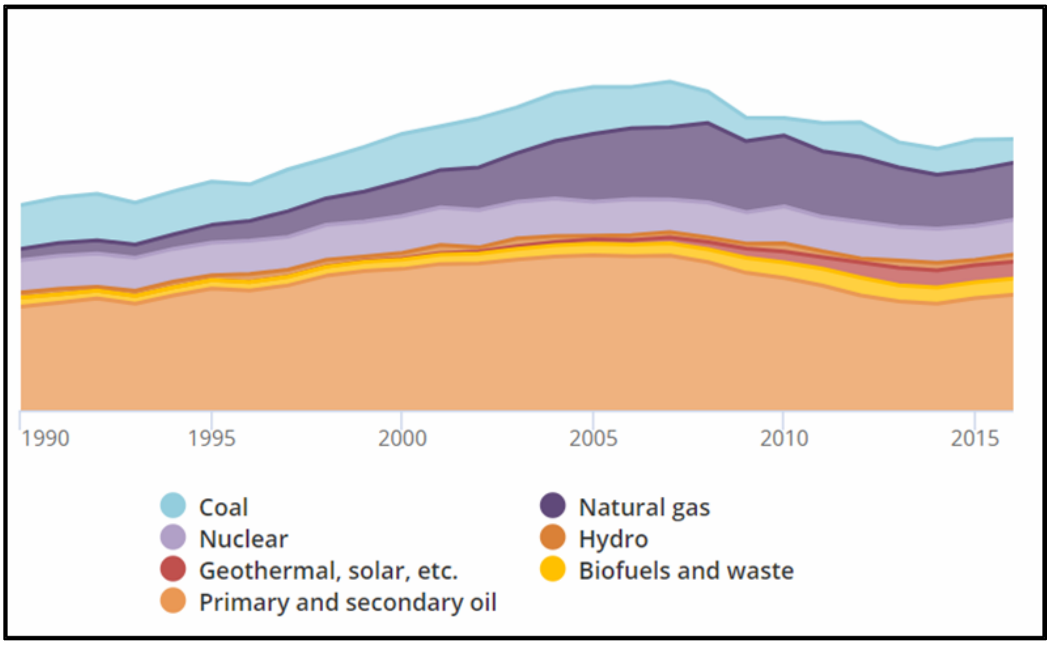


Source: PPC (n.d.), "Detailed Map of Power Plants", online: https://www.dei.gr/en/i-dei/i-etairia/tomeis-drastiriotitas/paragwgi/analutikos-xartis-stathmwn, viewed in November 2018.

5.4.4 Spain

In Spain in 2016, total energy generated was 119.8 Mtoe (IEA, 2018). Most of the energy was generated from oil (47.8 Mtoe), followed by natural gas (31.2 Mtoe), nuclear (14.8 Mtoe), and coal (13.3 Mtoe). Renewable energies provided only relatively small portions, mostly by geothermal, solar and wind (7.6 Mtoe), biofuels and waste (7.0 Mtoe), and hydro (3.3 Mtoe). Figure 17 shows the development of the various sources of energy from 1990-2016.

Figure 17: Total Primary Energy Supply in Spain



Source: IEA (2018), 'World Energy Balances 2018", online: https://www.iea.org/statistics/?country=SPAIN&year=2016&category=Key%20indicators&indicator=TPESbySource&mode=chart&categoryBrowse=false&dataTable=BALANCES&showDataTable=false, viewed in November 2018.

Endesa: Endesa is the leading company in the Spanish electricity sector and the second largest operator in the Portuguese electricity market. Their core business is the generation, distribution and sale of electricity in Portugal and Spain (Endesa, n.d.a). At the end of 2017, Endesa's total assets were EUR 15.4 billion, with EUR 1.8 in turnover and profits of EUR 1.5 billion (Endesa, 2018). Endesa had over 10,000 employees in Spain, serving 9 million customers. Enel Group owns 70.1% of Endesa's shares, the rest is free float on the Spanish stock markets (Endesa, n.d.b). Endesa's total installed capacity is 16.7 GW (259 plants in total with the majority in Spain), with 3.6 GW in hydropower, spread over 133 plants in Spain (Endesa, n.d.c). Total power generation in Spain was 52 TWh, with 8.3 TWh coming from hydro. Figure 18 shows the Endesa hydropower plants in Spain.

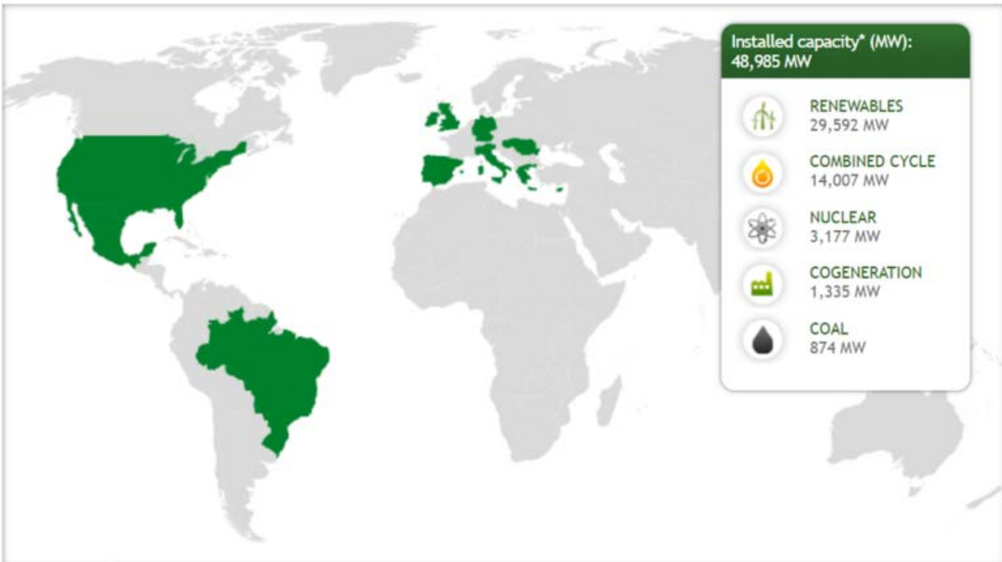
Figure 18: Endesa Hydropower Plants in Spain

Source: Endesa (n.d.), "Plant Map", online: https://www.endesa.com/en/plant-map.html?topic=hydro, viewed in November 2018.

Iberdrola: Iberdrola's total assets were EUR 110.7 billion at the end of 2017, with a turnover of EUR 31.3 billion and profits of EUR 2.7 billion (Iberdrola 2018). The company had 34,255 employees (over

10,000 in Spain) and 30.3 million customers, of which 11 million in Spain. Iberdrola is listed on the Spanish stock exchanges and on the New York Stock Exchange (Ibderdrola, n.d.). Iberdrola's total installed capacity was 49 GW at the end of September 2018, of which 25.9 GW based in Spain (Iberdrola, 2018). Total hydropower capacity was 12.8 GW, with 10 GW installed in Spain. Total power generation in Spain was 52 TWh, of which 8.3 produced by hydropower. Figure 19 shows the installed capacity of Iberdrola.

Figure 19: Installed capacity of Iberdrola



Source: Iberdrola (2018, September), "Installed Capacity", online: https://www.iberdrola.com/about-us/lines-business/facilities-map, viewed in November 2018

Naturgy: The Naturgy Energy Group (Naturgy), previously Gas Natural Fenosa, is the largest integrated gas and electricity company in Spain and the third gas and electricity distribution company in the Iberian Peninsula market (Naturgy, n.d.). At the end of 2017, Naturgy's total assets were EUR 47.3 billion, with EUR 23.3 billion in turnover and profits of EUR 1.7 billion. Naturgy had 7,350 employees in Spain, serving 3.7 million customers. Naturgy is listed on the Spanish Stock Exchange (Naturgy, 2018). Naturgy's 2017 total installed capacity in Spain was 12.7 GW, with 2.1 GW in hydropower (Naturgy, n.d.a). Total power generation in Spain was 28 TWh, with 1.5 TWh coming from hydro.

5.5 Discussion

The eel supply chain in the countries of focus is composed of a multitude of economic actors, from individual fishers with informal and formal collective organisations to large and diverse processing or retailing enterprises. Predominantly, the sector is composed of vertically integrated small and medium enterprises, often specialised in eel as a product and therefore significantly dependent on eel for their revenues.

Eel capture, both in fresh and marine waters, is dominated by commercial fisheries. In Greece, and recently in the Loire in France, these fishers are organized under producer organizations. In other countries and areas there is less formal organization of eel fishers.

Eel aquaculture and processing are much more integrated stages of the supply chains, where many companies specialise in eel production and have their own farming, processing, smoking and retailing or trading facilities and operations. Additionally, a few companies were identified to be primarily involved in processing and/or marketing. The largest activities in aquaculture and processing were identified in Germany, with a total of 18 companies identified, of which three are vertically integrated and produce collectively more than 1,200 t of eel annually.

In contrast to the eel industry, the main companies identified to have activities in hydropower were globally active energy companies, with operations in generation and distribution of electricity through various types of power generation. Where the majority of the eel production companies have assets up to EUR 12 million, hydropower companies included in this study generally have more than EUR 1 billion in assets, demonstrating the extreme difference in size of the economic actors of these two sectors.

For economic actors operating in the mid- and downstream segments of the eel supply chain economic and financial data is often readily obtainable. These actors are registered companies whose financial reports are archived in national company registries, published on their websites, and/or accessible through statistical databases. As the upstream actors are generally small-scale fishers, similar economic and financial data is not maintained in a central registry. In Spain, survey data from five regions provides a general picture of income from eels and other species for fishers for the period 2014-2017. This also allows a rough assessment of the economic dependency of these fishers on eels.

In Germany, information on eel catch for marine fishers at a company level is available, however could not be shared with this research for confidentiality reasons. As shown above, for four POs there is information on their eel landings revenue and the proportions of eel revenue in their total turnover. However, the bulk of eel landings in Germany comes from inland fisheries, for which there is no data.

In France there is aggregated eel dependence data for the Loire. However, similar information is not available for other regions where eel is targeted by fishers. In Greece economic data on for small-scale fishers is not available.

It is recommended that data on both income and dependency on eel capture also for individual inland and coastal fishers are assessed. These data are necessary to make adequate assessments of the socio-economic impact of eel management measures on fishers (see Chapters 6 and 7).

6 IMPACT OF THE FISHERIES SECTOR ON THE EEL STOCK AND THEIR SOCIO-ECONOMICS

Key findings

- Commercial and recreational fisheries directly affect the eel stock.
- Glass eel fisheries are very traditional métiers at the coasts of France and Spain. They are locally important (e.g. 14% of the value of fisheries in the Pays de Loire region in France) and provide juvenile eels for stocking purposes and aquaculture production.
- In Spain and France, effort in glass eel fisheries was reduced over the last decades. Prices for glass eels are high compared to other fisheries (including yellow and silver eel) and are correlated to catch variability. Other factors that might influence glass eel prices are illegal trade and CITES implementation.
- European eel aquaculture and processing companies depend on glass eel catches and, therefore, indirectly influence the eel stock.
- Silver and yellow eel is a valuable product and, therefore, important for many coastal and freshwater fishers.

6.1 Introduction

There are several sectors affecting the eel stock. One of the main actors is the fishing sector. Aquaculture and fish-processing are not directly affecting the stock but the demand for eel on the markets drives the fisheries. This chapter describes and, where possible, quantifies the impact of the main fishery related economic actors (fishing, processing, trading, stocking and aquaculture) on the European eel stock and illustrates their socio-economics (employment, dependency of economic actors). Though it is a complex task to quantify the impact of specific sectors, it is obvious that the number of actors impacting the eel stock is large, due to the eel's life cycle and the market structure. This chapter is structured into the following sections: 6.2 Fisheries (commercial fishing, marine and freshwater (adult and glass eel), recreational fishing), 6.3 Aquaculture and Processing and 6.4 Trading. Due to a lack of economic data only a general overview will be provided for Europe and more detailed information will only be presented for the four focus countries: France, Germany, Greece and Spain (for methods see ANNEX IV.4).

6.2 Fisheries

6.2.1 General introduction

In Europe, a large number of companies are fishing commercially on glass, yellow and silver eel. The overall glass eel landings reported to ICES for the season 2016/17 (ICES 2018a) accounted for approximately 67 t in the UK, Spain, France, Portugal and Italy. Assuming an average price of about EUR 300-360 per kg this would mean revenues between about EUR 2o million and EUR 24 million. For yellow and silver eel catches, 2,224 t were reported to ICES (ICES 2018a). It is not possible to give an estimate of revenues as prices for eel vary a lot between areas. Assuming a price of approximately EUR 10 as paid in Germany on average over the last years would mean revenues of about EUR 22.2 million (see also Chapter 7). However, prices in some of the EU Member States differ considerably.

6.2.2 Country descriptions

6.2.2.1 France

In France, the marine and freshwater areas are depending on different administrative authorities and regulated by different rules. Downstream from the saline limit, the fishery is regulated by the marine fisheries regulation. Fishers must have a European fishing licence. Upstream from this limit, the freshwater regulation applies. Commercial fisheries are restrained to freshwater fishers, but there is a possibility for some marine fishers to fish in an intermediary zone upstream from the saline limit and downstream from the marine navigation limit. As a result, both freshwater and marine fishers exert the glass eel fishery, with fishing areas that overlap partially in large estuaries.

Freshwater and marine fishers are regulated by a licence system, quotas for glass eel, and seasonal restrictions (5 month opening) for the yellow eel fisheries. Table 8 summarizes glass, silver and yellow eel catches in France between 2000 and 2018, if available.

Table 8: Glass, silver and yellow eel catches in France (t)

Year	Glass	Silver	Yellow		Year	Glass	Silver	Yellow
2000	206		1321		2010	41	n.a.	1002
2001	101		1280		2011	31	11	357
2002	202		1280		2012	34	96	377
2003	151		1280		2013	34	112	392
2004	89		1280		2014	35	76	358
2005	89		1223		2015	36	92	265
2006	67		1150		2016	46	116	327
2007	77		1005		2017	46	n.a.	279
2008	79		986		2018	54	n.a.	n.a.
2009	n.a.		n.a.					

Source: ICES 2018

Glass eel fishery: The glass eel fishery is regulated by a 5-month opening period, which corresponds to the main glass eel arrival season, so in practice the quota and licence system are the rules exerting a regulation in the fishing mortality at the glass eel stage. The licences are delivered annually; their number has diminished by about 60% since 2006 (Tab. 9).

Table 9: CMEA Licences delivered for the glass eel fishery in France, glass eel fisheries are not authorized in the Mediterranean

Fishery	2006	2010	2011	2012	2013	2014	2015	2016	2017	2018	Change 2006-18
Marine	853	643	573	500	475	457	413	420	437	417	-51%
Freshwater	371	180	158	147	145	129	126	112	109	109	-71%
Total	1224	823	733	647	620	586	539	532	546	526	-57%

Source: Plan de gestion de l'anguille pour la France, rapport de mise en œuvre 2018

When looking at a longer time trend, freshwater glass eel fisheries using traditional gears with anchored boats and hand nets have progressively disappeared in the estuaries and most of the glass eel fishery is now done by boats in the estuary.

***Commercial yellow and silver eel fisheries*:** The yellow eel fisheries in France consist of several categories. Commercial fisheries targeting yellow eel in the estuaries, bays and lagoons of the Atlantic coast (39 t) and commercial fisheries targeting yellow and silver eels in the Mediterranean lagoons, by far the most important in catch (239 t). While the glass eel fishery has never been practiced in the Mediterranean, historically a part of the catch of small yellow eel from the Mediterranean was also used as stocking material in the lagoons, for instance in Italy. Table 10 provides information on eel landings in French Mediterranean and Atlantic areas.

Licencing and seasonal closure are the regulations used to restrict the mortality at the yellow eel and silver eel stages. The number of licences in Table 11 corresponds to rights for fishing in a restricted area. Some fishers that carry out commercial fisheries are exerting in more than one area, and most are exerting fishery for several stages. The real number of fishers is 592 in 2018 for both marine and freshwater areas, and it has diminished by 43% and 41% for marine and freshwater fisheries, respectively. Some marine fishers not targeting glass eels are allowed a longer fishing season as an exception (7 month), but this exception is restricted to the Arcachon Bay (southwest of France). The number of fishing licences for the Mediterranean is presented in Table 12.

Table 10: Landings for yellow eel in France, for Mediterranean and Atlantic areas

Year	Atlantic	Mediterranean
2012	87.3	289
2013	70.3	322
2014	69.9	288
2015	40.6	224
2016	39.6	286
2017	39.1	239

Source: ICES 2018

Table 11: Number of fishers with yellow or silver eel fishing rights from 2009 to 2018 in France (only commercial fisheries; not including fishers from the Mediterranean area)

		2009	2012	2013	2014	2015	2016	2017	2018	2009-2018
Yellow eels	Marine	309	236	224	248	222	228	229	216	-30%
	Freshwater	169	169	172	146	143	134	135	128	-24%
	Total	478	405	396	394	365	362	364	344	-28%
Silver eels	Freshwater	44	34	34	34	33	34	34	33	-25%

Source: Plan de gestion de l'anguille pour la France, rapport de mise en œuvre 2018

Table 12: Number of fishing licences for yellow eel delivered to fishers in the Mediterranean in France (including Corsica) from 2009 to 2018 (only commercial fisheries)

Mediterranean sea	2009	2012	2015	2016	2017	2018	Trend 2009-2018
Fishing authorization – yellow eel	290	264	206	216	219	218	-24.8%
Fishing authorization – silver eel	283	269	209	216	219	218	-23.0%
Fishing enterprises	297	251	199	204	193	193	-35.0%

Source: Plan de gestion de l'anguille pour la France, rapport de mise en œuvre 2018

Recreational fisheries: No recent catch estimates for recreational fishers from France exist at the national level, but an estimation was built in 1995, showing that recreational catches were about half the commercial catches when including the Mediterranean area (684 t). More recent estimations are only available from some regions. Surveys in Brittany give an order of magnitude for the catches of recreational fishers with rods, with landings diminishing from 40 t in 2007 to 15 t (2011), 12.8 t (2013) and 9.5 t in 2015. In this region, the catch by recreational fishers is about the same order of magnitude as the commercial fishery (5-20 t). However, no such estimation exists at the national level. In France, recreational glass eel fishery was banned from 2010 onward.

6.2.2.2 Germany

In Germany, eel are caught by commercial (marine and freshwater) and recreational fisheries. For commercial marine and coastal fisheries logbook data including eel catches are available and there is also a regular collection of economic data. For freshwater and recreational fisheries data availability is poor, as no regular economic data collection exists.

Commercial yellow and silver eel fisheries**:** The overall small-scale marine fishing sector in Germany comprises of still over 1,000 vessels mostly based along at the Baltic Sea coast. In contrast, North Sea fisheries are dominated by shrimp fishing vessels and larger vessels fishing outside coastal areas due to the character of the Wadden Sea coast. Therefore, basically no commercial eel catches are reported for the North Sea coast while catches are concentrated in coastal waters of the Baltic Sea. Most of the marine fishers are based in the federal state of Mecklenburg-Western Pomerania. For 2016, 255 full-time and 128 part-time fishers had a licence. Vessels are mostly between 8 and 15 m long, deploying passive gear (gill and trap nets). Catches of the small-scale marine fishers are decreasing since the beginning of the 21st century. In 2002 landings were 134.3 t, in 2010 74.3 t and in 2016 38.9 t[2]. The respective value of landings was EUR 1,034 million in 2002, EUR 538,584 in 2010 and EUR 401,562 in 2016. However, since the number of fishers decreased substantially during that period, eel can have the same importance regarding revenues for the remaining fishers as compared to the beginning of the century.

In general, small-scale marine fishers are mostly catching herring, cod and a number of freshwater and diadromous species (including eel) along the Southern Baltic Sea coast. The Western Baltic herring stock spawns around the Island of Ruegen and can easily be targeted with passive gear. Both stocks, the Western Baltic herring and the Western Baltic cod, are below the limited reference point and fishing quotas are substantially lower than a few years ago. Therefore, the economic situation of many Baltic Sea Fishers is precarious and a reason why a substantial number has ceased fishing over the last years.

For freshwater fisheries, however, eel is considered of high importance. Many fishers process their eel catches themselves (mostly by smoking) and market them directly to local consumers. Data on this segment is scarce, but the available information reveals that the number of full-time fishers decreased from 475 in 2006 to 373 in 2016. The number of fishers working only part time decreased es well from around 400 to 300 (Brämick 2018). In 2016, the average price for fresh eel was approximately EUR 19 per kg and for smoked eel EUR 31 per kg. Catch estimates varied from 185.6 t in 2006, 224.4 t in 2010 to 141.2 t in 2016 (Tab. 13). The decline is not as steady over the years as in marine eel fisheries, probably as a result of continuous stocking efforts. The data presented here are

[2] All data is coming from reports of the Bundesanstalt für Landwirtschaft on landings of fishers that carry out commercial fisheries in Germany (BLE several years)

official landing data. However, Brämick (2018) suggests that according to data collection following the implementation of the EMPs the real catches would be around 500 t (Brämick 2018).

There is some information on fishing effort in certain areas as Germany implemented Regulation EG (EC) 1100/2007 (see ANNEX II.1, Table II.1.10).

Table 13: Eel freshwater catches by commercial fisheries

Year	1995	1996	1997	1998	1999	2000	2001	2002
Eel catch (t)	369.3	300.2	280.7	251.9	261	276.4	239.3	236.9
Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Eel catch (t)	170.9	168.6	174.4	185.6	206	177.7	232	224.4
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	
Eel catch (t)	229.7	214.2	261.2	155.7	159.2	141.2	143.1	

Source: Brämick, several years (Jahresbericht der Deutschen Binnenfischerei)

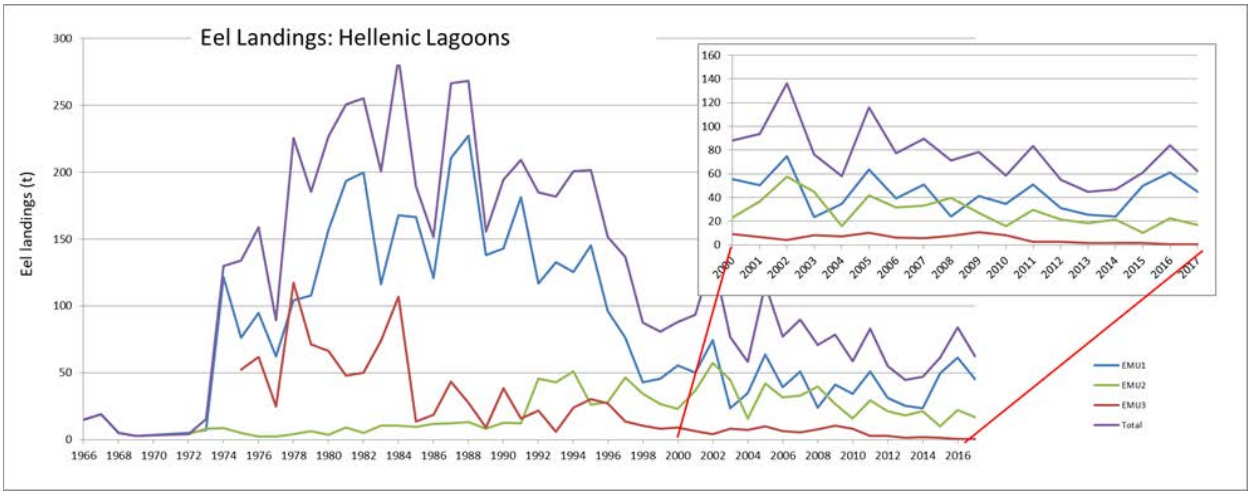
***Recreational fisheries*:** The European eel is one of the most important target species for recreational anglers in Germany (e.g. Dorow et al. 2010, Fladung and Brämick 2018). Yet, only a rough estimate of recreational landings is available, based on the number of recreational fishing licences (~900.000 in 2018) multiplied by an average eel landing of 0.2-0.7 kg per angler and year (Fladung and Brämick 2015; 2018). According to the latest estimate (ICES 2018a), total recreational landings in Germany were approximately 250 t in 2016. It should be noted, however, that there is considerable uncertainty in this estimate, since the average landings per angler are extrapolated from only a limited set of regional studies.

6.2.2.3 Greece

In Greece, glass and yellow eel fisheries are strictly prohibited. In fact, the Royal Decree 142/1971 clearly mentions that both fishing and the commercial exploitation of eels smaller than 30 cm are entirely prohibited. Therefore, there is no glass eel and young yellow eel fishing in Greece and it is not necessary to ensure price control, as provided by Article 7 (5) of Regulation No 1100/2007. Fishing activities targeting individuals smaller than 30 cm are allowed by special authorization only for stocking purposes (RD/142, Article 1/1971), but until today no authorization was issued.

Commercial yellow and silver eel fisheries: Since glass eel and yellow eel fisheries are forbidden, commercial exploitation of eels is restricted to silver eels. More than 80% of the landings are provided by lagoon fisheries. Figure 20 indicates the trend in lagoon landings from the late 1970s until today for three EMUs. The figure shows a clear decreasing trend since the late 1980s. It is notable that the mean annual eel landings in western and northern Greek lagoons decreased from 10 kg/ha during the period prior 1980 to 2.4 kg/ha in recent years. On the other hand, in southwestern Greece, eel annual landings increased from 10 kg/ha during the period before 1985 to 20-25 kg/ha from 1990 onwards. The reason for this inverse pattern in southwestern Greek lagoons is not identified yet. However, since the rise in the 1990s, landings have stabilized and is slightly fluctuating in all areas, where eel fishery exists.

Figure 20: Eel landings in Greek lagoons since the late 1970s until today in total and per EMU



Source: Figure based on data from regional Greek Departments of Fisheries

In any case, despite a stable fishing effort, total landings decreased considerably since the installation of "modern fishing traps" in the 1980s.

In several areas of Western Greece, individually operating fishers, who do not belong to a particular fishing cooperative, target eels with total catches varying from 200 kg to 1,000 kg per season (Koutsikopoulos et al. 2001). The number of these fishers remains unknown along with their spatial distribution and their gears. Individually operating fishers also appear in lagoons, lakes and estuaries of Southwest Greece, but no information exists on their activities. For the rest of Greece some information suggests that intense eel fishing activities in some rivers have stopped at the late 1970s, as a result of the severe degradation of the corresponding ecosystems.

Until today, no silver eels were reported to be captured in marine waters by commercial fisheries, using longlines, trawlers, seine nets etc. Moreover, the General Directorate for Sustainable Fisheries, Ministry of Rural Development & Food has issued licences for silver eel fishery only to fishers that carry out commercial fisheries in freshwaters using lines and hooks, but not any type of traps. However, the reported landings in the freshwater fisheries were very low, less than 0.8 t and are not considered of high importance.

Recreational fisheries: Recreational fisheries for eels of all stages are prohibited in Greece.

6.2.2.4 Spain

The autonomous regions (hereafter referred to as regions) are in charge of the management of the fisheries in inner waters (including coastal waters). This causes great differences among regions. The amplitude of the historical data series is variable among regions, depending on the date in which the regulation of each region was issued. In some regions, the same regulation is applied to all the river basins while in others, each basin or even a particular zone within the same basin has its own regulation. Additionally, even in the same region, the fishery is regulated in some river basins but not in others. In some regions, fishers are professional and sell their catches to the fish market, while in others they are non-professional. In this sense, the accuracy of the information related to catches and landings differs greatly among regions. Each region has its own way of managing the stock (e.g.

different fishing techniques are allowed). Data sources of the information compiled in this section are explained in ANNEX IV.3.3.

The overall number of fishers catching eel (glass eel, yellow and silver eel) decreased between 2015 and 2018 from 979 to 895 (Tab. 14).

Table 14: Number of fishers in Spain catching eel

Year	Glass eel	Eel	Total
2015	643	336	979
2016	590	311	901
2017	620	352	972
2018	541	354	895

Source: Survey at regional authorities

Commercial and recreational glass eel fisheries: Glass eel fishery in Spain is a very traditional activity practiced for many years. In Spain, glass eel is captured in five regional autonomies: Basque Country, Cantabria, Cataluña, Valencia and Asturias and in the international river Minho (shared with Portugal). Nowadays, glass eel fishing is a commercial fishery in all regions except for the Basque Country, where there still is a recreational fishery.

Basque Country: Glass eel fishery is very traditional in the Basque Country and it is associated to river mouths, including beaches, estuaries and river banks. Glass eel fishery is located in most of the river basins of Bizkaia (Artibai, Lea, Oka, Butrón and Nervión- Ibaizabal) and Gipuzkoa (Bidasoa, Oiarzun, Urumea, Oria, Urola, and Deba). Basque fishers are not allowed to sell the catches and should therefore be considered as recreational. Although the fishery was very traditional, there was not any management plan for glass eels until 2001, when the Basque Government with the advice of AZTI, launched a fisheries monitoring plan. In 2003, a new regulation for glass eel fisheries was issued. It stated that there must be only one licence per person and fishing basin and that it is mandatory to fill in the Daily Catches report with catches and effort data. The authorized fishing gear is a sieve with a maximum dimension of 1.8 m diameter. The use of mechanical instruments or other fishing gear is prohibited. The boats that capture glass eel are between 3 and 6 metres long, with a power of 20 – 80 horsepower. The crews range from 1 to 3 people. The number of fishers has been decreasing for the last three decades. Although the number of boat licences is lower than for land licences, the amount of catches of boats accounts around 40% of the total catches.

Cantabria: Both, commercial and recreational glass eel fisheries existed in Cantabria, mainly located in the Nansa, Pas and Campiazo River basins. However, Cantabria prohibited recreational fisheries from 2014 onward. Fishers that carry out commercial fisheries sell their catches in the market or in other licenced establishments. Fishers fish inland and they are only allowed to use one sieve (≤1.2 m^2) per fisher. Since 2005, fishers report their catches.

Asturias: Glass eel fishery is very traditional in the zones associated to river mouths, including beaches, estuaries and riverbanks. There are 18 fishing guilds in Asturias; in the San Juan de la Arena fishing guild data is available since 1952 and for the other 17, data is available since 1983. Fishers fish from land in all the rivers except from the Nalón were they can also fish from boat. In October 2010, a new regulation was implemented in the Nalón River limiting the number of boat and land licences in the Nalón River to 45 and 55 respectively. The gear type is also limited to a sieve no bigger than 200 x 60 cm. Boat dimensions and power together with fishing effort has also been regulated in this area.

Miño-Sil RBD: In the international estuary of the Minho River there is an important commercial glass eel fishery. The lower part of the Miño River represents the border between Spain and Portugal and for that reason the permanent International Commission of the Miño is responsible for the management of this part of the River.

Andalucia: A new regulation is in force in Andalucía since November 2010, in which several measures have been established in order to implement a recovery plan for the European eel (*DECRETO 396/2010, de 2 de noviembre, por el que se establecen medidas para la recuperación de la anguila europea (A. anguilla)*). A complete closure of the eel fishery has been issued. Only some aquaculture factories will get a permission to fish and then grow a certain amount of eel per year.

C. Valenciana: There are six professional associations of glass eel fishers distributed between the provinces of Valencia and Castellón. In the Albufera, Perelló-Perellonet fishing association has the exploitation rights. Fishers of the Albufera fish in different "Golas", the channels that connect the Albufera with the sea. In the province of Alicante, commercial fishery occurs in 11 fishing preserves located between the El Hondo wetlands (Elche) and the salt flats of Santa Pola. In the fishing preserve of Alicante, a maximum number of fishing tackles (named "mornells") is allowed. The fishing guilds and associations give their catches data to the territorial service of each province responsible for the continental fishing. In the case of glass eel, they also report the fishing days.

Catalonia: The glass eel fishery is professional in the Ter, Muga and Fluviá Rivers (province of Gerona) and the delta of the Ebro River (province of Tarragona).

Table 15: Number of Glass eel licences in Spain (commercial and recreational fishery)

	Land-based		Boats		
	Recreational	Commercial	Recreational	Commercial	Total
2005	0	375	54	50	479
2006	363	338	50	47	798
2007	367	592	42	45	1046
2008	1032	311	44	45	1432
2009	814	303	46	45	1208
2010	377	451	47	43	918
2011	413	423	45	37	918
2012	427	423	45	37	932
2013	398	753	43	33	1227
2014	937	699	42	38	1716
2015	583	581	28	37	1229
2016	829	253	41	36	1159
2017	799	226	35	36	1096

Source: AZTI Data base

In Spain, the average number of licences in the three past years was around 1,150, with 94% of the licences for land-based fishing and 6% for boat. From these 1,150 licences, an average of 66% are for recreational fisheries. Most of the recreational licences (95%) are given to land modality (Tab. 15).

Since the implementation of the EMP in 2010, the fishing effort has decreased by shortening the fishing season (Asturias, Galicia, Cantabria, Basque Country and Valencia), reducing the number of licences and fishing places (Cantabria, Cataluña, Basque Country and Galicia) and prohibiting fishing in some basins (Cantabria, Basque country and Valencia) or even in all EMUs (Andalucía). In Valencia, the fishers are obliged to give a percentage of the catches for stocking purposes.

Depending on the regions, efforts are reported in different units (fishing days or fishing hours). In Figure 21 the trend of effort in Spanish glass eel fisheries is presented by region. Landings of glass eel started to decrease in the late 1970s. Nowadays catches remain low compared to the pre-1980s and show some small variations among years (Fig.22).

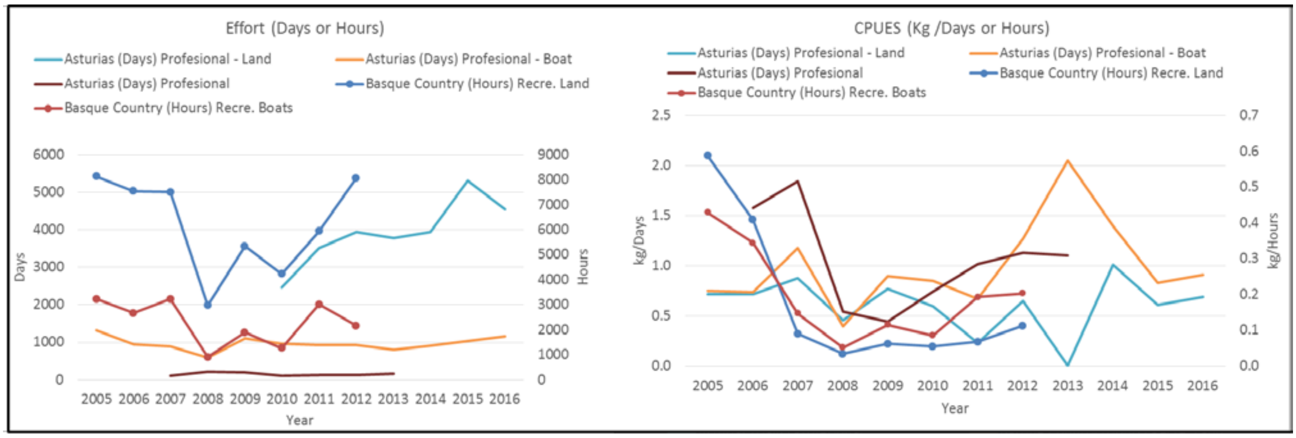
Commercial and recreational yellow and silver eel fisheries: Even yellow and silver eels catches should be assessed separately, they are jointly analysed in this study, since in most of the regions data for catches and prices of the two stages are not differentiated. The yellow and silver eel fishery is mainly located in Galicia, Valencia and Murcia (Korta and Diaz 2017). Yellow and silver eel catches and licence numbers in Spain are shown in Figure 23 and in Table 16, respectively.

Basque Country: There is no commercial yellow or silver eel fishery in the Basque Country. The recreational fishery for yellow and silver eel is forbidden since 2009, even if the catches were insignificant.

Cantabria: There is no commercial yellow or silver eel fishery, and the catches of recreational fisheries are insignificant.

Asturias: Commercial fishery has been banned after 2015. The recreational fishery was forbidden in 2007.

Figure 21: Fishing effort (days or hours depending on the region) and CPUE by region in Spain

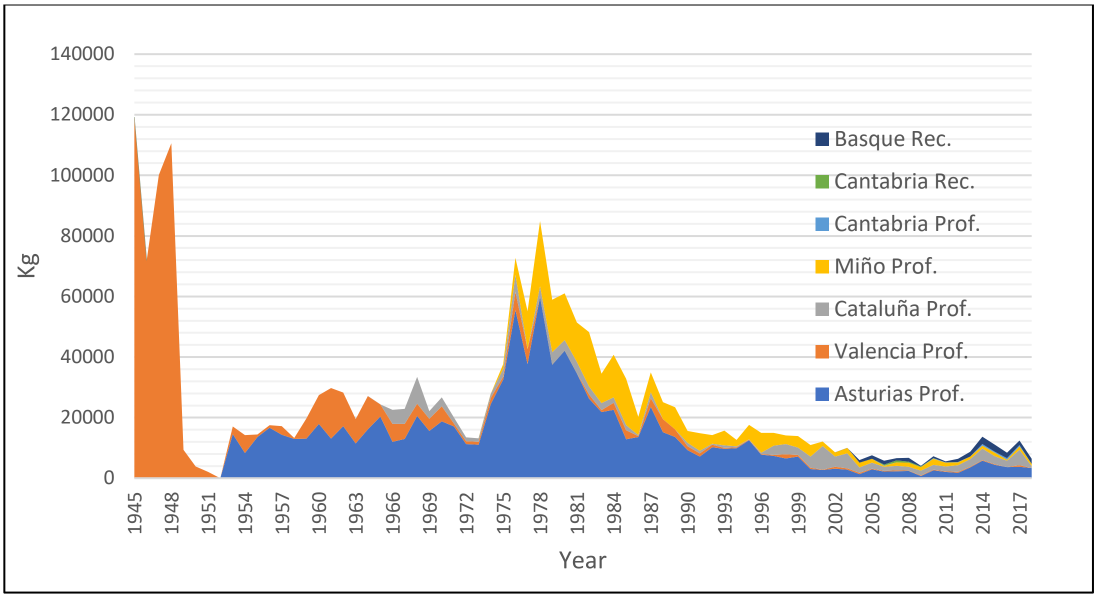


Galicia: Yellow and silver eel fisheries are performed from boat using a limited number of gear. The boats need a specific licence for the fishing gear used in each fishing trip. They might have more than one fishing gear licence, but only one of them can be used in each fishing operation. According to the resolution that allows eel fishing in the Arousa, Ferrol and Vigo Rivers ("Resolución do 23 de decembro de 2010, da Dirección Xeral de Ordenación e Xestión dos Recursos Mariños, pola que se autoriza o plan de pesca de anguía para as confrarías de pescadores das rías de Arousa, Ferrol e Vigo" publicado no DOG nº 251 de 31 de diciembre de 2010), the maximum number of sieves is 80, and the fishing period is limited from the 1st of February to the 29th of October. Nowadays, there are 66 boats allowed to fish using fyke nets, but only 37 of them are active. There are 41 boats with licences for pots but this gear has been practically abandoned, and there is only 1 boat currently working with it.

As mentioned in the introduction, Miño-Sil RBD is one of the most important eel fishing areas in Spain. There are both, commercial and yellow and silver eel fisheries in this RBD. The catches are established using auctions data from the different fishing guilds, which are assigned to a determined river basin. The estuaries are considered basins themselves because of their size, and are managed as basin units. In this way, the estuaries listed below contain catch data from the following fishing guilds: Arousa Estuary: Cambados, Carril, and Rianxo fishing guilds. Eo River: Asturians fishing guilds. Ferrol Estuary: Barallobre, Mugardos and Ferrol fishing guilds. Pontevendra Estuary: Pontevedra fishing guilds. Vigo Estuary: Arcade and Redondela fishing guilds.

Data from the Miño River are collected from the Miño River Command. Two thirds of the river basin drainage area is located inside the autonomous region of Galicia. There is an international stretch of Miño between Spain and Portugal. There, the eel fishing is commercial and land-based fishing is allowed only if sieves are used. The conic tackle was allowed only for 2 years after the publication of the regulation of the international stretch of Miño and until the sand barrier of the Miño estuary is dredged that will facilitate the entry of the migratory species.

Figure 22: Catches of glass eel in Spain by region and modality (prof = commercial, rec = recreational)



Andalucia: A complete closure of the eel fishery has been issued in the management plan. However, during the 2013-2014 campaign, the Department of Environment and Land Management (hereinafter CMAOT) and the fish farm PIMSA S.A. (the largest exploitation of eels in Andalusia) signed an agreement through which it was allowed to fish the species (not differentiated between yellow and silver phase) as long as 60% of the surface remains unharvested.

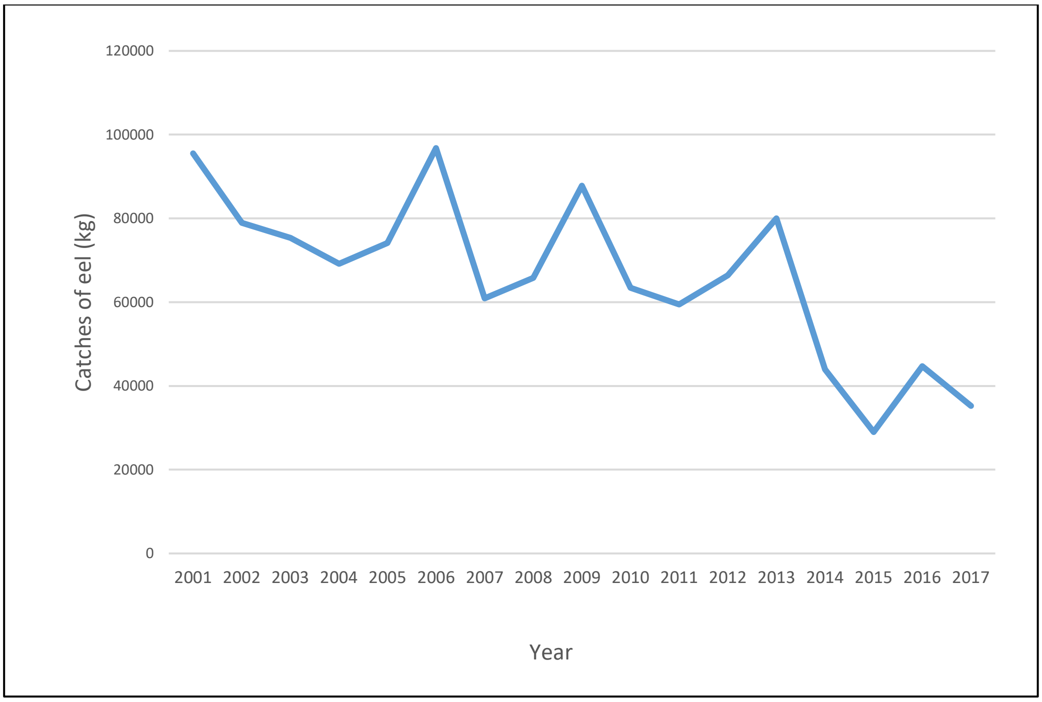
Murcia: Eel fishery is professional and the minimum landing size for eel is set to 38 cm. The number of boats varies between 30 and 40 per year. Eels are fished using a "paranza" (a fixed box made with net and/or canes) or bottom set long lines. This fishery takes place in the Mar Menor and catches are sold through the "Lo Pagán" guild.

C. Valenciana: There are two types of commercial yellow/silver fisheries depending on the province. In Valencia, there are four fishing associations: in the Albufera, El Palmar, Silla, Catarroja associations exercise their rights to exploit yellow and silver eels around the Albufera which is a costal lagoon of 2,100 ha between Turia is and Júcar Rivers. On the other hand, Molinell association operates in Pego-Oliva fen, which constitutes an agrarian landscape with a traditional economic activity. The fisher community of El Palmar is the fishing organization with the major tradition and number of members, and the only one that is allowed to fish in fixed places in the lagoon. Eel fishery in the Albufera has its own regulation and two types of fishing are considered: the fixed place fishing (named "redolins") and the traveling fishing.

Catalonia: There are two RBDs in Catalonia: the Catalonia Inner River Basin, which includes small and medium Rivers, and the Ebro RBD, which is the second largest river basin in Spain. The delta of the Ebro River is the most important eel fishing point in Catalonia regarding the number of active fishers with licence and eel catches. The glass eel fishery is professional in the Ter, Muga and Fluviá Rivers (province of Gerona) and the delta of the Ebro River (province of Tarragona). Recreational fishing on yellow and silver eel is only allowed with rods, except from the lagoons of the Delta, where there is a commercial yellow and silver eel fishery.

BALEARIC ISLANDS: Commercial eel fisheries (>40.cm) were allowed only in Mallorca and Menorca, but there has not been any licence in Menorca during the last seasons. Fishers use a conic pot called "gánguil". In the Albuferas of Mallorca recreational fishery is allowed, but catches are very low. Nowadays, there are 1,000 licences for river fishing and it is estimated that only from 10 to 20% of them are devoted to eel fishery.

Figure 23: Yellow and silver eel catches



Source: ICES

Table 16: Number of yellow and silver eel licences in Spain

	Recreational	Commercial	Total
2006	0	127	127
2007	0	98	98
2008	0	197	197
2009	0	198	198
2010	0	182	182
2011	0	191	191
2012	0	158	158
2013	0	152	152
2014	0	155	155
2015	0	144	144
2016	0	272	272
2017	0	162	162

Source: Survey at regional authorities

According to data of the STECF Annual Economic report (https://stecf.jrc.ec.europa.eu/dd/aqua/graphs) the sales volume of European eel is 406 t and the turnover is EUR 3.35 million, which means that the turnover for European eel is around EUR 8.25 per kg. Although it is not specified to which developmental stage this corresponds, it is assumed it corresponds to yellow and silver eel only, since it would be higher if glass eel were included.

The dependency of Spanish fishers on eel varies substantially (Tab.17). Considering only revenues, in Andalucía (land) the dependency on eel ranges from 1% to 7%, in Galicia (vessels) from 20% to 80% and in Murcia from 8% to 14%.

Table 17: Dependency on eel of the Spanish regions

Year	Region	Catches of glass eel (kg)	Catches of eel (kg)	Catches of other species (kg)	Catches of glass eel (€)	Catches of eel (€)	Catches of other species	Economic dependency (only revenues)	By
2014	Andalucía		0	7500		0	6000	0%	By Fisher
2015	Andalucía		8	7500		72	6000	1%	By Fisher
2016	Andalucía		28	7500		252	6000	4%	By Fisher
2017	Andalucía		48	7500		432	6000	7%	By Fisher
2014	Asturias								
2015	Asturias								
2016	Asturias								
2017	Asturias								
2014	Cantabria	20.8							By Fisher
2015	Cantabria	15.1			4,035				By Fisher
2016	Cantabria	9.3			3,082				By Fisher
2017	Cantabria	10.7			4,626				By Fisher
2014	Cataluña	12	49.3		2658.5	641			By Fisher
2015	Cataluña	11.4	55		3747.3	714.4			By Fisher
2016	Cataluña	23	59.1		6395	768.3			By Fisher
2017	Cataluña	4.2	70.1		1274	981.6			By Fisher
2014	Galicia	7.54	760.54	1,737.22	1,462.05	7,621.03	11,242.48	81%	By vessel
2015	Galicia	5.71	471.73	2,066.08	1,752.29	4,606.17	13,911.24	46%	By vessel
2016	Galicia	9.3	525.84	2,467.50	3,037.64	5,246.46	17,906.87	46%	By vessel
2017	Galicia	10.4	377.38	8,103.19	3,925.24	4,573.89	34,743.25	24%	By vessel
2014	Murcia		798.5			6,372			By vessel
2015	Murcia		442.1	6,344		3,214	42,446	8%	By vessel
2016	Murcia		791.5	5,977		6,094	39,566	15%	By vessel
2017	Murcia		455	6,331		3,917	41,743	9%	By vessel

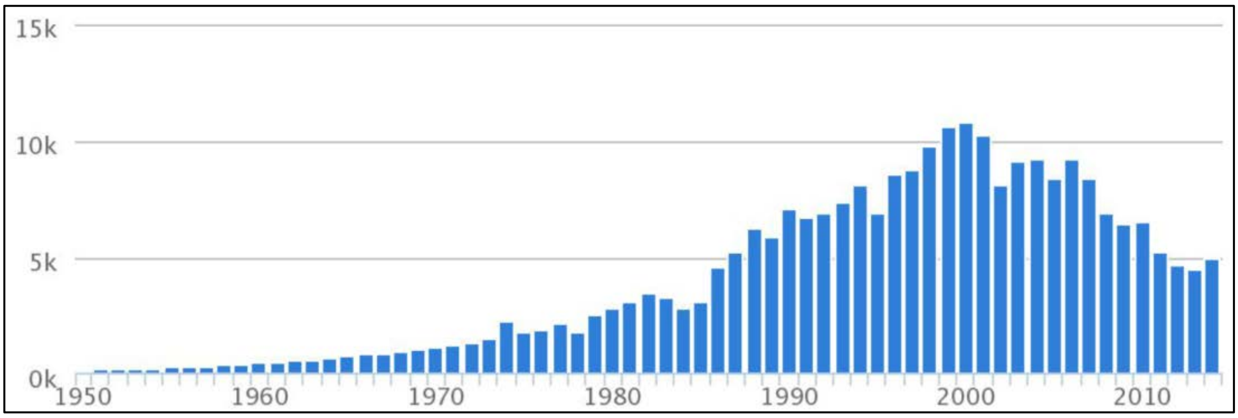
Source: Survey to regional authorities

6.3 Aquaculture and fish processing

6.3.1 General introduction

The production of eel from aquaculture increased substantially between 1950 and 2000 (Fig. 24). After that, the production dropped again to values produced in the mid-1980s.

Figure 24: Worldwide eel aquaculture production (in t)



Source: FAO

6.3.2 Country descriptions

6.3.2.1 France

Aquaculture: Aquaculture in France was mostly focused on the supply of young yellow eel to Italy. Warm water aquaculture facilities located near nuclear power plants (Pierrelatte – Saint André des eaux) have stopped their activities in the 1980s. Other societies have stopped their activities later and were mostly small scaled (Van De Wijdeven 1990). Now the only aquaculture in France is that related to holding or pre-growing glass eels (2017).

Fish processing: The French Market for consumption was little developed in the 1990 and mostly at a regional scale for local market (Van De Wijdeven 1990). This situation still prevails, and consumption areas are located near the large rivers (Somme, Loire, Marais Poitevin, Gironde Adour and the Mediterranean Coast).

6.3.2.2 Germany

Aquaculture: The influence of aquaculture companies on the eel stock is indirect as they rely on the catches of glass eel in other countries. The overall production and related revenues give an indication on the necessary supply of glass eels. In 2011, 18 companies reported an overall production of eel of 660 t. The number of companies decreased to 12 by 2017, but production increased to 1,202 t (data from DESTATIS, German Statistical Federal Agency). There is no information available on prices ex production facility.

In Germany, a substantial stocking program is ongoing to fulfil EMP requirements and to sustain fisheries. Eels are stocked either as glass eels or as ongrown eels reared in aquaculture facilities, which produced 38 t of ongrown eel for stocking purposes in 2017 (Brämick 2018).

Fish processing: The fish processing sector in Germany is substantial with over EUR 2 billion of revenue (STECF 2018). However, eel is not among the main species for the processing companies and no information about their overall importance is available.

6.3.2.3 Greece

Aquaculture: Until 2017, four fish farms rearing eels operated in the Western Greece. After the siege by EUROPOL in February 2017, revealing illegal trade of glass eels via Greece to China, only two fish farms remained active in eel rearing.

These eel farms import glass eels from the UK and France and rearing takes place in closed aquaculture systems. The amount of imported glass eels ranged from 32 kg (2015) up to 1,598 kg in 2016. These two companies are involved in both, eel aquaculture and eel processing.

Fish processing: The two aforementioned companies are involved in eel rearing and eel processing. They trade eels alive, frozen or smoked. Most of the production (almost 95%) is exported to other EU countries, like Germany, Italy, Poland, Netherlands, Croatia and Spain and only 2-3% is sold in the Greek market. The annual aquaculture production is not stable, but depends on the demand of the market. It was lowest in 2014 (164,895 t) increased in 2016 (289,464 t) and was at 184,157 t in 2017.

Regarding the price of the products, in 2017 the products that were exported had a mean value of EUR 10.98 per kg, while the products sold in the Greek market had a mean value of EUR 9.5 per kg.

6.3.2.4 Spain

***Aquaculture*:** According to Perez et al. (2004), there were four producers of eel in aquaculture in 2004 in Spain. However, in 2018 only one company from Valencia, the most productive, continued its activity aquaculture production by EMU is presented in Tables 18 and 19.

In Spain, the value of the eel aquaculture production was EUR 4,435,829 and EUR 3,425,489 in 2015 and 2016, respectively.

Fish processing: In Spain there are several companies that in addition to trading, also process eel. For example, 'Angulas Roset' smokes and filletes eels. Most of the glass eel traders, in addition to selling live glass eel, freeze or boil and packet them for human consumption. The price of the final product depends on the type of product and processing.

Table 18: Freshwater aquaculture production of yellow eel (t) by EMU

Year	ES_Anda	ES_Basq	ES_Vale
1998	130		100
1999	145		90
2000	109		80
2001	80		70
2002			60
2003			50
2004	14		40
2005			30
2006	70		20
2007	11	80	10
2008	11	65	369.7
2009		80	
2010		31.5	
2011		19.2	4.4
2012			
2013			82
2014			5.4
2015			82
2016	0	0	0
2017	0	0	0

Source: Korta and Díaz 2018

Table 19: Open sea aquaculture production of yellow eel (t) by EMU

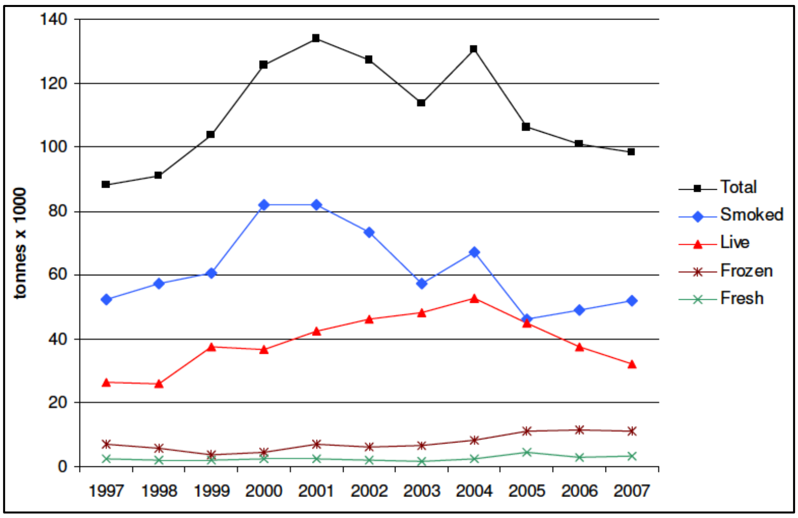
Year	Es_Anda	Es_Astu	Es_Cata	Es_Vale
1998	16.7	0	700	200
1999	37.9	0	300	200
2000	22.5	0	3.7	275.4
2001	20.9	0	0	238
2002	34.5	0	0	260.3
2003	31.4	0	0	260.2
2004	46	0	0	316.7
2005	20.4	0	0	300.5
2006	19.2	0	0	185.6
2007	16.7	0	0	261.4
2008	14.1	0	0	
2009	13.4	0	0	399.2
2010	12.2	0	0	348
2011	7.2	0	0	437.8
2012	860	0	0	371.9
2013		0	0	311.3
2014	12	0	0	385.4
2015	0	0	0	372
2016	0	23	0	329.9
2017	0	0	0	292.3

Source: Korta and Díaz 2018

6.4 Trade and Markets

Eel is marketed in several ways. The main trade of this species is alive for both, glass eel and yellow eels. For fresh consumption, they are slaughtered by decapitation, but for the preparation of products, the sacrifice is usually done by electrocution. Other ways of international trade are: fresh or chilled yellow eels, frozen, smoked or canned. The transport of live eels is carried out in trucks equipped with tanks and oxygenation, thermally insulated. The air travel to Asian countries used to be done in expanded polystyrene boxes with dry ice and pores for ventilation, where eels can survive up to 36 hours (Perez et. al. 2004).

Figure 25: Trade of eel between 1997 and 2007

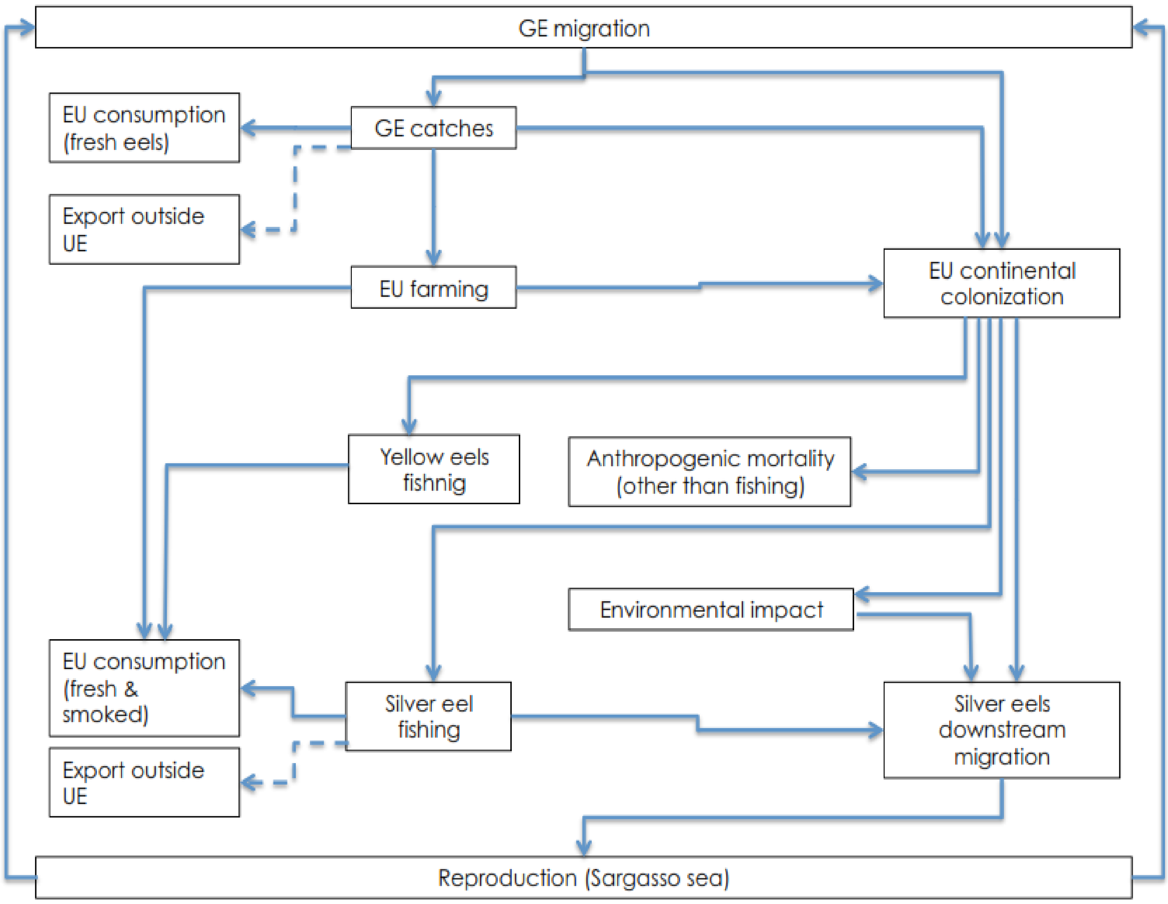


Source: Crook 2010

According to the European eel market chain (FranceAgrimer 2014) the catches have four different destinations: direct consumption, export, farming and stocking. Although the production increased significantly until 2000 the amount of trade increased after 1997 but decreased after 2004 and was in 2007 at around the same level as 1997 (Fig. 25, see also the market chain in Fig. 26).

There is a substantial import of eel from outside the EU (mainly China and New Zealand). In 2017 about 1.500 t (EUROSTAT Comext database), which roughly corresponds to 1/5 of the total eel trade, is imported. While the data do not distinguish between different eel species, these imports must be considered to not consist of European eel, since this would require a specific CITES permit.

Figure 26: The European eel market chain



Source: FranceAgrimer

6.4.1 Glass eel market (Spain and France)

In Spain, trading is another important sector supplied by eel fisheries. There are at least 14 trading companies (5 in the Basque Country, 5 in Cantabria, 1 in Asturias and 3 in Catalonia). The Basque Country was the pioneer of glass eel consumption. This is the reason why Basque Country was the driver for the exploitation of glass eel in other regions not only of Spain, but also other European regions.

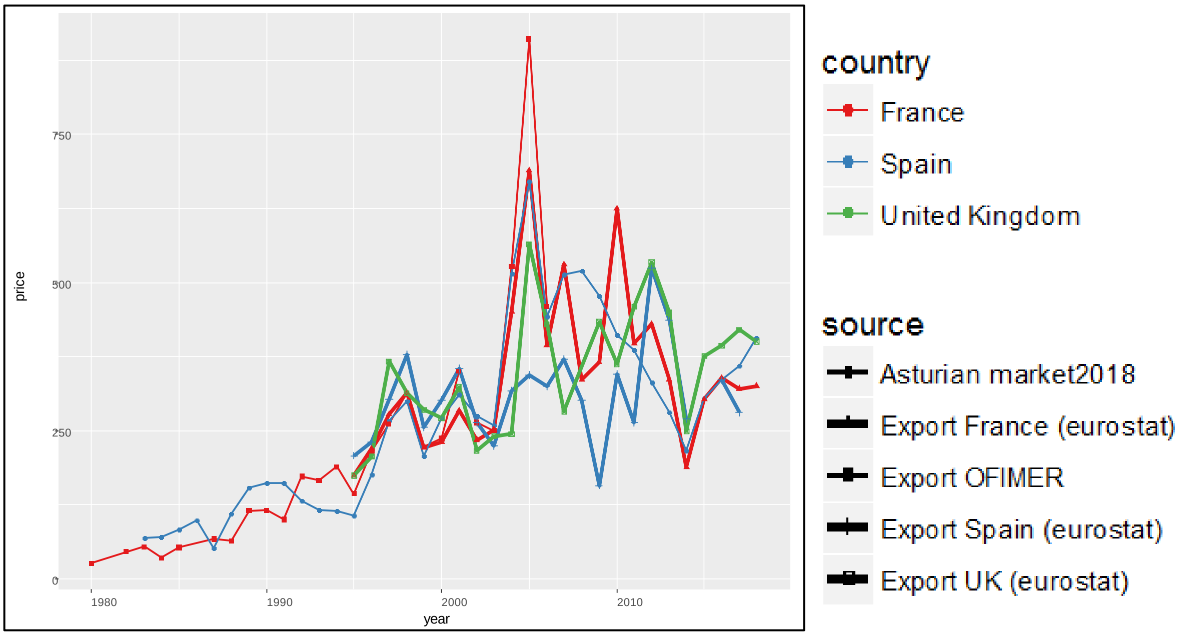
In France, glass eel fisheries have been active since the end of the 19th century. Fisheries and trade developed mainly in the south of France, exporting eels to the Basque Country by railway. After 1936, the Spanish war and Franco's regime closed the Spanish borders and hence restricted the trade of eels to Basque buyers. This market "officially" disappeared until 1975 although smugglers still supplied the Spanish Basque market and buyers crossed the frontier. However, international troubles at that time suggest that glass eel fisheries were probably restricted to a local market until 1945 (Briand *et. al.* 2007). Until decree 41/2003 prohibited the sale of eels in the Basque Country, the eel marketing companies based on Aguinaga/Usurbil bought glass eel directly from local fishers, although eels caught in rivers of the Basque Country only represented 3-4% of the total purchase volume. This direct sale produced the greatest economic benefits for the fishers, reaching sales prices higher than those offered by eel companies. Although Basque glass eel traders dominated the European glass eel market, nowadays traders from other regions of Spain (Delta del EBRO, Asturias) and Europe (France and UK) have replaced them. In fact, some of these traditional companies have abandoned the commercialization of glass eels and today exclusively produce alternative products (e.g. Angulas Aguinaga S.A., producers of La Gula del Norte).

In the French Basque region, the trade is based mostly on eel wholesalers of France, where most of the eel are traditionally sold to Spain. The number of companies trading eel has been decreasing as the market is very competitive and many small family-size companies were unable to compete for the Chinese market.

According to FranceAgrimer (2014), Spain captures and imports glass eel from UK, France and Portugal. These glass eels are marketed to the grocers/glass eel traders. In Valencia (Spain), fishers from the Albufera and from the Bullent and Molinell rivers must give a percentage of their glass eel catches to regional managers for stocking (10% during the last season). These glass eels are fattened in the public Centre for the Production and Experimentation of Warm Water Fishes until they reach a weight of 8-10 g. These ongrown eels are then released in rivers and wetlands of Valencia. In the rest of the regions, regional managers have also obliged fishers to donate a percentage of the glass eel catches punctually, but Valencia is the only one doing that in a regular basis.

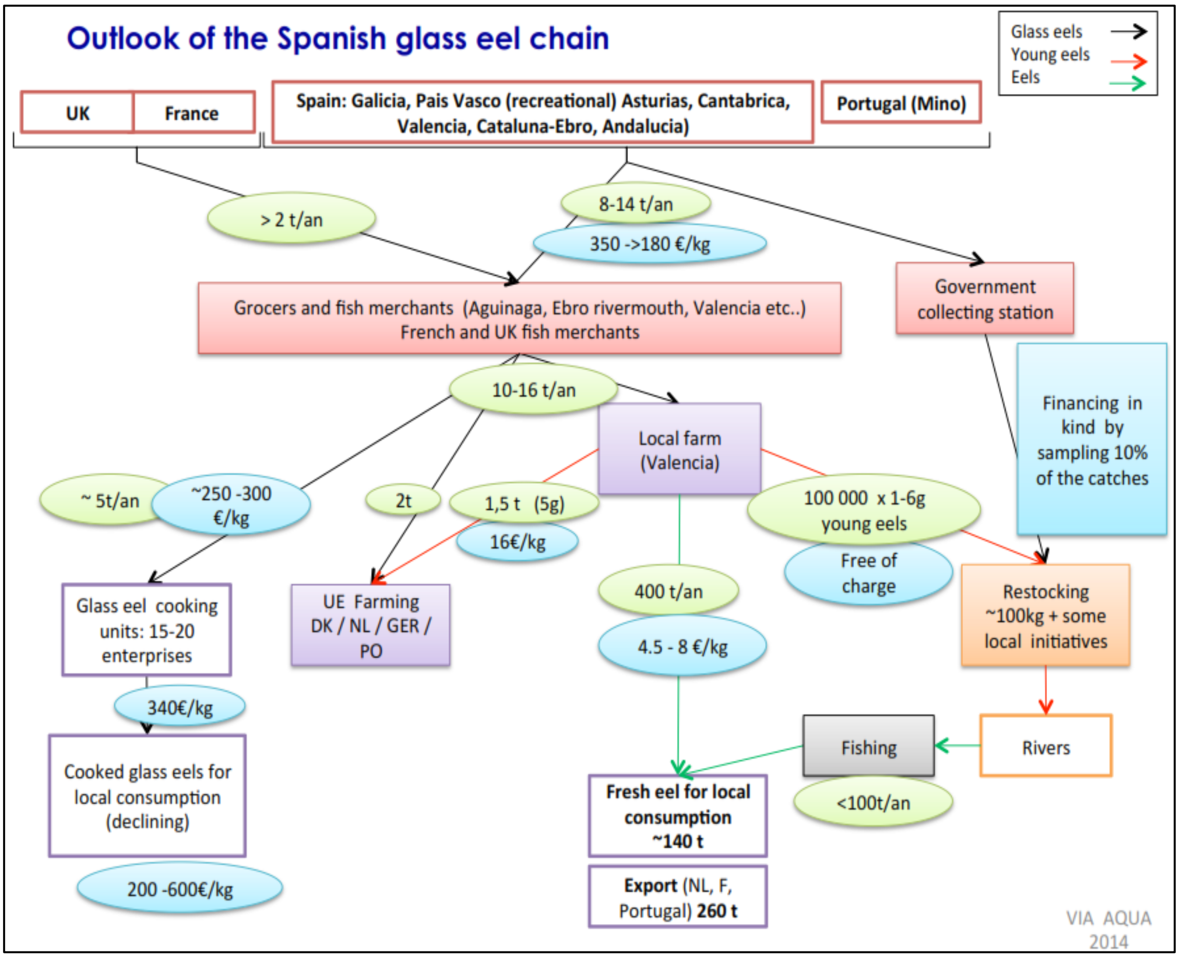
Spanish grocers and glass eel traders sell the glass eel to the farms (local and other European farms) and another amount goes to the glass eel cooking enterprises who in turn sell the product for the local consumption. The glass eel has a strong cultural root in Spain because it is a product with a long tradition in festive seasons (Christmas, family occasions, etc.). The opening of glass eel trade to Asia and shortage of glass eel availability worldwide has progressively led to an increase of prices from the 1980s to 2015 (Briand et al. 2008) (Fig. 27). The CITES Regulation has affected the glass eel fisheries and markets. The traditional market for stocking in Europe led by the UK and the French glass eel trade chain has been more impacted as illustrated by the lower prices obtained in France. Prices have been the lowest in 2014 when recruitment was highest. From 2011 higher prices for trade have been obtained in the UK than for Spain and France. The price for glass eel has stabilized after the implementation of the eel management and CITES (Fig. 27).

Figure 27: Trend is glass eel price, prices corrected from inflation



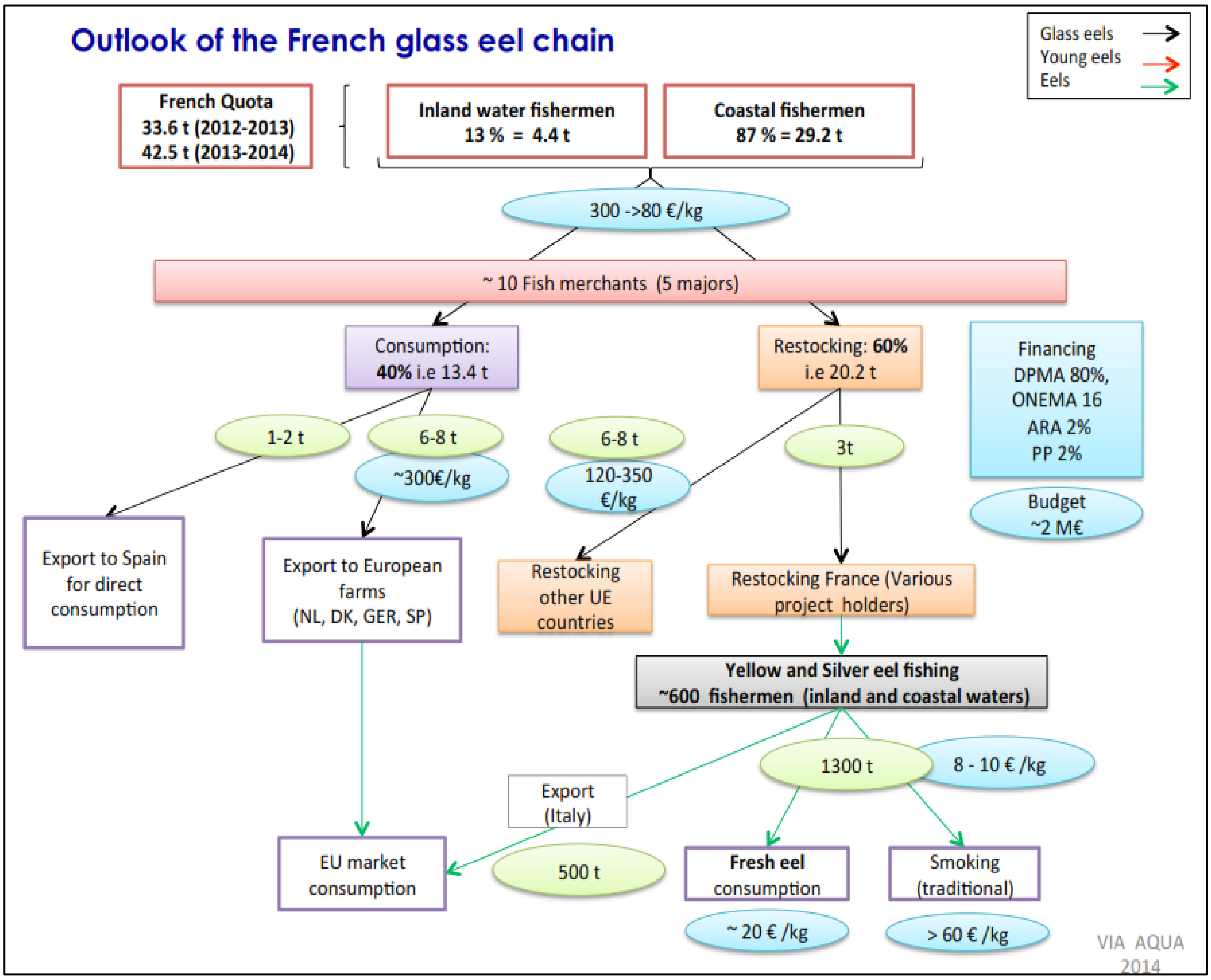
Source: Data from Eurostat, OFIMER, AZTI. Prices in Spain represent the prices in the Asturian market and the prices for Eurostat.

Figure 28: Spanish glass eel chain



Source: FranceAgrimer, modified by AZTI

Figure 29: French glass eel chain



Source: FranceAgrimer

The dimension of the illegal glass eel market is discussed in section 2.2.2.

Spain imports glass eel from UK, France and Portugal in addition to its own fishery (Fig. 28). The Spanish production goes to the grocers and glass eel traders. In Valencia 10% of the catches goes to a public farm for stocking. The glass eel traders sell the glass eel to the glass eel cooking units, farm companies outside of Spain and local farm companies. Local farm companies sell an amount of young eel for stocking purposes. As shown in Figure 28, glass eel traders have an important role in the glass eel value chain.

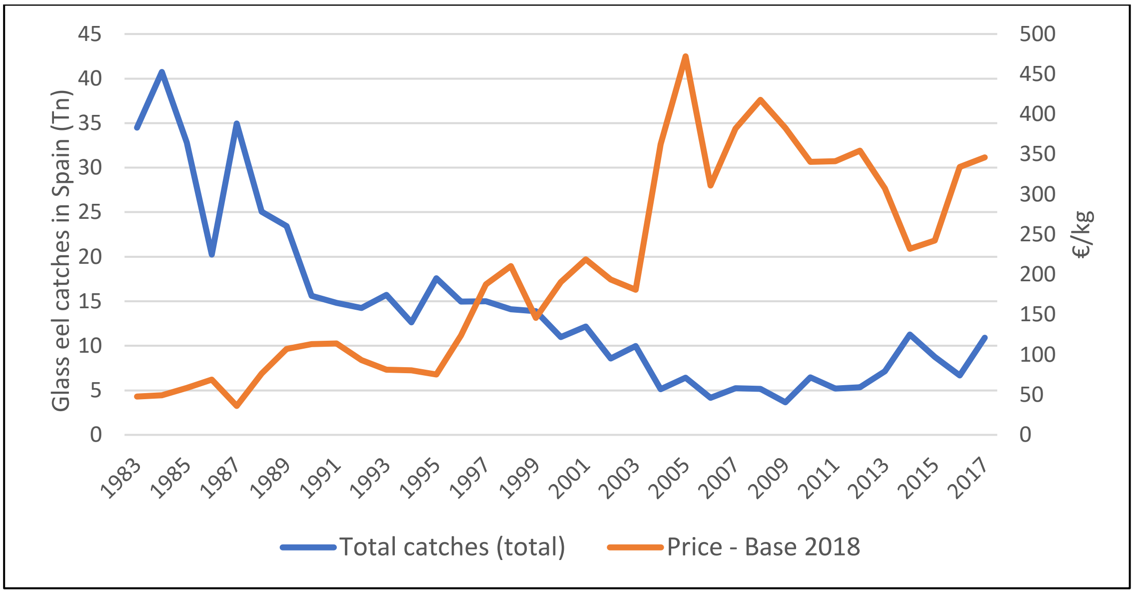
According to FranceAgrimer, 40% catches of glass eels in France are exported to Spain, European farms, and 60% are used for stocking (Fig. 29).

In Spain, there is a negative correlation between glass eel catches and prices (Fig. 30). Taking catches and average prices into account, the total value of the glass eel catches in Spain ranges in the last 5 years, from EUR 2 to EUR 3.7 million per season.

The direct glass eel consumption market is quasi-exclusively Spanish. FranceAgrimer estimated the direct consumption in 2014 at around 5 ton per year, essentially controlled by Spanish fishers.

However, the statistical basis for this estimation is not explained. The rules to access this market are not very clear. French are less present on this market since it is decreasing, and it is no longer a strategic market (FranceAgrimer 2014).

Figure 30: Glass eel catches and prices in Spain



6.4.2 Yellow and silver eel markets

6.4.2.1 France

The market for yellow and silver eel in France is split between small yellow eels < 20 cm, caught for the largest part in the Mediterranean lagoons and also corresponding to pre-grown glass eel and sent to Italy (the traditional market root – 71 t average 1012-2018), Germany (28 t) the Netherlands (17 t) and Belgium (1 t). Prices range from EUR 25 to EUR 100 per kg.

Market for yellow and silver eel is mostly local in traditional fishing areas (Somme, Loire, Marais Poitevin, Gironde, Adour and the Mediterranean coast). The eels are also sent to the European market, 99% as live eel – average 2012-2018 207 t. The largest export is to Italy (142 t), Belgium (58 t) and an additional 6 t to the Netherlands. The remaining trade is negligible (< 2 t to Romania, Sweden, and Germany). The price to Belgium ranges from EUR 5 to EUR 30 with a median price around EUR 12. Prices to Italy are between EUR 4 and EUR 10 with a median price of about EUR 8.

6.4.2.2 Germany

In Germany, contrary to most of the catches of coastal commercial fisheries, freshwater fishers sell most of their catches directly or with very little steps in between to consumers. In 2017, coastal eel fishers reported 51.6 t of eel catches with an average price of EUR 9.28 (BLE 2018) - a quite high price for the fishers for a kilo of fresh fish (in comparison the price for a kg of herring is EUR 0.36 and cod EUR 1.76). However, the price of EUR 9.28 applies only when fishers sell their catch to a wholesaler or cooperation. When directly sold to consumers, they receive between EUR 13 and EUR 34 per kg. For a kg of smoked eel even prices between EUR 20 and EUR 50 are achieved (Brämick 2018). This alone is an indication how important eel catches can be for individual companies and especially also small smoking facilities.

6.4.2.3 Greece

Similarly to Germany, also in Greece eels are sold directly from the fishing cooperatives to wholesalers, mainly from abroad. According to data provided by the Directorate General of Fisheries, Ministry of Rural Development and Food, the price for eels sold for export was EUR 9.27 per kg in 2017. The price for Eels sold to wholesalers for domestic consumption was EUR 7.73 per kg. However, the price for the Greek consumer is up to EUR 12 per kg. For the fishing cooperatives, eel is of high economic importance since the most abundant species they trade are grey mullets (Mugilidae), which are sold not higher than EUR 1.0 per kg. For smoked eel, consumers must pay from EUR 70 to EUR 85 per kg in Greece.

6.4.2.4 Spain

The yellow/silver eel market is a traditional market in Spain. The first sale prices for yellow/silver eel range from EUR 7.27 per kg to EUR 14 per kg (data reported to the survey corresponding to years 2015:2017). According to Servizo de Producción Pesqueira, in the period 2004 – 2006 the average price of eel was EUR 8.1 per kg. The fishers (marine fishers) usually sell their eel through fishing guilds. The guilds usually charge a percentage of the sales, but according to the survey done to the regional authorities, there are also other fishers that sell their eel directly to restaurants.

6.5 Summary and conclusions

In this chapter, we describe the different sectors affecting the eel stock. While commercial and recreational fisheries (marine and freshwater) have a direct impact of on the eel stock, fish processing and aquaculture companies are only indirectly affecting the development of the eel stock as they are dependent on the delivery of eels from fisheries, but they certainly increase the demand. Also, eel trade influences the capture sectors as, for example, high prices for glass eel on Asian markets led to an illegal market in Europe after trade was banned due to the CITES listing.

Although commercial coastal and freshwater fishing companies and individual fishers might be partially or totally dependent on eel catches, this dependence cannot be quantified since economic data especially for individual inland fishers that carry out commercial fisheries are scarce. Therefore, data collection is urgently needed to quantify the contribution of eel for the total income of those companies. It is obvious that eel aquaculture, in case eel is the main product, is dependent on the availability of glass eel supply. Eel aquaculture together with the production of yellow eels for consumption purposes also profits through the sale of ongrown juvenile eels for stocking. For the fish processing sector eel may be important for a small group of specialised companies. However, in general eel forms just a small fraction of the total amount of processed fish in Europe.

The number of fishers catching eel decreased substantially since 2006. This is not only due to the restrictions following the Eel Regulation with a decrease in eel catches, but primarily because the small-scale fishing sector is generally under economic pressure and the fishers have problems to stay in business.

Glass eel fisheries are very traditional at the Atlantic coasts especially of France and Spain. They are locally important (both in economic and social terms) and provide eels for stocking purposes in other parts of Europe and for aquaculture production.

There is a substantial decrease in fishing effort in glass eel fisheries. However, prices for glass eel are negatively correlated with landings thus revenues stayed high. The high prices are also an incentive for the illegal markets for glass eels.

7 SOCIO-ECONOMIC REPERCUSSIONS TO STAKEHOLDERS OF POSSIBLE STOCK MANAGEMENT MEASURES

Key findings

- Environmental, social and economic impact assessment is a standard instrument to inform decision makers regarding impacts of new or revised regulations in the EU.
- There was no impact assessment of the eel regulation so far.
- Only very limited economic data of the companies involved in eel fisheries is available and an impact assessment would require a substantial data collection exercise.
- Estimated revenues for silver, yellow and glass eel fisheries are at about EUR 50 million per year.
- European eel aquaculture is depending on glass eel catches and in case of a closure of glass eel fisheries would have to close its facilities.
- The fish processing sector specialized on eel products also relies on European eel aquaculture and to a minor extent yellow and silver eel fisheries. To what extent European eel could be substituted by imports of other eel species from outside Europe could not be assessed.
- The impact of two eel migration measures on hydropower companies could be properly assessed: a seasonal closure of hydropower facilities obstructing migration routes and installing upstream and downstream migration facilities.
- A 10-week seasonal closure of hydropower facilities impacting eel migration would yearly impact the aggregated hydropower companies' revenues with an estimated EUR 634 million in France, EUR 532 million in Spain, EUR 124 million Greece and EUR 23 million in Germany.
- In France, installing upstream and downstream migration equipment on hydropower facilities impacting migration would be 1.7 to 4.9 times as costly as a 10-week seasonal closure of hydropower facilities. Thus, installing migration equipment would be more cost effective after a two to five-year period, ignoring maintenance costs related to the installed migration equipment.
- Regional assessment would allow equipping only the most impacting dams, which would substantially lower the estimated costs of installing migration equipment and would potentially diminish a large fraction of the overall eel mortality.
- The costs of trapping and transporting eels vary per location and no countrywide data is available to make a proper cost assessment.

7.1 Introduction

In this chapter we analyse possible economic impacts of eel management measures on the economic sectors described in Chapters 5 and 6. The assessment of environmental, social and economic impacts has become a standard procedure for every new or revised fisheries regulation in the EU (COM 2005/97). The aim is to assess trade-offs between different management options from an economic point of view. Impact assessments issued by the European Commission are for proposals on new as well as revised regulations. They require solid background information, mostly provided by researchers and consultants outside of Directorate-Generals (DGs) of the European Commission. For this report, basic economic impacts were considered.

A management framework for eel within the EU was established in 2007 through an EU Eel Regulation (EC Regulation No. 1100/2007; EU 2007), but an internationally coordinated management plan for the whole stock area, which extends beyond the EU, is lacking. The objective of the EU Regulation is the protection, recovery, and sustainable use of the stock. To achieve this objective, EU Member States have developed EMPs for their River Basin Districts, designed to reduce mortality to a level that allows at least 40% of the silver eel biomass to escape to the sea with high probability, relative to the best estimate of escapement that would have existed if no anthropogenic influences had impacted the stock. ICES has evaluated the conformity of the national management plans with EC Regulation No. 1100/2007 (ICES 2009, 2010) and the progress in implementing EMP actions (ICES, 2013a, b; 2018a in progress). The EU Member States produced Progress Reports in 2012, 2015, and 2018. The 2015 has not been post-evaluated at the time of writing this report and the 2018 report assessed only the biomass indicators and did not evaluate the implemented measures. As described in the previous chapters a number of measures are already implemented. However, it was unclear already at the time of the adoption of the eel management framework what beneficial effects these measures will have for the eel stock. The EC Regulation of 2007 (EU 2007), establishing measures for the recovery of the stock of European eel, has not been evaluated by ICES for its conformity with the precautionary approach and has for this reason not been used as the basis for this study.

The EU Eel Regulation is based on the provision of nationally elaborated management plans on the level of River Basin Districts and presumes the following assumptions:

1. The achievement of the 40% target of the Eel Regulation is sufficient to lead to a recovery of the stock.
2. The estimates of escapement that would have existed if no anthropogenic influences had impacted the eel stock (Bo) are correct, irrespective the fact that these estimates vary substantially between different EMPs and have never been properly evaluated.
3. The underlying escapement models that are used to calculate the stock indicators are retrospectively scientifically approved, although not all of them have been scientifically evaluated.
4. The nationally elaborated EMPs are retrospectively scientifically approved, although they have never been scientifically evaluated.

There is wide consensus within the scientific community that for the improvement of the stock status the mortality of eel needs to be reduced – without exactly knowing to which extent.

Section 7.2.1 provides general background information on the methodology for impact assessments. The general economic considerations for an impact assessment are described in section 7.2.2 and possible scenarios for management approaches distinguishing between scenarios regarding fisheries (including indirect effects on aquaculture and fish processing companies) in section 7.2.3. Effects on companies running river installations are described in section 7.3. An assessment of impacts is provided to the extent possible and it is described what background information is lacking to carry out a thorough economic impact assessment. In addition, information on what needs to be done in the future to enable such an analysis is provided.

7.2 Fisheries

7.2.1 Standard approach for assessment of impacts

The assessment of economic impacts (IA) is a common tool for an evaluation of environmental, social and economic impacts within the Common Fisheries Policy (COM 2015). In case scientific background work is required, there is a standard procedure proposed by STECF for the impact assessments of fisheries management plans (STECF 2010, Simmonds et al. 2011). Although this procedure is not fully comparable with an economic assessment required for the eel management measures, it nevertheless provides a reliable background to explain the necessities for IA and their process. In case of the assessment of impacts on companies running river installations the procedure may have to be adjusted but in principle the same steps would be necessary.

Step 1 - Scoping event: In a scoping phase, the management authority, researchers and stakeholders clarify the scope of the analysis. It is important to narrow down possible scenarios to a manageable number and, especially, to analyse options that seem to be implementable and guarantee the required effects. The involvement of stakeholders at this stage is important to improve the acceptance of measures and the results of the IA.

Step 2 - Analysis: In a second phase, researchers assess possible impacts and provide the results in an understandable way. For the assessment of, for example, long-term management plans, bio-economic models are applied that include a biological and economic module. In data-poor cases, interviews and background data collection are necessary to enable at least a limited analytical analysis of impacts of management measures (e.g. Goti 2017).

Step 3 - Assessment meeting with stakeholder feedback: In a second meeting, the results of the analysis are presented and discussed with managers and stakeholders. The results can be adjusted according to their feedback. Thereafter, the report is delivered to the persons preparing the impact assessment report.

Step 4 - Impact assessment report: The researchers are in case of the new or revised regulations on EU level not in charge of providing the internal impact assessment report within the European Commission. The fourth step is, therefore, the preparation of the report by the responsible persons within DG Mare and the presentation of that report to the respective authority within the European Commission. After approval, the report is published.

The described procedure is the standard approach for new regulations within the CFP and at least the steps 1-3 are common for all IAs. Such a standardized assessment has, to our knowledge, never been performed for the European eel; neither for the implementation of the Eel Regulation on a European level, nor for single management plans on a River Basin District level.

7.2.2 General economic considerations

***Short vs. long-term gains*:** All measures that are implemented to support the recovery of the eel stock will have short-term costs compared to largely uncertain long-term gains. To effectively reduce eel mortality, fishers will have to reduce catches and the reduction of mortality at river barriers will produce additional costs.

In the case of eel it is not possible at this stage to have a clear link between the proposed management measures and the effects on the stock. There is, for example, no bio-economic model to predict the development of the eel stock depending on the management measures and the resulting behaviour of the fishers. Therefore, we cannot compare the short-term costs of management measures with the long-term gains from an improvement of the eel stock.

***Top down vs. bottom up management*:** As described in Chapter 3, many measures have been proposed and implemented to comply with the goals of the European Eel Regulation (Council Regulation 1100/2007). Possible instruments were already listed in the Regulation, but MS could also implement other measures to reach the target. Such approaches, in which MS decide on the selection of the management instruments, are called 'results-based-management-approaches'. The EU defined the management objective at the central level, while MS decide on the concrete measures to reach that objective (this procedure requires in many cases that several MS work together to manage in a regional context).

In general, this approach is preferable to a command and control approach where everything is decided at the central level. For European eel management, however, it is to discuss, if the 40% biomass-based objective is the preferable target over a mortality-based target. On the one hand, this target is largely influenced by the definition of B0, the estimate of escapement that would have existed if no anthropogenic influences had impacted the eel. The scientific basis for such an estimation is lacking and therefore, these estimates vary substantially between EMPs. On the other hand, such an approach does not consider that natural recruitment has dramatically declined since the 1970s. In areas of low to completely absent natural recruitment, stocking is the only possible way to fulfill the escapement targets. For this reason, stocking programs have been introduced in many countries, despite stocking is heavily disputed as a suitable method for a stock recovery of the European eel within the scientific community. ICES (2018) requests internationally coordinated research to determine any net benefit of stocking on the overall population, including carrying capacity estimates of glass eel source estuaries, detailed mortality estimates at each step of the stocking process, and performance estimates of stocked vs. non-stocked eels. Stocking is even performed upstream of hydropower dams and other obstacles, which effectively impede silver eel escapement. Finally, the 40% escapement target has never been scientifically evaluated for compliance with the Precautionary Approach. Therefore, the move to a mortality target may be the preferable option for the setting of an overall objective.

***Direct vs. indirect effects*:** Management measures directly affect certain sectors, for example the fishing sector. Limiting the eel catches will reduce the revenues for companies. In addition, management measures often have indirect effects on secondary sectors. For instance, in case of a total closure of the glass eel fishery, aquaculture companies would have no seed supply for their production. This scenario would also affect processing companies, as the supply of eel for fish processing companies would be significantly reduced. In theory, it could be possible to use imported American glass eels for aquaculture purposes as an alternative. However, in this case the aquaculture companies would have to apply for a permit according to the EU Regulation 708/2007 "concerning use of alien and locally absent species in aquaculture", which sets high security standards. In addition, sufficient sources of American glass eels would have to be available, what is also not guaranteed.

7.2.3 Possible management scenarios - Fisheries

The economic impact assessment for eel fisheries and installations is quite different from other fish species (also see ANNEX IV.5) and the description is divided into two respective parts.

***Data availability*:** Economic data for the European eel fishery is generally lacking. MS are required to deliver economic data for marine fisheries, but not for inland fisheries. In addition, fishers catching eel belong to the small-scale sector for which economic information is usually scarce. Only coastal fisheries provide basic economic data in the yearly data collection and these data are not sufficiently detailed to distinguish between vessels catching eel and vessels without eel landings. The main reason is that eel catches form a very small fraction of the overall catches of the vessels and the national fleets. Only a specific data collection, including both, marine and inland waters, would provide some of the necessary data from individual fishers. The organisation of focus groups with some of the potentially impacted fishers could provide information on possible impacts of eel management measures at least on a regional or national level.

For inland fisheries, even fewer economic data is available. So far, no regular collection of economic data is requested in e.g. Data Collection Framework (DCF). For some countries, basic figures on number of companies, employment etc. is available, but no costs and earnings data of companies that would be necessary to issue a specific data collection exercise in case a thorough analysis is required.

In Chapter 5, information on companies from the aquaculture and fish processing sectors is provided. For aquaculture companies some basic economic data is available. This is also true for large fish processing companies, but most of the activities are within small facilities, e.g. smoking of eel, and an overall estimate of economic effects on the fish processing sector is therefore not possible. Such an estimate would also require a specific data collection exercise.

***Impacts of management measures*:** Four fisheries scenarios are elaborated in this study. Extreme scenarios or specific cases were selected in order to show trade-offs when implementing management measures. No mixed measures scenarios were made, as these hampers the identification of factors for observed changes. The scenarios presented below are solely based on economic considerations regarding specific management options, not due to their possible biological effects. It is not possible to assess the effects of management measures for the whole panmictic eel stock. Depending on data quality and availability, the impact of the following management measures on stakeholders is (partly) assessed or data needed for a proper impact assessment of these measures are listed:

Scenario 1: Total closure of yellow and silver eel fisheries, while a limited glass eel fishery remains open to supply aquaculture and processing facilities.
Scenario 2: Total closure of the glass eel fishery and (as a consequence) also cessation of stocking activities.
Scenario 3: Total closure of eel fisheries for 5 years and compensation of fishers.
Scenario 4: Closure of recreational fisheries

The Consortium decided not to analyse seasonal closures as a specific case or scenario although this is a management measure already implemented at the moment. The analysis of economic effects does not vary much from the total closure scenario or is even more complicated as information on the reduced catches during a period of closure compared to the overall landings may not be available at the moment. For the already implemented temporal closure of eel fisheries in marine waters, MS widely use the offered time window to set the actual closure to times when the impact on fisheries is minimal, so effectively elude the Regulation.

Scenarios 1 and 3: For the assessment of impacts of scenarios 1 and 3, direct effects on the fisheries need to be assessed. For that the following data would be necessary (Tab. 20). The availability of these data was included only for two countries (Germany and Spain), as only minor differences are expected between countries.

Table 20: Data requirements and availability for the assessment of Scenarios 1 and 3

	Necessary data for assessment	Availability for Germany	Availability for Spain
Marine and Freshwater Fisheries	Catches/official landings EU/specific countries	ICES WGEEL report	ICES WGEEL report
	Earnings data	Available with average prices for eel landings	Available with own estimation of average prices and in general terms, not by individual fisher.
	Cost data	Not available or only in very few cases	Only data that were obtained in a survey done in this project. Only for one region. No public statistics.
	Employment	Limited availability (estimations from number of licences possible)	Can be estimated from the licences. It is not a FTE.
Glass eel fishery	Catches/official and unofficial landings	n.a.	ICES WGEEL report official landings. Unofficial landings are not available.
	Earnings data	n.a.	Available if average prices are calculated.
	Cost data	n.a.	No official data. There are some data from the survey done in this project.
	Employment	n.a.	Can be estimated from the licences. Not data of FTE.

For scenario 3 and partly for scenario 1, a limited analysis of possible direct economic impacts on the fisheries can be provided:
The overall reported landings to ICES in 2017 were 2,224 t (ICES 2018a). This does not include landings from countries for which only FAO data is available. For those countries the latest available data is from 2016. For the years 2012-2016 the overall landings (including ICES and FAO data) were: 3,014 t (2012), 3,205 t (2013), 3,100 t (2014), 2,534 t (2015) and 2,948 t (2016). On average for the years 2013-2017 fishers landed approximately 3,000 t.

Official glass eel landings varied between 42.8 t in 2012 to 67.1 t in 2017. On average fishers landed 54.7 t between 2012 and 2018.

On the basis of these data, a total closure of eel fisheries would result in the loss of the revenues from those catches for fishing companies. In Germany, the price for eel in commercial catches fluctuated in the last year around EUR 10 (BLE 2018). Assuming this as an average price per kg for silver and yellow eel and assuming EUR 360 per kg of glass eel, this would account for annual losses of approximately EUR 30 million for yellow and silver eel fisheries and EUR 20 million for glass eel fisheries. Assuming a slightly lower price for yellow and silver eel of EUR 8 or a higher price of EUR 13 would result in revenues of EUR 24 million and EUR 39 million, respectively.

A compensation for these losses would therefore require about EUR 50 million per year. These are, however, only the official landings with the prices marine fishers put in their sale slips, which they send to the authorities. In reality, many of the companies also process the fish and then directly sell it to the consumer at higher prices.

Scenario 2*:* For the assessment of impacts, which in this case include direct effects on fisheries as well as indirect effects on aquaculture and fish processing, the following data would be necessary (Tab. 21).

Table 21: Data requirements and availability for the assessment of Scenario 2

	Necessary data for assessment	Availability for Germany	Availability for Spain
Marine and Freshwater Fisheries	Catches/official landings EU/specific countries	ICES WGEEL report	ICES WGEEL report
	Earnings data	Available with average prices for eel landings	Available with own estimation of average prices and in general terms, not by individual fisher.
	Cost data	Not available or only in very few cases	Only data that were obtained in a survey done in this project. Only for one region. No public statistics.
	Employment	Limited availability (estimations from number of licences possible)	Can be estimated from the licences. It is not a FTE.
Glass eel fishery	Catches/official and unofficial landings	n.a.	ICES WGEEL report official landings. Unofficial landings not available.
	Earnings data	n.a.	Available for Spain if average prices are calculated.
	Cost data	n.a.	No official data. Some data from the survey done in this project.
	Employment	n.a.	Can be estimated from the licences. Not data of FTE.
Aquaculture	Production data	Available	Available
	Earnings data	Available – as only a few companies are involved data may need to be aggregated	Available (but there is only one active company in Spain).
	Cost data	Not available	Not available in official statistics but can be estimated.
	Employment	Available	Not available in official statistics but can be estimated.
Fish processing	Production data	Can be estimated for a few companies.	Not available in official statistics but can be estimated for some companies.
	Earnings data	Only available for large companies	Not available in official statistics but can be estimated for some companies.

The closure of the glass eel fishery would cause several indirect effects on the aquaculture and fish processing sectors. For some of the relevant companies, information on possible losses is available (see Chapter 5). On the basis of a selection of these companies the impacts of a total closure of the glass eel fishery is assessed

Aquaculture

The overall turnover of aquaculture companies processing eel in Europe was EUR 37 million in 2017. Information is given below on individual companies in the four focus countries:

France**:** In France there is no aquaculture facility for eel except a subsidiary of the Dutch company Nijvis. Only for the Nijvis Holding data is available for 2016. Approximately 30% of the revenues are eel related – EUR 9.5 million.

Germany**:** For Germany only data for one of the three companies listed in Chapter 5 is available. For Albe Fischfarm a total closure of the glass eel fishery would result in a loss of 100% of the revenue – EUR 10.9 million.

Greece**:** In Greece data for the Simonis company is available. In case no eel aquaculture would be possible they would lose approximately 50% of their revenues – EUR 205,600.

Spain**:** For Valenciana de Acuicultura data for 2015 is available and with a closure of glass eel fishery the company would have a loss of 2/3 of its revenues – EUR 2.3 million.

Fish processing

The fish processing industry is importing part of the eel from countries outside Europe. For Germany 115 t in 2017 are imported mainly from New Zealand and China while about 515 t are coming from countries of the EU (Destatis.de/Aussenhandelsstatistik). It is, therefore, questionable if imports can substitute the catches and aquaculture production in Europe.

France**:** In 2016 the company Aguirrebarrena had a turnover of EUR 6.7 million. From that EUR 3.4 million were related to eel processing. For 2015 data for the company J. Barthouil is available: in case of a total closure of the glass eel fishery the company would have lost EUR 263,334 compared to a total turnover of EUR 4.7 million.

The third company described in Chapter 5, Margain Maree, would have lost EUR 301,890 in 2017 compared to a total turnover of EUR 27.2 million.

Germany**:** The last data available for the company Möller & Reichenbach is from 2015. For that year the company reported EUR 1.17 million in turnover from eel activities. That are approximately 17% of the total turnover of the company. The Fiedler company reported EUR 1 million eel-related turnover in 2017 compared to an overall turnover of EUR 12 million. For Transgourmet eel formed in 2016 a very small part of the activities with approximately EUR 3.2 million compared to a total turnover of EUR 4.9 billion.

Greece**:** The Pitenis company had in 2016 a very small turnover for eel related activities – EUR 101,174. This is small compared to the overall turnover of EUR 4 million.

Spain**:** The Roset company had a total turnover of EUR 3.34 million in 2016. As this is all eel related a ban of glass eel fishing would mean a total loss of the turnover.

In case of total closures of fisheries, it has to be acknowledged, that these measures might be irreversible. In case companies totally depending on eel, a closure of the glass eel fishery would basically end their business. Even a compensation for the losses for some time may not be sufficient as all markets are gone after a short while and cannot easily regain. Therefore, companies would have to be compensated for the total loss of business. In cases where the business is not totally depending on eel, compensation may be a suitable option as the company may be able to afford the reduction in revenues or can switch to other activities at least for some time in order to not risk bankruptcy. In these cases, compensation would help in during the transition phase.

Scenario 4: A totally different case for an impact assessment is the assessment of the closure of the recreational fishery. The fishers catch eel not for commercial use, but for pleasure and private consumption. As in other recreational fisheries, the economic effects are mostly indirect as fishers pay for equipment and angling trips. Therefore, there is a lot of value added around recreational fishing, but no direct economic value of eel catches itself.

Due to this special character, the assessment of impacts has to be done with different methods basically assessing non-market values. There are some studies assessing the economic value of recreational angling on eel. An example is the study by Dorow et al. (2010), who applied a choice experiment to assess the possible reaction of anglers to regulatory changes. The anglers expressed their preferences for regulatory settings in a number of scenarios, which also included the assessment of changes in welfare the individual anglers indicated via the experiment. This was translated into a "Willingness to Pay" for a fishing day. The assessment of the "Willingness to Pay" is typically for the assessment of economic values of non-market goods. It indicates what other goods (represented in money) the persons are willing to give up to keep or get the benefit from angling.

An assessment of economic impacts of a closure requires a large effort. However, as recreational angling is basically a non-economic activity it could be argued that it may not matter as much as restricting other fishing due to the risk of bankruptcies for companies. Anglers may also switch to other species and also the indirect effects may not be that severe as many anglers may continue the activities targeting other species, when not allowed catching eel.

Eel measures in the European Maritime and Fisheries Fund (EMFF): Many of the local angler associations in Germany regularly do stocking projects in their areas. For that they use own funds but also apply for funding from the EMFF. For Germany in the current period of the EMFF (2014-2020) the projects directly related to eel stocking or eel monitoring account to about EUR 5.7 million with about EUR 2.8 million funding from the EMFF (source BLE, agrar-fischerei-zahlungen.de/Fischerei_empfaenger). This means a yearly payment of about EUR 400,000. In Greece and Spain no EMFF funds are used for eel stocking and data from France were not accessible.

7.3 Economic impact assessment of possible migration measures on hydropower companies

This section assesses the impact of possible eel migration measures on hydropower companies in each of the selected MS. This section shows, where possible, the estimated impact for each selected Member State and each of the identified hydropower companies (for methods see ANNEX IV.6).

7.3.1 France

In France, the total number of dams is 95,642 and 28,737 of these are located within 250 km from the sea. Out of this dataset, 4,725 dams were identified as hydropower dams, 1,185 of which are within 250 km from the sea. As per our methodology, these dams are thus considered to be impacting the eel migration routes in France. As will be shown in the sections below, 94.5% of the hydropower dams that will be impacted by possible eel migration measures are operated by Électricité de France (EDF) and Engie. The remaining 5.5% is operated by various smaller private sector hydropower companies.

Figure 31-A shows the estimated loss in total revenue, net profit and power generation for the combined companies operating the affected hydropower dams when all the hydropower facilities within 250 km from the sea related to these dams are shut down for 2 to 10 weeks. The impact on the aggregated revenue ranges from EUR 127 million to 634 million, the impact on the aggregated net profit ranges from EUR 4 million to 20 million and the total loss in power generation ranges from 1.5 to 7.7 TWh.

As for the impact assessment of installing upstream and downstream migration equipment, it was only possible to estimate the costs for France as a whole. In total, 64 dams on large rivers and 1,121 dams on smaller rivers were analysed. These are all hydropower related dams that are located within 250 km of the sea. For the dams on large rivers (> 50 m^2/s average river flow), the average costs of installing downstream migration equipment (bar racks, pathways, etc.) ranges from EUR 806 million to EUR 2,419 million. For the dams on smaller rivers, the average costs of installing downstream migration equipment ranges from EUR 149 million to EUR 373 million. So, in total, the costs for installing downstream migration equipment in France will on average range from EUR 956 million to EUR 2,793 million. However, for the largest rivers, the costs might be underestimated, since installing riverwide equipment might necessitate rebuilding the entire dam structure. For some of those large dams, installing more simple bypasses might also be beneficial. However, this has to be evaluated on an individual dam level.

As for the costs of installing upstream migration equipment (multiple species fishway), in France a total of 50 and 1,065 dams were identified on large rivers (> 50 m^2/s average river flow) and smaller rivers respectively. All of these dams are currently not equipped with a fishway. For the dams on large rivers (> 50 m^2/s average river flow), the average costs of installing upstream migration equipment ranges from EUR 25.9 million to EUR 45.1 million. For the dams on smaller rivers, the average costs of installing upstream migration equipment ranges from EUR 69.6 million to EUR 272.2 million. So, in total, the costs for installing upstream migration equipment in France will on average range from EUR 95.6 million to EUR 317.4 million. This estimation corresponds to the costs of equipping a fishway for all species. A specific fishway for eel is much less costly and the total cost for equipment of eel specific fishways would be estimated between EUR 38.5 and 48.1 million.

Adding the estimated costs of installing upstream and downstream migration equipment gives an average total cost range of EUR 1,051.6 million to 3,110.4 million. This is 1.7 to 4.9 times as costly as a 10-week seasonal closure of the affected hydropower facilities, which means that installing migration equipment would be more cost effective after a two to five-year period. This comparison ignores any maintenance costs related to the installed upstream and downstream migration equipment. Therefore, including these costs in the analysis would skew the cost effectiveness of installing migration equipment more towards a five-year period.

Regional assessment of the effects of hydropower plants on silver eel mortality would allow targeting the most impacting dams. Equipping only those dams would substantially lower the estimated cost of installing equipment and would potentially diminish a large fraction of the overall mortality. Also, the cost of installing downstream migration equipment can vary according to the condition for setting up the construction work (sometimes it is possible to isolate the power plant), whether it is necessary to modify the dam structure to enlarge or deepen the water intake, and according to the design of the downstream migration pathway for fishes. These elements can account for a factor one to five in the total cost, and this estimation requires site specific elements which are not possible to gather at a large scale.

The analysis above focuses only on hydropower dams. There are 28,737 other dams within 250 km of the sea. Those would also require upstream migration equipment and downstream migration equipment in the cases where eel might be injured or blocked. Including those would have led to a much higher cost.

The sections below discuss the impact of the seasonal closure migration measure for the hydropower companies that were identified in section 5.4.

CNR: As described in section 5.4.1, CNR is France's leading producer of exclusively renewable energy and the concessionary of the Rhone for hydroelectricity production, river transport and irrigation for agricultural use, and it produces approximately 25% of the French hydroelectricity (CNR, n.d.a). The company owns and operates 19 dams and hydropower plants on the river, with a total installed hydropower capacity of 3.0 GW (CNR, n.d.b). CNR's reference shareholder is ENGIE. Engie considers that it exercises de facto control over CNR as it holds the majority of the voting rights exercised at shareholders' meetings due to the widely dispersed shareholding structure and the absence of evidence of the minority shareholders acting in concert (Engie, 2018c). Therefore, the impact of potential eel migration measures on CNR is already consolidated in the estimations for Engie (see below) and will not be reported separately.

Direct Energie: As described in section 5.4.1, with 4.5 MW Direct Energie's installed hydropower capacity in France is only limited. It uses the hydropower generated by power plants located in the Belledonne mountain range (Isère) owned by the Compagnie des hautes Chutes de Rocques (CHCR) Group (Direct Energie, n.d.b). Since these hydropower installations are located more than 250 km from the sea, they will not be affected by potential eel migration measures.

Électricité de France ("EDF"): As described in section 5.4.1, EDF is one of the largest energy producers in France and the country's most important hydropower producer, account for approximately 80% of the country's total installed hydropower capacity. Table 22 shows the relevant data for EDF that was gathered in order to assess the impact of the different migration measures on EDF's revenue, profit and power generation.

Table 22: EDF's financial and hydropower data 2016-2017

Indicator	2017	2016	Average
Revenue (EUR million)	69,632	71,203	70,418
Segment revenue France (EUR million)	35,606	35,191	35,399
Net profit (EUR million)	3,289	3,011	3,150
Segment net profit France (EUR million)	1,477	1,240	1,359
Power generation France (TWh)	444.4	450.9	447.6
Hydropower generation France (TWh)	42.1	44.3	43.2
# dams France	622	622	622
# dams within 250 km of sea	424	424	424

Source: EDF (2018, July), *Performance 2017*, p. 14-25, 30-39; EDF (n.d.), "Carte de nos implatations industrielles en France", online: https://www.edf.fr/groupe-edf/nos-energies/carte-de-nos-implantations-industrielles-en-france#!field_poi_type_1=363|id=rzr-poi-behavior-filter-form, viewed in November 2018; EDF (2018), *Reference Document 2017*, p. 272, 298, 332-334; EDF (2018), *2017 Facts & Figures*, p. 5, p.8, p.22, p.40, p.169, p.175, p.180; EDF (n.d.), "EDF at a glance", online: https://www.edf.fr/en/the-edf-group/who-we-are/edf-at-a-glance, viewed in November 2018; EDF (2017, August), Performance 2016, p. 6-16, 24-25; Engie (n.d.), "Leading Renewable Energy", online: https://www.edf.fr/en/edf/leading-renewable-energy, viewed in November 2018.

Figure 31-B shows the estimated loss in total revenue, net profit and power generation when EDF's hydropower facilities within 250 km from the sea are shut down for 2 to 10 weeks. The impact on EDF's revenue ranges from EUR 90 million to 447 million, the impact on EDF's net profit ranges from EUR 3 million to 17 million and the loss in power generation ranges from 1.1 to 5.7 TWh.

Based upon the cost range of installing upstream and downstream migration equipment on a Member State level, and using the percentage of the country's total installed hydropower capacity that EDF accounts for (79.5%), the costs related to installing migration equipment on EDF's hydropower dams would range from EUR 836.0 million to 2,472.8 million. This is 1.9 to 5.5 times as costly as a 10-week seasonal closure of the affected hydropower facilities, which means that installing migration equipment would be more cost effective after a two to six-year period. This calculation does not account for any maintenance costs related to the installed migration equipment.

Engie: As described in section 5.4.1, Engie is one of the largest energy producers in France and the country's second most important hydropower producer, account for approximately 15% of the country's total installed hydropower capacity. Table 23 shows the relevant data for Engie that was gathered in order to assess the impact of the different migration measures on Engie's revenue, profit and power generation.

Figure 31-C shows the estimated loss in total revenue, net profit and power generation when Engie's hydropower facilities within 250 km from the sea are shut down for 2 to 10 weeks. The impact on Engie's revenue ranges from EUR 30 million to 152 million, the impact on Engie's net profit ranges from EUR 0.3 million to 1.6 million and the loss in power generation ranges from 0.3 to 1.6 TWh.

Based upon the cost range of installing upstream and downstream migration equipment on a Member State level, and using the percentage of the country's total installed hydropower capacity that Engie accounts for (15%), the costs related to installing migration equipment on Engie's hydropower dams would range from EUR 157.7 million to 466.6 million. This is 1.0 to 3.1 times as costly as a 10-week seasonal closure of the affected hydropower facilities, which means that installing migration equipment would be more cost effective after a one to three-year period. This calculation does not account for any maintenance costs related to the installed migration equipment.

Unidentified hydropower companies: Besides the large hydropower companies discussed above, in France there are multiple private sector companies operating (smaller) hydropower plants. These companies account for approximately 5.5% of the total French hydropower market, based upon the fact that 24.1 GW of the in total 25.4 GW of installed hydropower capacity is accounted for by the large hydropower companies. With similar reasoning it can be derived that these private sector companies make use of 746 dams that are located within 250 km of the sea.

Table 23: Engie's financial and hydropower data 2016-2017

Indicator	2017	2016	Average
Revenue (EUR million)	65,029	64,840	64,935
Segment revenue France (EUR million)	2,960	3,517	3,239
Net profit (EUR million)	2,238	163.0	1,201
Segment net profit France (EUR million)	62.6	3.8	33.2
Power generation France (TWh)	34.3	34.2	34.3
Hydropower generation France (TWh)	17.3	17.3	17.3
# dams France	31	31	31
# dams within 250 km of sea	15	15	15

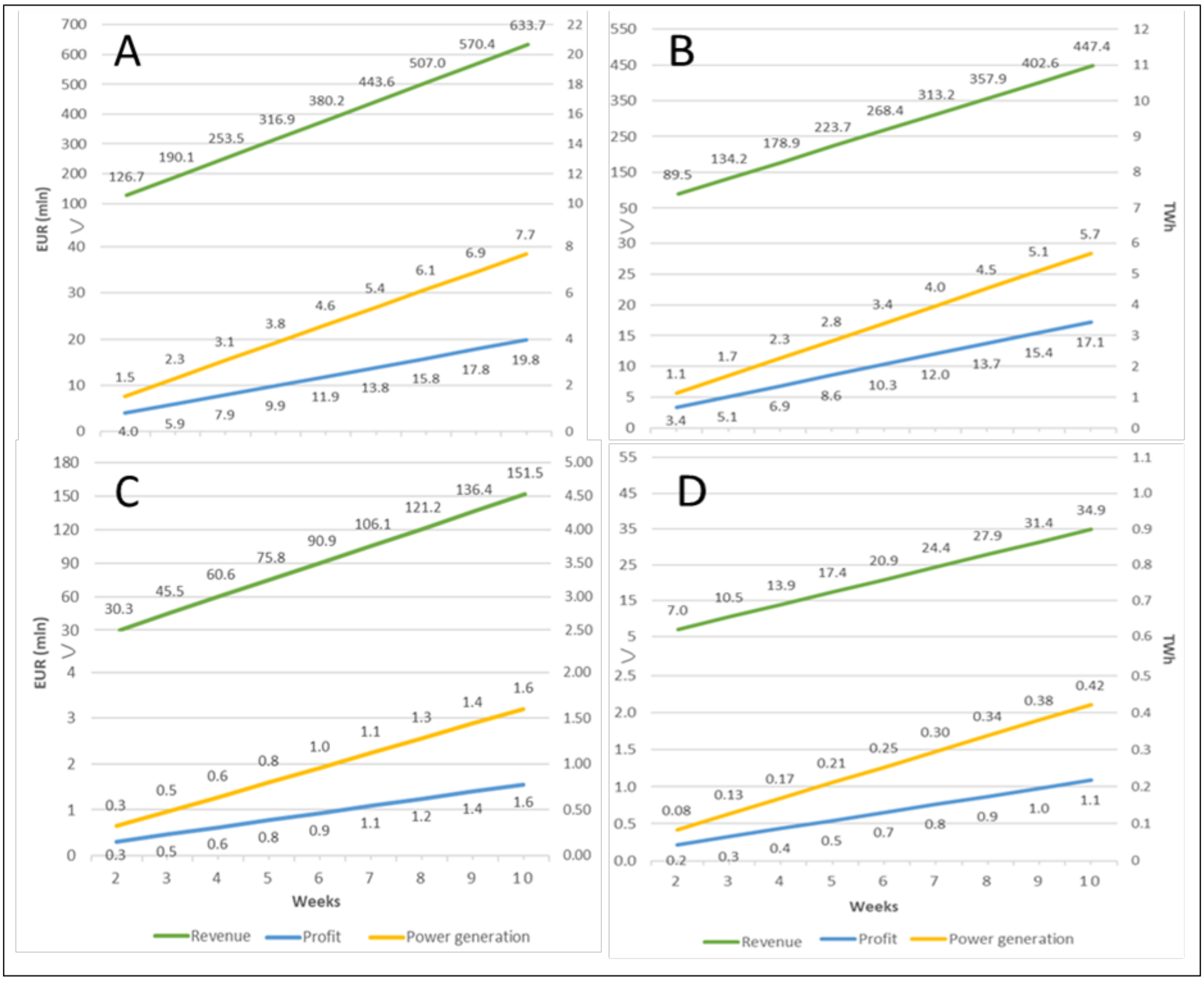
Source: Engie (2018, June), *2018 Integrated Report*, p. 4, 19; Engie (2018, March), *2017 Registration Document*, p. 70, 192; Engie (n.d.), "Hydropower", online: https://www.engie.com/en/businesses/electricity/hydropower/, viewed in November 2018; Engie (2018), *Annual Report 2017*, p.30-32; Engie (n.d.), "About the Group", online: https://www.engie.com/en/group/, viewed in November 2018; Engie (n.d.), "Shareholder Structure", online: https://www.engie.com/en/shareholder/engie-share/shareholder-structure/, viewed in November 2018; Engie (n.d.), "Engie in France", online: https://www.engie.com/en/group/our-international-presence/france/, viewed in November 2018; Engie (2017, April), *2017 Integrated Report*, p. 15; Engie (2018, March), *Management Report and Annual Consolidated Financial Statements*, p. 93.

Figure 31-D shows the estimated loss in total revenue, net profit and power generation for the combined unidentified private sector companies when the hydropower facilities within 250 km from the sea are shut down for 2 to 10 weeks. The impact on revenue ranges from EUR 7 million to 35 million, the impact on net profit ranges from EUR 0.32 million to 1.1 million and the loss in power generation ranges from 0.1 to 0.4 TWh.

Based upon the cost range of installing upstream and downstream migration equipment on a Member State level, and using the percentage of the country's total installed hydropower capacity that the combined unidentified hydropower companies account for (5.5%), the costs related to installing migration equipment on these companies' hydropower dams would range from EUR 57.8

million to 171.1 million. This is 1.7 to 4.9 times as costly as a 10-week seasonal closure of the affected hydropower facilities, which means that installing migration equipment would be more cost effective after a two to five-year period. This calculation does not account for any maintenance costs related to the installed migration equipment.

Figure 31: Estimates loss in revenue, profit and power generation in France



A) Estimated total loss in revenue, profit and power generation in France. B) EDF's estimated loss in revenue, profit and power generation. C) Engie's estimated loss in revenue, profit and power generation. D) Unidentified companies' estimated loss in revenue, profit and power generation.

7.3.2 Germany

There are 371 large dams and multiple smaller dams in Germany (ICOLD, n.d.). A large part of these dams is not located within 250 km from the sea and is therefore, as per our methodology, not considered to be impacting the eel migration routes in Germany. However, in contrast to the situation in France, German stocking programs also include river stretches far upstream, as for example Lake Constance, about 1.000 km upstream the River Rhine. To adapt the German to the French situation, all stocking activities in river sections located above 250 km from the sea and blocked for eel migration would need to be ceased. As will be shown in the sections below, the hydropower dams that would be impacted by eel migration measures are used by Innogy and Statkraft. Unlike France and Spain, the presence of any unidentified private sector companies in

Germany within 250 km of the sea is considered negligible and is therefore not accounted for in the country level estimations.

Figure 32-A shows the estimated loss in total revenue, net profit and power generation for the combined companies operating the hydropower facilities when all the hydropower facilities in Germany within 250 km from the sea are shut down for 2 to 10 weeks. The impact on the aggregated revenue ranges from EUR 5 million to 23 million, the impact on the aggregated net profit ranges from EUR 0.7 million to 3.6 million and the total loss in power generation ranges from 0.03 to 0.13 TWh.

EnBW: Within Germany, EnBW does not have any hydropower facilities located within 250 km of the sea. Therefore, as per our methodology, its hydropower facilities will not be affected by potential eel migration measures.

Innogy: As described in section 5.4.2, Innogy engages in the supply and distribution of electricity and gas and accounts for approximately 6.4% of Germany's total installed hydropower capacity. Table 24 shows the relevant data for Innogy that was gathered in order to assess the impact of the different migration measures on Innogy's revenue, profit and power generation.

Figure 32-B shows the estimated loss in total revenue, net profit and power generation when Innogy's hydropower facilities within 250 km from the sea are shut down for 2 to 10 weeks. The impact on Innogy's revenue ranges from EUR 5 million to 23 million, the impact on Innogy's net profit ranges from EUR 1 million to 4 million and the loss in power generation ranges from 0.02 to 0.1 TWh.

Table 24: Innogy's financial and hydropower data 2016-2017

Indicator	2017	2016	Average
Revenue (EUR million)	43,139	43,611	43,375
Segment revenue Germany (EUR million)	878.7	679.1	778.9
Net profit (EUR million)	1,149	1,786	1,468
Segment net profit Germany (EUR million)	93.4	145.1	119.3
Power generation Germany (TWh)	3.4	3.5	3.5
Hydropower generation Germany (TWh)	1.5	1.7	1.6
# dams Germany	30	30	30
# dams within 250 km of sea	10	10	10

Source: Innogy (2018), *Annual Report 2017*, p. 52-53, 115-116, 174-175.

Table 25: Statkraft's financial and hydropower data 2016-2017

Indicator	2017	2016	Average
Revenue (EUR million)	6,353	5,442	5,898
Segment revenue Germany (EUR million)	179.0	77.6	128.3
Net profit (EUR million)	1,192	-12.9	589.4
Segment net profit Germany (EUR million)	33.6	-0.2	16.7
Power generation Germany (TWh)	10.5	10.5	10.5
Hydropower generation Germany (TWh)	0.2	0.2	0.2
# dams Germany	10	10	10
# dams within 250 km of sea	6	6	6
% of hydropower capacity affected	80%	80%	80%

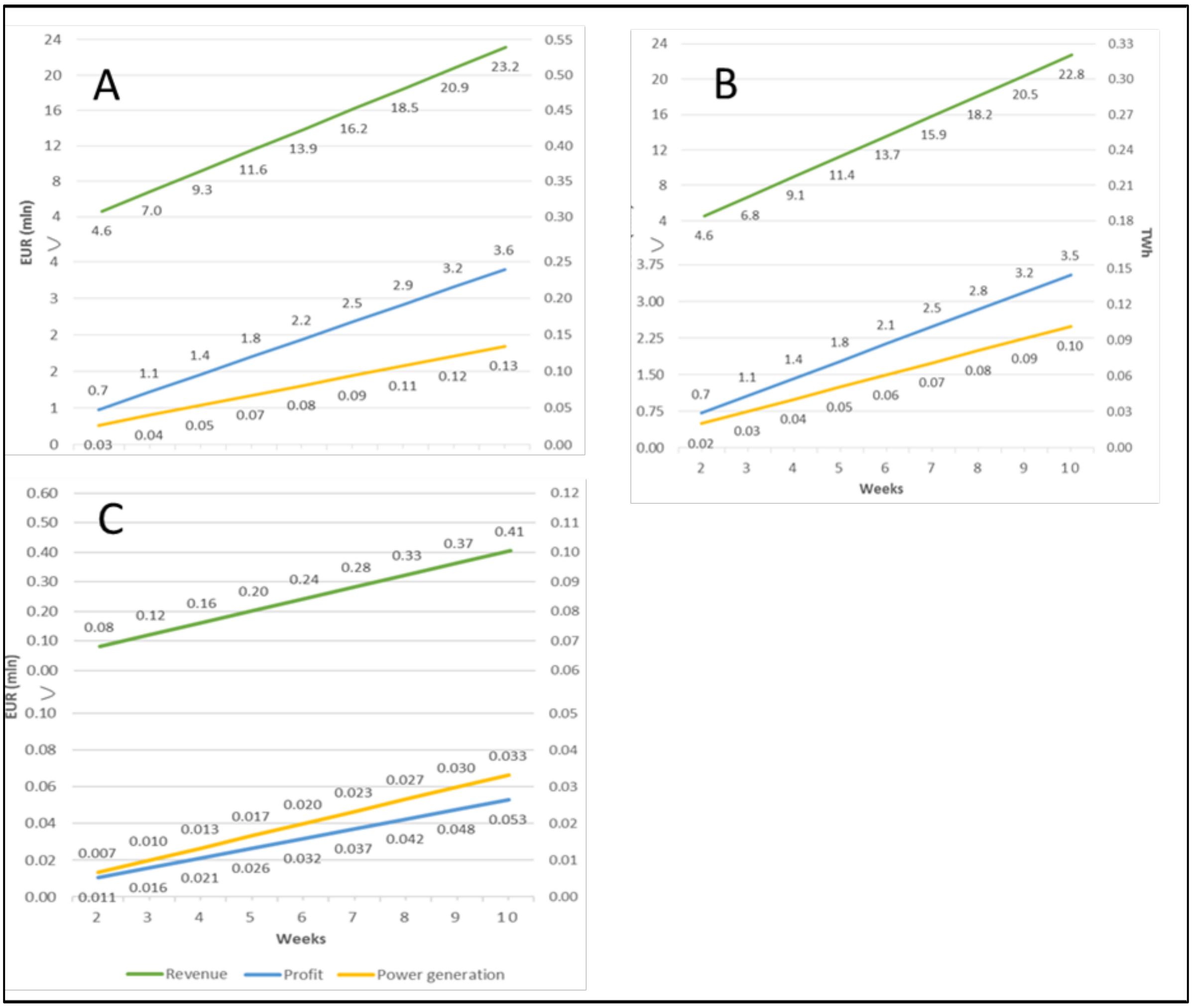
Source: Statkraft (2018), *Statkraft Annual Report 2017*, p.7-8, 31, 45, 54, 137-138, 145; Statkraft (n.d.), "Corporate Governance", online: https://www.statkraft.com/IR/corporate-governance/, viewed in November 2018; Statkraft (n.d.), "Affoldern power plant", online: https://www.statkraft.com/energy-sources/Power-plants/Germany/Affoldern/, viewed in November 2018; Statkraft (n.d.), "Wahnhause power plant", online: https://www.statkraft.com/energy-sources/Power-plants/Germany/Wahnhausen/, viewed in November 2018; Statkraft (n.d.), "Werrawerk power plant", online: https://www.statkraft.com/energy-sources/Power-plants/Germany/Werrawerk/, viewed in November 2018; Statkraft (n.d.), "Petershagen power plant", online: https://www.statkraft.com/energy-sources/Power-plants/Germany/Petershagen/, viewed in November 2018; Statkraft (n.d.), "Schlüsselburg power plant", online: https://www.statkraft.com/energy-sources/Power-plants/Germany/Schluesselburg/, viewed in November 2018; Statkraft (n.d.), "Landesbergen power plant", online: https://www.statkraft.com/energy-sources/Power-plants/Germany/Landesbergen/, viewed in November 2018; Statkraft (n.d.), "Drakenburg power plant", online: https://www.statkraft.com/energy-sources/Power-plants/Germany/Drakenburg/, viewed in November 2018; Statkraft (n.d.), "Dörverden power plant", online: https://www.statkraft.com/energy-sources/Power-plants/Germany/Dorverden/, viewed in November 2018; Statkraft (n.d.), "Langwedel power plant", online: https://www.statkraft.com/energy-sources/Power-plants/Germany/Langwedel/, viewed in November 2018.

Statkraft: As described in section 5.4.2, Statkraft is Europe's largest supplier of renewable energy, with most of its installed capacity located in Norway. In Germany, Statkraft accounts for approximately 0.4% of Germany's total installed hydropower capacity. Table 25 shows the relevant data for Statkraft that was gathered in order to assess the impact of the three different migration measures on Statkraft's revenue, profit and power generation.

Figure 32-C shows the estimated loss in total revenue, net profit and power generation when Statkraft's hydropower facitlities within 250 km from the sea are shut down for 2 to 10 weeks. The impact on Statkraft's revenue ranges from EUR 80,000 to 410,000, the impact on Statkraft's net profit ranges from EUR 11,000 to 53,000 and the loss in power generation ranges from 0.01 to 0.03 TWh.

Uniper: Within Germany, Uniper does not have any hydropower facilities located within 250 km of the sea. Therefore, as per our methodology, its hydropower facilities will not be affected by potential eel migration measures.

Figure 32: Estimated total loss in revenue, profit and power generation in Germany



A) Estimated total loss in revenue, profit and power generation in Germany. B) Innogy's estimated loss in revenue, profit and power generation. C) Statkraft's estimated loss in revenue, profit and power generation.

7.3.3 Greece

There are 162 large dams and multiple smaller dams in Greece (ICOLD, n.d.). All dams are located within 250 km from the sea and could therefore, as per our methodology, be impacted by possible eel migration measures. As will be shown in the sections below, the hydropower dams that are impacted by eel migration measures are used by PPC, Protergia and Terna Energy. Unlike France and Spain, the presence of any unidentified private sector companies in Greece within 250 km of the sea is considered negligible and is therefore not accounted for in the country level estimations.

Figure 33-A shows the estimated loss in revenue, net profit and power generation for the combined companies operating the hydropower facilities when all the identified hydropower facilities in Greece are shut down for 2 to 10 weeks. The impact on the aggregated revenue ranges from EUR 25 million to 124 million, the impact on the aggregated net profit ranges from EUR 0.6 million to 3.2 million and the total loss in power generation ranges from 0.16 to 0.80 TWh. It must be noted that the power generation loss only consists of data from PPC, since power generation data for the other identified companies was not available.

Public Power Corporation: As described in section 5.4.3, PPC is the most important power generation company in Greece and is also a dominant company in the Greek hydropower sector, accounting for approximately 38% of the total installed hydropower capacity. Table 26 shows the relevant data for PPC that was gathered in order to assess the impact of the different migration measures on PPC's revenue, profit and power generation.

Figure 33-B shows the estimated loss in total revenue, net profit and power generation when PPC's hydropower facilities are shut down for 2 to 10 weeks. The impact on PPC's revenue ranges from EUR 25 million to 122 million, the impact on PPC's net profit ranges from EUR 1 million to 3 million and the loss in power generation ranges from 0.16 to 0.80 TWh.

Table 26: PPC's financial and hydropower data 2016-2017

Indicator	2017	2016	Average
Revenue (EUR million)	4,968	5,166	5,067
Segment revenue Greece (EUR million)	4,594	4,907	4,750
Net profit (EUR million)	237.1	56.1	146.9
Segment net profit Greece (EUR million)	219.8	53.3	136.5
Power generation Greece (TWh)	32.6	30.3	31.5
Hydropower generation Greece (TWh)	3.5	4.8	4.2
# dams Greece	22	22	22
# dams within 250 km of sea	22	22	22

Source: PPC (2018, May), Financial Report 2017, p. 114; PPC (2017, June), Annual Report 2016, p. 13; PPC (2018, June), Annual Report 2017, p. 7, 12-13; PPC (2018), "Investor Relations", online: https://www.dei.gr/en/i-dei/enimerwsi-ependutwn, viewed in November 2018; PPC (2018), "PPC's Shareholding Structure", online: https://www.dei.gr/en/i-dei/enimerwsi-ependutwn/xrimatistiriaka-stoixeia/metoxiki-sunthesi, viewed in November 2018; PPC (2018), Annual Report 2017, p. 12-13, p.123, PPC (2018), "Corporate Identity", online: https://www.dei.gr/en/i-dei/enimerwsi-ependutwn/etairiki-eikona/tautotita-etaireias, viewed in November 2018; Renewables Now (2018), "H1 profit falls 33% for PPC Renewables of Greece", online: https://renewablesnow.com/news/h1-profit-falls-33-for-ppc-renewables-of-greece-627906/, viewed in November 2018.

Protergia: As described in section 5.4.3, Protergia's portfolio of energy assets has a total installed capacity of 1.2 GW of thermal capacity and 200 MW of renewable energy. However, the hydropower capacity only accounts for approximately 0.2% of Greece's total installed hydropower capacity. Table 27 shows the relevant data for Protergia that was gathered in order to assess the impact of the different migration measures on Protergia's revenue, profit and power generation.

Table 27: Protergia's financial and hydropower data 2015-2016

Indicator	2016	2015	Average
Revenue (EUR million)	356.8	188.8	272.8
Segment revenue Greece (EUR million)	201.2	104.3	152.8
Net profit (EUR million)	-12.6	-41.8	-27.2
Segment net profit Greece (EUR million)	-2.77	-32.9	-17.8
Installed capacity Greece (MW)	1,393	1,393	1,393
Hydropower capacity Greece (MW)	6.0	6.0	6.0
# dams Greece	4	4	4
# dams within 250 km of sea	4	4	4

Source: Protergia (n.d.), "Energy portfolio", online: https://www.protergia.gr/en/content/energy-portfolio, viewed in November 2018; Protergia (n.d.), "Development & operation of RES plants", online: https://www.protergia.gr/en/content/development-operation-res-plants, viewed in November 2018; Mytilineos (2018, June), Annual Report 2017, p. 76-78, 145.

Figure 33-C shows the estimated loss in total revenue and net profit when Protergia's hydropower facilities are shut down for 2 to 10 weeks. The impact on Protergia's revenue ranges from EUR 76,000

to 380,000 and the impact on Protergia's net profit ranges from EUR 1,400 to 6,900. Since there is no data available on power generation, it is not possible to estimate the total loss of power generation.

Terna Energy: As described in section 5.4.3, Terna Energy's total installed capacity in Greece is 579 MW, 17.8 MW of which is hydropower capacity. This accounts for approximately 0.5% of the country's total installed hydropower capacity. Table 28 shows the relevant data for Terna Energy that was gathered in order to assess the impact of the different migration measures on Terna Energy's revenue, profit and power generation.

Figure 33:-D shows the estimated loss in total revenue, net profit and power generation when Terna Energy's hydropower facilities are shut down for 2 to 10 weeks. The impact on Terna Energy's revenue ranges from EUR 0.2 million to 1.1 million and the impact on Terna Energy's net profit ranges from EUR 30,000 to EUR 130,000. Since there is no data available on power generation, it is not possible to estimate the total loss of power generation.

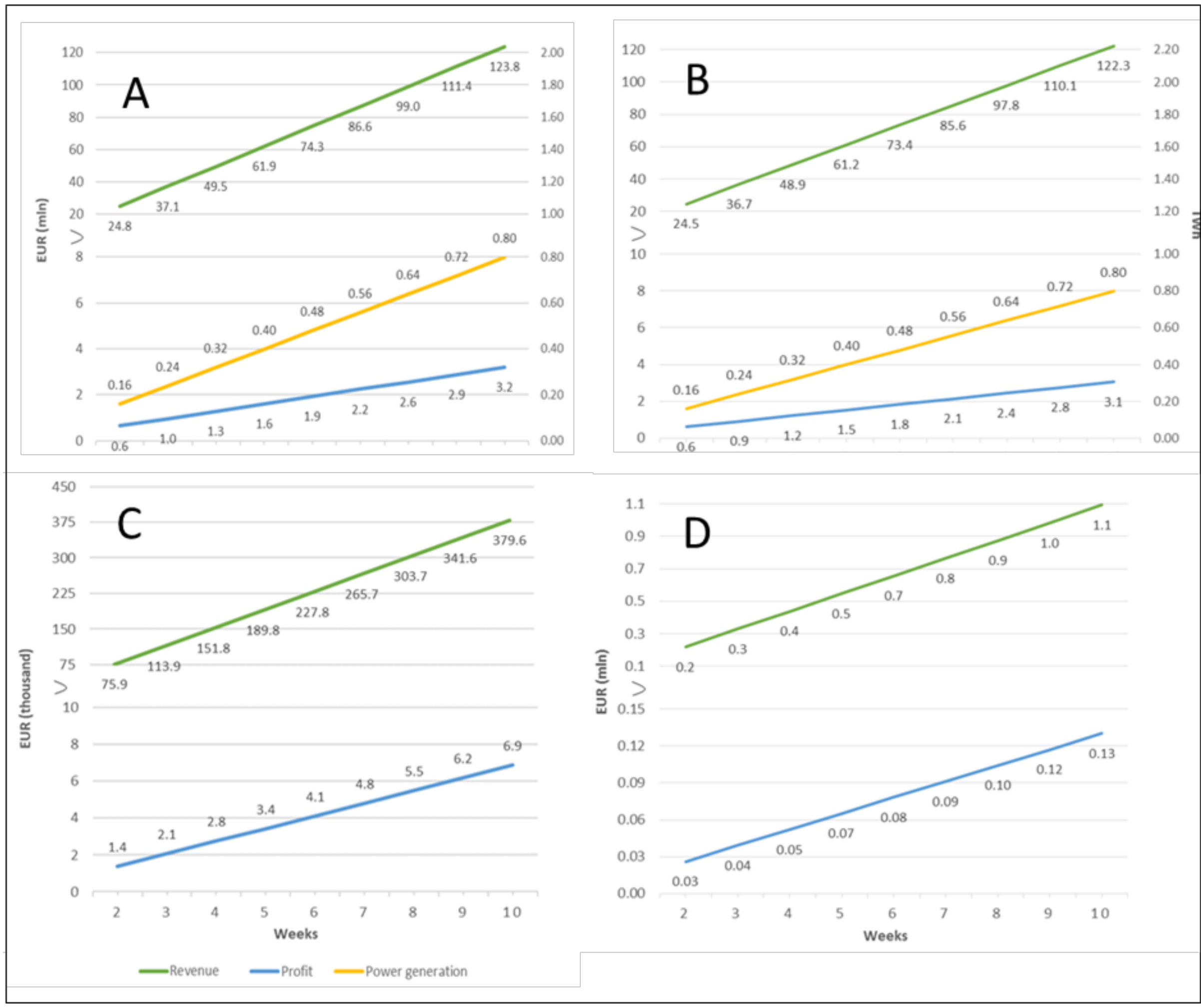


Figure 33: A) Estimated total loss in revenue, profit and power generation in Greece. B) PPC's estimated loss in revenue, profit and power generation. C) Protergia's estimated loss in revenue and profit. D) Terna Energy's estimated loss in revenue and profit

Table 28: Terna Energy's financial and hydropower data 2016-2017

Indicator	2017	2016	Average
Revenue (EUR million)	276.5	225.6	251.1
Segment revenue Greece (EUR million)	221.4	148.3	184.9
Net profit (EUR million)	37.9	20.8	29.4
Segment net profit Greece (EUR million)	30.4	13.7	22.0
Installed capacity Greece (MW)	579.3	579.3	579.3
Hydropower capacity Greece (MW)	17.8	17.8	17.8
# dams Greece	2	2	2
# dams within 250 km of sea	2	2	2

Source: Terna Energy (2018, June), *Annual Financial Report 2017*, p. 34-36, 101; GEK Terna Group - Terna Energy (n.d.), "Activities", online: http://www.terna-energy.com/activities/, viewed in November 2018; GEK Terna Group - Terna Energy (n.d.), "Hydroelectric Projects", online: http://www.terna-energy.com/activities/?catid=9ed16d56-3ec8-47ea-97a2-37c2fc5604aa, viewed in November 2018; http://www.terna-energy.com/activities/?EntryId=bb201f84-0f7d-4949-a949-3054da5d9a0c&catid=9ed16d56-3ec8-47ea-97a2-37c2fc5604aa&countryId=5a53c3a7-cff0-49a4-ba90-5538b3418e40; http://www.terna-energy.com/activities/?EntryId=61d84871-5bc8-470a-8fef-d3bbcf17d630&catid=9ed16d56-3ec8-47ea-97a2-37c2fc5604aa&countryId=5a53c3a7-cff0-49a4-ba90-5538b3418e40.

7.3.4 Spain

There are 1,038 hydropower dams in Spain, 346 of which are located within 250 km from the sea. As per our methodology, these dams are thus considered to be impacting the eel migration routes. As will be shown in the sections below, the hydropower dams that are impacted by eel migration measures are used by Endesa, Iberdrola, Naturgy and various other unidentified (smaller) companies.

Figure 34-A shows the aggregated estimated total loss in revenue, net profit and power generation for the combined companies operating the hydropower facilities when all the hydropower facilities in Spain within 250 km from the sea are shut down for 2 to 10 weeks. The impact on the aggregated revenue ranges from EUR 106 million to 532 million, the impact on the aggregated net profit ranges from EUR 4 million to 21 million and the total loss in power generation ranges from 0.6 to 3.0 TWh.

Endesa: As described in section 5.4.4, Endesa is the leading company in the Spanish electricity sector and accounts for approximately 20% of the country's total installed hydropower capacity. Table 29 shows the relevant data for Endesa that was gathered in order to assess the impact of the different migration measures on Endesa's revenue, profit and power generation.

Table 29: Endesa's financial and hydropower data 2016-2017

Indicator	2017	2016	Average
Revenue (EUR million)	20,057	18,979	19,518
Segment revenue Spain (EUR million)	13,794	13,224	13,509
Net profit (EUR million)	1,473	1,412	1,443
Segment net profit Spain (EUR million)	215.1	598.1	406.6
Power generation Spain (TWh)	78.6	69.8	74.2
Hydropower generation Spain (TWh)	5.0	7.2	6.1
# dams Spain	133	133	133
# dams within 250 km of sea	123	123	123
% of hydropower capacity affected	92%	92%	92%

Source: Endesa (2018), *Legal Document 2017*, p. 421, 433-436; Endesa (2018), *Annual Report 2017*, p. 2-4, 26 (412); Endesa (2018), *Activities Report 2017*, p.13; Endesa (n.d.), "Profile", online: https://www.endesa.com/en/about/a201611-profile.html, viewed in November 2018; Endesa (n.d.), "Shareholder Structure", online: https://www.endesa.com/en/investors/a201611-shareholder-structure.html, viewed in November 2018.

Figure 34-B shows the estimated loss in total revenue, net profit and power generation when Endesa's hydropower facilities within 250 km from the sea are shut down for 2 to 10 weeks. The impact on Endesa's revenue ranges from EUR 39 million to 197 million, the impact on Endesa's net profit ranges from EUR 1.3 million to 6.6 million and the loss in power generation ranges from 0.2 to 1.1 TWh.

Iberdrola: As described in section 5.4.4, Iberdrola is the leading hydropower company in Spain, accounting for approximately 55% of the country's total installed hydropower capacity. Table 30 shows the relevant data for Iberdrola that was gathered in order to assess the impact of the different migration measures on Iberdrola's revenue, profit and power generation.

Table 30: Iberdrola's financial and hydropower data 2016-2017

Indicator	2017	2016	Average
Revenue (EUR million)	31,263	29,215	30,239
Segment revenue Spain (EUR million)	11,252	10,815	11,034
Net profit (EUR million)	2,713	4,554	3,633
Segment net profit Spain (EUR million)	348.0	512.8	430.4
Power generation Spain (TWh)	51.9	62.8	57.3
Hydropower generation Spain (TWh)	8.3	19.0	13.7
# dams Spain	159	159	159
# dams within 250 km of sea	93	93	93
% of hydropower capacity affected	44%	44%	44%

Source: Iberdrola (2018), *Annual Report 2017*, p. 10-14, 16, 25; Iberdrola (2018, March), *Annual Financial Report 2017*, p. 77-79, 278; Iberdrola (n.d.), Iberdrola (2017, April), *Integrated Report 2017*, p. 69, "Shares", online: https://www.iberdrola.com/shareholders-investors/share/share-capital/shares, viewed in November 2018.

Figure 34-C shows the estimated loss in total revenue, net profit and power generation when Iberdrola's hydropower facilities within 250 km from the sea are shut down for 2 to 10 weeks. The impact on Iberdrola's revenue ranges from EUR 43 million to 214 million, the impact on Iberdrola's net profit ranges from EUR 1.8 million to 8.9 million and the loss in power generation ranges from 0.2 to 1.2 TWh.

Naturgy: As described in section 5.4.4, Naturgy is the largest integrated gas and electricity company in Spain, accounting for approximately 11% of the country's total installed hydropower capacity. Table 31 different migration measures on Naturgy's revenue, profit and power generation.

Table 31: Naturgy's financial and hydropower data 2016-2017

Indicator	2017	2016	Average
Revenue (EUR million)	23,306	21,908	22,607
Segment revenue Spain (EUR million)	4,349	4,217	4,283
Net profit (EUR million)	1,697	1,711	1,704
Segment net profit Spain (EUR million)	130.9	262.3	196.6
Power generation Spain (TWh)	28.0	28.0	28.0
Hydropower generation Spain (TWh)	1.5	4.5	3.0
# dams Spain	43	43	43
# dams within 250 km of sea	34	34	34

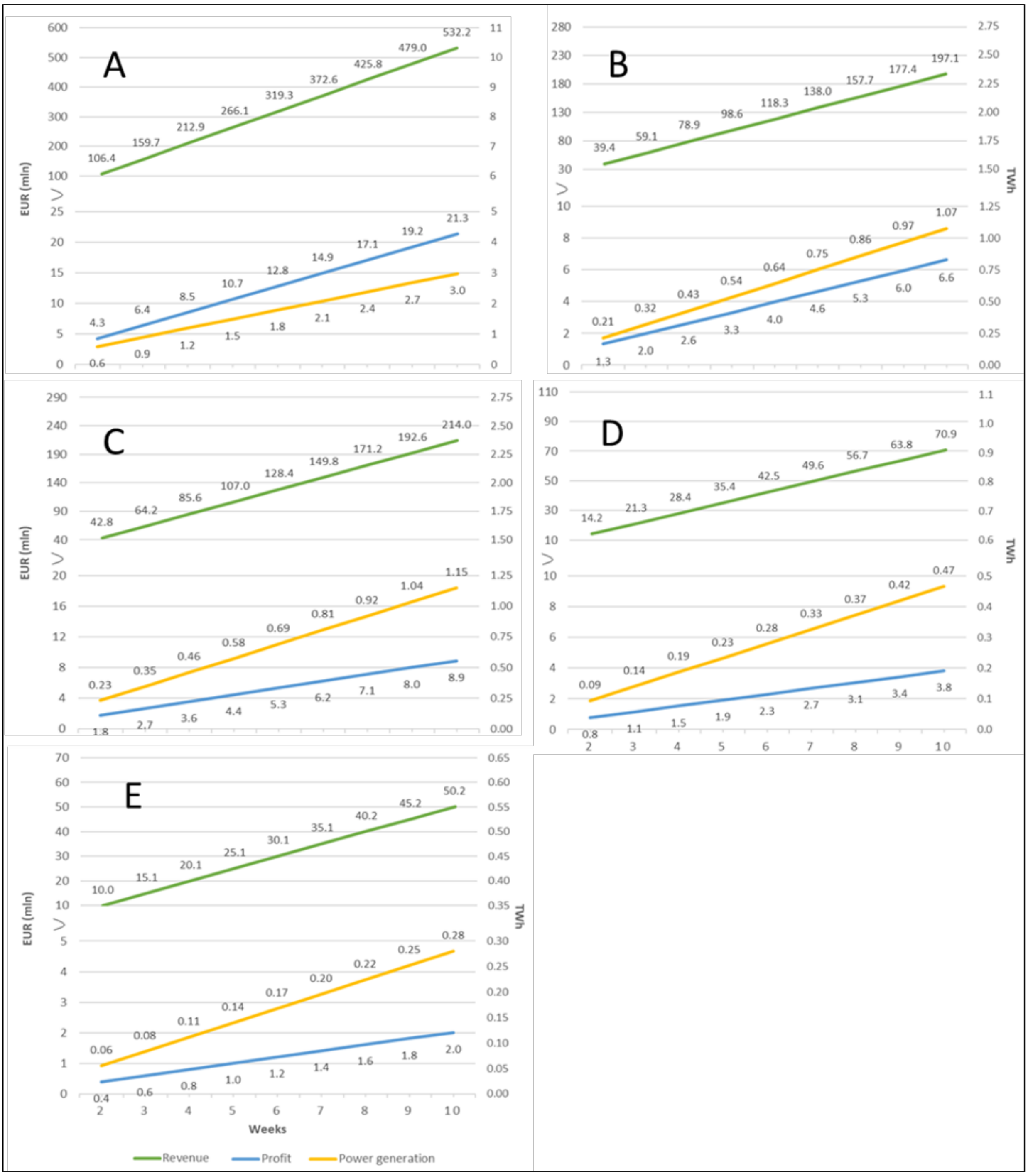
Source: Natugy (2018, May), 2017 Annual Consolidated Financial Report, p. 16, 68, 180, 229.

Figure 34-D shows the estimated loss in total revenue, net profit and power generation when Naturgy's hydropower facilities within 250 km from the sea are shut down for 2 to 10 weeks. The impact on Naturgy's revenue ranges from EUR 14 million to 71 million, the impact on Naturgy's net profit ranges from EUR 0.8 million to 3.8 million and the loss in power generation ranges from 0.1 to 0.5 TWh.

Unidentified hydropower companies: Besides the large hydropower companies discussed above, in Spain there are multiple private sector companies operating (smaller) hydropower plants. These companies account for approximately 9.4% of the total Spanish hydropower market, based upon the fact that 16.8 GW of the in total 18.6 GW of installed hydropower capacity is accounted for by the large hydropower companies. With similar reasoning it can be derived that these private sector companies make use of 95 dams that are located within 250 km of the sea.

Figure 34-E shows the estimated loss in total revenue, net profit and power generation for the combined private sector companies when the hydropower facilities within 250 km from the sea are shut down for 2 to 10 weeks. The impact on revenue ranges from EUR 10 million to 50 million, the impact on net profit ranges from EUR 0.4 million to 2.0 million and the loss in power generation ranges from 0.1 to 0.3 TWh

Figure 34: Estimated total loss in revenue, profit and power generation in Spain



A) Estimated total loss in revenue, profit and power generation in Spain. B) Endesa's estimated loss in revenue, profit and power generation. C) Iberdrola's estimated loss in revenue, profit and power generation. D) Naturgy's estimated loss in revenue, profit and power generation. E) Private sector estimated loss in revenue, profit and power generation.

7.4 Discussion and Conclusions

In this chapter, we described economic losses of possible management measures on the sectors depending on eel catches or which negatively influence the eel stock and need to be regulated (like installations). An environmental, social and economic impact assessment is a standard instrument for every new or revised Regulation within the EU. The aim is to compare short versus medium to long-term impacts and especially costs and benefits. For this chapter we have only looked at economic impacts.

One of the problems regarding eel management measures is that their effect is not quantified normally in terms of stock improvement. In addition, the very limited availability of economic data for the fishing sector including aquaculture and fish processing makes a real impact assessment impossible. It would, therefore, be necessary to issue follow up work with a substantial effort for data collection. Nevertheless, the consortium assessed some of the economic impacts of selected management measures as far as the available data allowed it.

Overall the consortium selected seven scenarios regarding fisheries and installations. Those scenarios are not based on biological information and are somewhat extreme cases. A total closure of all fisheries may not be realistic, but for an impact assessment effects are relatively clear opposite to scenarios where we would have a mix of measures to avoid a total closure. Then the reason for changes in economic indicators is not easily detectable anymore.

Due to the lack of economic data especially on cost structures of fishers that carry out commercial fisheries (marine and freshwater) it was not possible to analyse the impacts in a great depth. It was only possible to assess the influence on revenues to a certain extent and indirect effects on aquaculture and very limited on fish processing. The loss of revenues for a total closure of fisheries in Europe (yellow, silver and glass eels) is approximately EUR 50 million per year. A closure of the glass eel fishery would result in a loss of EUR 37 million of revenues of the aquaculture farms specialised on eel. As those farms depend on eel this would mean the farms would be closed. The fish processing companies also depend on eel aquaculture as all of the eel going into fish processing are derived from aquaculture and, therefore, a loss of aquaculture production would also negatively affect fish processing companies. The fish processing industry is importing part of the eel from countries outside Europe. The industry is importing eel from outside Europe but the amounts are with 1,500 t low compared to the catches and production in Europe and it is, therefore, questionable if imports can substitute the catches and aquaculture production in Europe.

Especially small-scale fisheries (freshwater and marine waters) are to a certain extent dependent on eel catches. The overall number of fishers decreased substantially over the last decades due to the problematic economic situation of many companies. In addition, not only eel catches decreased for the coastal fishers but also other catch opportunities decreased in some areas of the European seas (e.g. the southern Baltic Sea coast), which led to a critical economic situation for many of the small-scale fishing companies. For freshwater fisheries the knowledge of the economic situation is even lower, as economic data is not collected. It is known that the number of companies also decreased over the last decades.

A total closure of the glass eel fishery may have the most severe economic impacts. In this scenario, there will be no stocking material for aquaculture companies and basically all eel processed and traded on markets comes from aquaculture. This would cause the bankruptcy of specialised companies for eel aquaculture and processing.

A closure of the commercial fishery, on the other hand, has negative impacts on the companies, but the losses in revenues are not as severe as, for example, a part-time closure of turbines in dams or the construction of bypasses or trap-and-transport activities. However, trap-and-transport could reduce eel mortality while on the other side can compensate fishers for the loss of catches.

As for hydropower companies, the economic impact of eel migration measures differs per selected Member State. For France, the impact of a seasonal shutdown of affected hydropower facilities on the aggregated revenue ranges from EUR 127 million to EUR 634 million, the impact on the aggregated net profit ranges from EUR 4 million to 20 million and the total loss in power generation ranges from 1.5 to 7.7 TWh. The possible costs of installing upstream and downstream eel migration equipment are estimated to range between EUR 1,051.6 million to 3,110.4 million. This is 1.7 to 4.9 times as costly as a 10-week seasonal closure of the affected hydropower facilities, which means that installing migration equipment would be more cost effective after a two to five-year period. However, this comparison ignores any maintenance costs related to the installed upstream and downstream migration equipment. Therefore, including these costs in the analysis would skew the cost effectiveness of installing migration equipment more towards a five-year period.

For Spain, the impact of a seasonal shutdown of all companies' affected hydropower facilities on the aggregated revenue ranges from EUR 106 million to 532 million, the impact on the aggregated net profit ranges from EUR 4 million to 21 million and the total loss in power generation ranges from 0.6 to 3.0 TWh. For Greece, the impact of a seasonal shutdown of affected hydropower facilities on the aggregated revenue ranges from EUR 25 million to 124 million, the impact on the aggregated net profit ranges from EUR 0.6 million to 3.2 million and the total loss in power generation ranges from 0.16 to 0.80 TWh. For Germany, the impact of a seasonal shutdown of affected hydropower facilities on the aggregated revenue ranges from EUR 5 million to 23 million, the impact on the aggregated net profits ranges from EUR 0.7 million to 3.6 million and the total loss in power generation ranges from 0.03 to 0.13 TWh.

It must be noted that, compared to the data on France and Spain, the identified hydropower companies in both Germany and Greece together account for a somewhat smaller portion of the total installed hydropower capacity in each country, which might to some extent explain why the estimated impacts for these countries are relatively small. Furthermore, for Greece some information on company specific hydropower generation was not available and could thus not be included in the estimated total loss of power generation. Nevertheless, it is clear that a seasonal shutdown of affected hydropower facilities will have a more severe impact in France and Spain. In addition, as shown by the French analysis, the installation of eel migration equipment is in the long run more cost effective than the seasonal closure measure. When eel migration equipment would only be installed on the hydropower dams that impact eel migration the most severe, the breakeven point would be even more decreased.

The assessment provided in this document is based on an overall dataset of hydropower plants (HPP) dams which would gain from a detailed spatial analysis and validation that was not possible in the time of the project. The seasonal variation of HPP production or the use of HPP to balance the load on the electricity network were not considered. The costs provided give an estimate of the overall cost but will not replace regional level and case specific analyses.

8 CONCLUSIONS AND RECOMMENDATIONS

This study uses four countries in Europe to try to put forward a first comprehensive analysis of the economic impact of management measures on eel. It also draws an overall picture of the state of knowledge on eel biology and current management. It should first be noted that our findings are partial (not covering all countries) and that the knowledge gathered for the economic analysis is insufficient to draw up a complete evaluation of both management measures and the consequences of management actions.

In order to improve the efficiency and coordination of implemented measures and to enable a proper stock management the following actions are recommended:

1) The EU Regulation needs to be changed towards a mortality target instead of the current 40% regional level escapement targets. However, such a mortality target needs to be sufficiently low to further reduce direct anthropogenic impacts on the stock. By introducing a mortality target, general problems of a biomass-based approach like setting a uniform and proper baseline B0 or the common practice of meeting regional biomass targets solely by stocking eels caught elsewhere, while sustaining or even increasing anthropogenic mortalities (through hydropower and fisheries or by stocking in waters not suitable for eels (due to high pollution status, etc.) would be obsolete.
2) Eel mortality at hydropower plants needs to be assessed according to the individual characteristics of installations. To achieve this, it is recommended to develop a map that provides detailed information on the position and individual technical characteristics of all turbine installations in European rivers. Effort is also needed to assess the efficiency of mitigation measures at barriers (e.g. bypasses, trap-and-transport) to enable an effective coordination of the implementation of these measures. This is only ensured if it is known, which fraction of migrating eels is effectively protected by these measures. Future installations should be planned in accordance with special requirements of eels during their up- and downstream migration in order to reduce eel mortality at new installations to a minimum.
3) Given the unknown efficiency of mitigation measures at barriers, the transport of eels to areas upstream of obstacles should be ceased. Bypasses and trap-and-transport are beneficial, but should not justify the continuation of eel stocking programmes upstream. Instead, pressure should be maintained to fully restore river continuity (according to EU Water Framework Directive).
4) The value of stocking as a management action in the EU Regulation and many Eel Management Plans needs to be critically evaluated. When stocking to increase silver eel escapement and thus aid stock recovery, an estimation of the prospective net benefit should be made prior to any stocking activity. Stocking should take place only where survival to silver eel escapement is high, and should not be used as an alternative to reducing anthropogenic mortality.
5) Accordingly, the effectiveness of all management actions listed in the EU Regulation and in national Eel Management Plans needs to be assessed and quantified. The implementation of mitigation measures generally needs scientific guidance, proper monitoring and ex-post-evaluation. As an example, to set seasonal closures, as recently decided for Union waters of the ICES area and brackish waters such as estuaries, coastal lagoons and transitional waters (Council Regulation (EU) 2019/124, Article 11), in times, where fisheries are traditionally inactive anyway, should not be regarded and broadcasted as a management action.

6) The coordination among different management levels (regional, national, European and sectoral) needs to be improved. A lack of coordination between management levels can impair the effect of single management actions.
7) A collection of economic data is urgently needed for companies involved in eel fisheries (especially in inland and estuarine waters). Economic data are required to assess the economic importance of eel for (inland) fisheries and small processing companies. With sufficient data, including the whole value chain (including fisheries, aquaculture, fish processing and trading companies) an economic impact assessment could test effects of e.g. a total closure of the fisheries. However, the problem remains that impacts of management actions on the stock level are unknown to conduct a real cost-benefit analysis of measures.
8) An international traceability system for glass eels needs to be implemented to follow the fate of legal catches within and among countries and to detect illegal catches. It is also important that regional and national enforcement agencies control illegal eel fishery. In addition, coordinated actions between the Member States' enforcement agencies should be promoted.

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ANNEX

Annex I: Glossary

Where applicable, definitions from ICES WGEEL reports were used

B0 (Pristine Biomass)	Spawner escapement biomass in absence of any anthropogenic impacts.
Bootlace	Intermediate sized eels, approx. 10–25 cm in length (fingerlings). These terms are most often used in relation to stocking. The exact size of the eels may vary considerably.
Diadromous fish	Fish species that migrate between salt water and fresh water as part of their life cycle.
Eel Management Unit (EMU)	"Member States shall identify and define the individual river basins lying within their national territory that constitute natural habitats for the European eel (eel river basins) which may include maritime waters. If appropriate justification is provided, a Member State may designate the whole of its national territory or an existing regional administrative unit as one eel river basin. In defining eel river basins, Member States shall have the maximum possible regard for the administrative arrangements referred to in Article 3 of Directive 2000/60/EC [i.e. River Basin Districts of the Water Framework Directive]." EC No. 1100/2007.
Elver	Young eel, in its first year following recruitment from the ocean. The elver stage is sometimes considered to exclude the glass eel stage, but not by everyone. To avoid confusion, pigmented 0+ cohort age eel are included in the glass eel term.
Escapement	The amount of silver eel that leaves (escapes) a water body, 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)	the competent scientific authority has advised in writing that the capture or collection of the specimens in the wild or their export will not have a harmful effect on the conservation status of the species or on the extent of the territory occupied by the relevant population of the species
Ongrown eels	Eels that are grown in culture facilities for some time before being stocked.
Panmixia	A situation in which an individual is just as likely to mate with another randomly chosen individual as any other in the population.
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 production	The amount of silver eel produced from a water body. Sometimes referred to as escapement + anthropogenic losses, or production-anthropogenic losses = escapement.
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.
Stocking/Restocking:	Stocking is the practice of adding fish to a waterbody from another source,

	to supplement existing populations or to create a population where none exists. Since eels cannot be artificially reproduced, stocking material is always wild caught.
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 (os- moregulatory, 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).
Translocation	Removal of eels from one place (e.g. the coast of arrival) to another (e.g. river or lake) to increase local popuation numbers.
Yellow eel:	Life-stage resident in continental waters. Often defined as a sedentary phase, but migration within and between rivers, and to and from coastal waters occurs and therefore includes young pigmented eels ('elvers' and bootlace). Sometimes yellow eel is also called 'brown eel'.

Annex II: Management Measures

Annex II.1: Germany

Corresponding chapter: 3.3.2 & 6.2.2.2

Table II.1.1: Measures implemented in the EMU Eider

Action type	Subaction	Life stage affected	Action planned	Progress
Commercial fishery	Increase minimum size limit	Yellow	EMP	implemented
Commercial fishery	Close stationary eel traps	Mixed	Other	Partially implemented
Recreational fishery	Increase minimum size limit	Yellow	EMP	implemented
Hydropower & pumps	Trap & Transport	Silver	EMP	implemented
Other	Predator control	Mixed	EMP	implemented
Other	Improve longitudinal connectivity	Mixed	EMP / Other	Partially implemented
Other	Scientific studies and monitoring and data collection	(Mixed)*	EMP	implemented
Other	Legal framework	Mixed	EMP	implemented
Other	Improve means of fishery control	Mixed	Other	implemented

*The studies relate to different life stages, but monitoring and scientific studies do not really affect the stock.

Table II.1.2: Measures implemented in the EMU Elbe

Action type	Subaction	Life stage affected	Action planned	Progress
Commercial fishery	Increase minimum size limit	Yellow	EMP	Partially implemented
Commercial fishery	Close stationary eel traps	Mixed	Other	Partially implemented
Commercial fishery	Reduction of fisheries intensity in coastal waters	Mixed	EMP	Partially implemented
Commercail fishery	Introduction of regional fishing limitations	Mixed	Other	implemented
Recreational fishery	Increase minimum size limit	Yellow	EMP	Partially implemented
Recreational fishery	Introduction of bag size limit for eel anglers	(Yellow)/Mixed	Other	implemented

Recreational fishery	Closing fishery at night for anglers	(Yellow)/Mixed	Other	Implemented
Restocking	Stabilize/increase amount stocked	Glass	EMP	(partially) implemented
Other	Improve longitudinal connectivity	Mixed	EMP / Other	(Partially) implemented
Other	Scientific studies and monitoring and data collection	(Mixed)*	EMP	(Partially) implemented
Other	Legal framework	Mixed	EMP	Partially implemented

*The studies relate to different life stages, but monitoring and scientific studies do not really affect the stock.

Table II.1.3: Measures implemented in the EMU Ems

Action type	**Subaction**	**Life stage affected**	**Action planned**	**Progress**
Commercial fishery	Increase minimum size limit	Yellow	EMP	Partially implemented
Commercial fishery	Reduction of fisheries intensity in coastal waters	Mixed	EMP	Not implemented
Recreational fishery	Increase minimum size limit	Yellow	EMP	Partially implemented
Hydropower & pumps	Hydropower mortality is of subordinate importance in the RBD Ems. There is no urgent need for measures.			
Restocking	Stabilize/increase amount stocked	Glass	EMP	(partially) implemented
Restocking	Supply financial support for stocking	Glass	EMP	Implemented
Other	Improve longitudinal connectivity	Mixed	Other	Partially implemented
Other	Scientific studies and monitoring and data collection	(Mixed)*	EMP	implemented
Other	Legal framework	Mixed	EMP	Partially implemented

*The studies relate to different life stages, but monitoring and scientific studies do not really affect the stock.

In response to the COUNCIL REGULATION (EU) 2018/120 and the "*Joint Declaration on strengthening the recovery for European eel (Commission and Member States)*" from the 16th January 2018 (No. 5382/18), further measures were adopted in the EMU Ems:

- Introduction of a closed season from November to January for the commercial fishery in the complete transitional waters (German part of the estuary) of this EMU. Hence, the measure applies to more than 82% of the wetted area of this EMU.
- Increase of the stocking target by 10% from 2019 (from 1 million individuals to 1.1 million).

Table II.1.4: Measures implemented in the EMU Maas

Action type	**Subaction**	**Life stage affected**	**Action planned**	**Progress**
Commercial fishery	Increase minimum size limit	Yellow	EMP	implemented
Recreational fishery	Increase minimum size limit	Yellow	EMP	implemented
Hydropower & pumps	No permission for new hydropower facilities	Silver / Mixed	EMP	No action needed
Restocking	Stabilize/increase amount stocked (30,000 glass eels and 30,000 ongrown eels)	Glass	EMP	implemented
Restocking	Supply financial support for	Glass	Other	

	stocking		implemented	
Other	Improve longitudinal connectivity	Mixed	Other	Partially implemented
Other	Scientific studies and monitoring and data collection	(Mixed)*	Other	implemented
Other	Include eel in existing species protection programmes	Mixed	Other	implemented
Other	Legal framework	Mixed	EMP	implemented

*The studies relate to different life stages, but monitoring and scientific studies do not really affect the stock.

Table II.1.5: Measures implemented in the EMU Oder

Action type	Subaction	Life stage affected	Action planned	Progress
Commercial fishery	Increase minimum size limit	Yellow	EMP	implemented
Commercial fishery	Close stationary eel traps (but no concrete targets)	Silver	EMP	Not implemented
Recreational fishery	Increase minimum size limit	Yellow	EMP	implemented
Recreational fishery	Introduction of bag size limit	Mixed	Other	implemented
Hydropower & pumps	Hydropower mortality is of subordinate importance in the RBD Oder. There is no urgent need for measures.			
Restocking	Stabilize/increase amount stocked	Glass	EMP	(partially) implemented
Restocking	Supply financial support for stocking	Glass	EMP	Implemented
Other	Improve longitudinal connectivity	Mixed	Other	Partially implemented
Other	Scientific studies and monitoring and data collection	(Mixed)*	EMP	Partially implemented
Other	Legal framework	Mixed	EMP	implemented

*The studies relate to different life stages, but monitoring and scientific studies do not really affect the stock.

Table II.1.6: Measures implemented in the EMU Rhine

Action type	Subaction	Life stage affected	Action planned	Progress
Commercial fishery	Increase minimum size limit	Yellow	EMP	implemented
Commercial fishery	Introduce closed season	Mixed	EMP	Implemented
Commercial fishery	Establish prolonged closed season	Mixed	Other	Implemented
Recreational fishery	Increase minimum size limit	Yellow	EMP	implemented
Recreational fishery	Introduce closed season	Mixed	EMP	Implemented
Recreational fishery	Establish prolonged closed season	Mixed	Other	Implemented
Hydropower & pumps	Trap & transport	Silver	EMP / Other	Implemented
Restocking	Stabilize/increase amount stocked	Glass	EMP	(partially) implemented
Restocking	Supply financial support for stocking	Glass	Other	Implemented
Other	Improve longitudinal connectivity	Mixed	Other	implemented
Other	Predator control	Mixed	EMP	Partially implemented
Other	Scientific studies and monitoring and data collection	(Mixed)*	Other	(Partially) implemented

Other	Legal framework	Mixed	EMP	Partially implemented
Other	Include eel in existing species protection programmes	Mixed	Other	Implemented

*The studies relate to different life stages, but monitoring and scientific studies do not really affect the stock.

Table II.1.7: Measures implemented in the EMU Schlei/Trave

Action type	Subaction	Life stage affected	Action planned	Progress
Commercial fishery	Increase minimum size limit	Yellow	EMP	implemented
Commercial fishery	Reduction of fisheries intensity in coastal waters	Mixed	EMP	Implemented
Commercial fishery	Close stationary eel traps	Mixed	Other	Partially implemented
Recreational fishery	Increase minimum size limit	Yellow	EMP	implemented
Recreational fishery	Introduce closed season	Mixed	EMP	Implemented
Recreational fishery	Introduction of a bag size limit	Mixed	Other	Implemented
Hydropower & pumps	Trap & transport	Silver	EMP	Partially Implemented
Restocking	Stabilize/increase amount stocked	Glass	EMP	Partially implemented
Other	Improve longitudinal connectivity	Mixed	EMP / Other	Partially implemented
Other	Predator control	Mixed	EMP	implemented
Other	Scientific studies and monitoring and data collection	(Mixed)*	EMP / Other	Partially implemented
Other	Legal framework	Mixed	EMP	implemented
Other	Improve means of fishery control	Mixed	Other	Implemented

*The studies relate to different life stages, but monitoring and scientific studies do not really affect the stock.

Table II.1.8: Measures implemented in the EMU Warnow/Peene

Action type	Subaction	Life stage affected	Action planned	Progress
Commercial fishery	Increase minimum size limit	Yellow	EMP	implemented
Commercial fishery	Reduction of fisheries intensity in coastal waters	Mixed	EMP	Implemented
Commercial fishery	Close stationary eel traps	Mixed	Other	Partially implemented
Commercial fishery	Introduce a closed season	Mixed	EMP	Implemented
Recreational fishery	Increase minimum size limit	Yellow	EMP	implemented
Recreational fishery	Introduce closed season	Mixed	EMP	Implemented
Restocking	Stabilize/increase amount stocked	Glass	EMP	Partially implemented
Other	Improve longitudinal connectivity	Mixed	Other	Partially implemented
Other	Predator control	Mixed	EMP	Partially implemented
Other	Scientific studies and monitoring and data collection	(Mixed)*	EMP / Other	Implemented
Other	Legal framework	Mixed	EMP	implemented

*The studies relate to different life stages, but monitoring and scientific studies do not really affect the stock.

Table II.1.9: Measures implemented in the EMU Weser

Action type	Subaction	Life stage affected	Action planned	Progress
Commercial fishery	Increase minimum size limit	Yellow	EMP	Partially implemented
Commercial fishery	Reduction of fisheries intensity in coastal waters	Mixed	EMP	Not Implemented
Commercial fishery	Establish or prolong closed season for eel fishery	Mixed	Other	Partially implemented
Recreational fishery	Increase minimum size limit	Yellow	EMP	Partially implemented
Hydropower & pumps	Introduce trap & transport programme and/or turbine management	Silver	Other	Partially Implemented
Restocking	Stabilize/increase amount stocked	Glass	EMP	(Partially) implemented
Restocking	Supply financial support for stocking	Glass	Other	Implemented
Other	Improve longitudinal connectivity	Mixed	Other	Partially implemented
Other	Scientific studies and monitoring and data collection	(Mixed)*	Other	implemented
Other	Legal framework	Mixed	EMP	Partially implemented

*The studies relate to different life stages, but monitoring and scientific studies do not really affect the stock.

In response to the COUNCIL REGULATION (EU) 2018/120 and the "*Joint Declaration on strengthening the recovery for European eel (Commission and Member States)*" from the 16th January 2018 (No. 5382/18), further measures were adopted in The EMU Weser:

- Introduction of a closed season from November to January for the commercial fishery in the transitional waters (estuary) of this EMU. Hence, the measure applies to more than 60% of the wetted area of this EMU.
- Establishing of Trap-&-Transport actions for silver eels at least for two years.
- Increase of the stocking target by 25% from 2019 (from 2 million individuals to 2.5 million).

Generally, the fishing effort for most gears for eel has reduced in Germany during the recent years (Table II.1.10), in particular for the most important gear (small fykes).

Table II.1.10: Fishing effort with the most relevant eel fishing gears of commercial and semi-commercial fisheries in German waters in 2016 and change (%) in relation to the 2008 data. Data are presented as *gear * days used*. (Source: Fladung & Brämick 2018)

RBD	Small fykes	Large fykes	Longlines (eel line 100 at hooks)	Aalpuppen ("Hook buoy"?)	Stow nets	Stationary eel traps	Electro fishing
Eider	7,985	6,268	0		127	0	0
Elbe*	230,489	287,902	171	4,180	1,618	255	49
Ems	2,552	5,609	0		3,995	0	0
Maas	0	0	0		0	0	0
Oder	195,460	26,534	3,354	5,626	240	2	55
Rhein	126,199	5,990	45		217	0	349
Schlei/Trave	418,150	7,450	415		0	20	0

Warnow/Peene	2,724,110	51,365	114,574	2,591	0	264	14
Weser	130,803	2,834	0	0	710	0	0
Total	**3,835,745**	**393,952**	**118,559**	**12,397**	**6,907**	**541**	**467**
Change from 2008 to 2013 (%)*, **	**-38**	**-8**	**-36**	**-69**	**-37**	**-77**	**-24**

*Without Hamburg, because no data delivered for 2010-2013.

**Without the State of Brandenburg, because no data from this State were available for 2008.

Annex II.2: Spain

Corresponding chapter: 3.3.4

Table II.2.1: EMU codes and their corresponding Ecoregion

EMU	EMU code	Ecoregion
Basque Country	ES_Basq	South European Atlantic shelf
Navarra	ES_Nava	South European Atlantic shelf
Cantabria	ES_Cant	South European Atlantic shelf
Asturias	ES_Astu	South European Atlantic shelf
Galicia	ES_Gali	South European Atlantic shelf
Andalucía	ES_Anda	South European Atlantic shelf (Guadalquivir, Tinto, Odiel, Piedras, Guadalete, Barbate) Western Mediterranean Sea (Almanzora, Andarax, Adra, Guadalfeo, Guaro, Guadalorce, Guadiaro, Guardarranque y Palmones)
Murcia	ES-Murc	Western Mediterranean Sea
Castillas la Mancha	ES_Cast	Western Mediterranean Sea
Valencia	ES_Vale	Western Mediterranean Sea
Catalunya	ES_Cata	Western Mediterranean Sea
Balearic Island	ES_Bale	Western Mediterranean Sea
Inner Bassins	ES_Inne	Western Mediterranean Sea (inner part of Ebro, Jucar and Segura) South European Atlantic shelf (Inner part of Guadina, Duero and Tajo)

Table II.2.2: Measures implemented in the Basque Country

Action type	Subaction	Life stage affected	Action planned	Progress	Comments
Habitat improvement	Improve water quality	ALL	WFD	Partially fulfilled	
Hydropower and obstacles	Demolition of obstacles	Y, S	Other	Partially fulfilled	17 dams have been removed
Hydropower and obstacles	Introduction of eel passes	Y	EMP	Fulfilled	23 passes installed
Hydropower and obstacles	Scientific studies. Corridor establishment study	Y, S	EMP	Partially fulfilled	
Hydropower and obstacles	Scientific studies. Study in the Oria to	ALL	EMP	Fulfilled	

	determine the theoretical impact in the Oria depending on the turbine type				
Hydropower and obstacles	Trap and transport	Y, S	Other	Fulfilled	Although it was not foreseen 14 kg of glass eels and elvers have been transported upstream.
Hydropower and obstacles	Elimination of barriers	Y, S	EMP	Fulfilled	17 obstacles have been demolished
Predator reduction	Scientific studies.	ALL	EMP	Not fulfilled	No study has been performed
Recreational fishery	Designation of protected Rivers where fishery is not allowed	ALL	EMP	Fulfilled	3 main rivers: Oiartzun, Urumea and Barbadun and 2 secondary rivers: Iñurritza and Andrakas
Recreational fishery	Total ban	Y, S	EMP	Fulfilled	
Recreational fishery	Introduce fishing quota	G	EMP	Fulfilled	2kg / night fisher
Recreational fishery	Reduce fishing effort	G	EMP	Fulfilled	Season reduced to a half. For the season 2018-2019 an additional measure has been included: before boat fishing was allowed from the 15th of November to the 31st of January. Now only 5 days before and after the new moon are open.
Stocking	Scientific studies.	ALL	EMP	Fulfilled	

Table II.2.3: Measures implemented in Cantabria

Action type	**subaction**	**Life stage affected**	**Action planned**	**Progress**	**Comments**
Commercial fishery	Reduce fishing effort	G	EMP	Fulfilled	
Stocking	Reserve of the catch for stocking	G	EMP	Fulfilled	
Habitat improvement	Introduction of eel passes	ALL	EMP	Fulfilled	24 passes installed
Predators reduction	Cormorant control	ALL	Other	Fulfilled	
Recreational fishery	Fishery forbidden	G	EMP	Fulfilled	No licences issued after 2014
Recreational fishery	Introduce closed fishery	Y, S	EMP	Fulfilled	

Table II.2.4: Measures implemented in Asturias

Action type	Subaction	Life stage affected	Action planned	Progress	Comments
Commercial fishery	Reduce fishing effort	G	EMP	Fulfilled	Reduction in fishing licences and fishing season
Commercial fishery	Reduce fishing effort	Y, S	EMP	Fulfilled	Fishery prohibited since 2016
Stocking	Reserve of the catch for stocking	G	EMP	Partially fulfilled	Only until 2012
Habitat improvement	Demolition of obstacles	ALL	Other	Partially fulfilled	1 Demolition in 2012
Habitat improvement	Improve water quality	ALL	Other	Fulfilled	
Habitat improvement	Introduction of eel passes	ALL	EMP	Partially fulfilled	2 fish pass installed in 2012
Habitat improvement	Predator control	ALL	EMP	Fulfilled	Annual operations against great cormorant
Hydropower and obstacles	Introduce sonic barrier	ALL	EMP	Partially fulfilled	1 sonic barrier installed in 2010
Recreational fishery	Introduce closed fishery	Y, S	EMP	Fulfilled	

Table II.2.5: Measures implemented in Galicia

Action type	Subaction	Life stage affected	Action planned	Progress	Comments
Commercial fishery	Introduce closed fishery	G	EMP	Fulfilled	
Commercial fishery	Introduce minimum size	Y, S	EMP	Fulfilled	
Commercial fishery	Introduce Regulation of the fishery	Y, S	EMP	Fulfilled	
Commercial fishery	Reduce fishing effort	Y, S	EMP	Fulfilled	
Habitat improvement	Recovery plan of endemic species	ALL	Other	Fulfilled	
Habitat improvement	Improve water quality	ALL	EMP	Partially fulfilled	
Hydropower and obstacles	Inventory of obstacles	ALL	EMP	Fulfilled	
Hydropower and obstacles	Temporal disconnection	ALL	EMP	Partially fulfilled	
Recreational fishery	Introduce closed fishery	Y, S	EMP	Fulfilled	
Recreational fishery	Introduce closed fishery	Y, S	EMP	Fulfilled	
Recreational fishery	Introduce total closed fishery	G	EMP	Fulfilled	
Stocking	Stocking of glass eel	G	Other	Fulfilled	Although no foreseen glass eels were stocked

Table II.2.6: Measures implemented in Andalucia

Action type	Subaction	Life stage affected	Action planned	Progress	Comments
Commercial fishery	Introduce total closed fishery	G	EMP	Fulfilled	
Commercial fishery	Introduce total closed fishery	Y, S	EMP	Fulfilled	
Habitat improvement	Introduction of eel passes	ALL	Not fulfilled	Not fulfilled	
Habitat improvement	Predator control	ALL	EMP	Partially fulfilled	
Hydropower and obstacles	Scientific studies	ALL	EMP	Partially fulfilled	
Hydropower and obstacles	Trap and transport	ALL	EMP	Fulfilled	
Stocking	Stocking of different stages	ALL	EMP	Fulfilled	Stocked glass eels come from seizures

Table II.2.7: Measures implemented in Murcia

Action type	Subaction	Life stage affected	Action planned	Progress	Comments
Commercial fishery	Introduce minimum size	Y, S	EMP	Fulfilled	
Commercial fishery	Reduce fishing effort	Y, S	EMP	Fulfilled	Decrease in the number of boats

Table II.2.8: Measures implemented in C. Valenciana

Action type	Subaction	Life stage affected	Action planned	Progress	Comments
Habitat improvement	Establishment of protected areas	ALL	EMP	Fulfilled	
Habitat improvement	Improve water quality	Y, S	Other	Fulfilled	
Hydropower and obstacles	Put grids in turbines, maintain offshoot channels	ALL	EMP	Partially fulfilled	
Hydropower and obstacles	Trap and transport	ALL	EMP	Fulfilled	Hydropower companies obliged to transport eels since 2015
Predators reduction	American mink control	ALL	Other	Partially fulfilled	
Commercial fishery	Effort reduction	G	EMP	Fulfilled	Reduction of the fishing days
Commercial fishery	Effort reduction	Y, S	EMP	Fulfilled	Reduction of the fishing days
Recreational fishery	Introduction of quotas	Y, S	EMP	Fulfilled	4 eel or 1 kg per day
Stocking	Reserve of the catch for stocking	ALL	EMP	Fulfilled	
Stocking	Stocking fee increase	Y, S	EMP	Fulfilled	

Table II.2.9: Measures implemented in Catalonia

Action type	Subaction	Life stage affected	Action planned	Progress	Comments
Commercial fishery	Reduce fishing effort	G	EMP	Fulfilled	12% of reduction
Commercial fishery	Reduce fishing effort	Y, S	EMP	Fulfilled	10% of reduction
Stocking	Reserve of the catch for stocking	ALL	EMP	Fulfilled	
Habitat improvement	Introduction of eel passes	ALL	EMP	Fulfilled	35 eel passes
Habitat improvement	Predator control	ALL	EMP	Fulfilled	Programs against cormorants, exotic fishes and American mink
Habitat improvement	Protected areas	ALL	EMP	Fulfilled	145 ha
Predactors reduction	Scientific studies	ALL	Other	Fulfilled	
Recreational fishery	Catch and release	Y, S	EMP	Fulfilled	

Table II.2.10: Measures implemented on the Balearic Islands

Action type	Subaction	Life stage affected	Action planned	Progress	Comments
Commercial fishery	Effort reduction	Y, S	EMP	Fulfilled	Eel fishery licences have not been issued since 2014. Eel might be only a bycatch of other fisheries

In all other EMUs, there are currently no significant eel abundances and, hence, no significant eel fisheries. Therefore, the actions taken mainly relate to habitat issues. They are summarized in the following tables.

Table II.2.11: Measures implemented in Castillas la Mancha

Action type	Subaction	Life stage affected	Action planned	Progress	Comments
Habitat improvement	Discharge control	ALL	EMP	Fulfilled	
Hydropower and obstacles	Scientific studies	ALL	EMP	Partially fulfilled	

Table II.2.12: Measures implemented in the Inner Basins

Action type	Subaction	Life stage affected	Action planned	Progress	Comments
Habitat improvement	Improve longitudinal connectivity	ALL	EMP	Partially fulfilled	unsure
Habitat improvement	Predator control	ALL	EMP	Partially fulfilled	
Recreational fishery	Catch and release	Y, S	EMP	Fulfilled	

Table II.2.13: Measures implemented in Navarra

Action type	Subaction	Life stage affected	Action planned	Progress	Comments
Habitat improvement	Demolition of obstacles	ALL	Other	Partially fulfilled	12 obstacles demolished
Habitat improvement	Introduction of eel passes	ALL	Other	Fulfilled	8 passes installed
Recreational fishery	Introduce closed fishery	Y, S	EMP	Fulfilled	
Stocking	Stock pre-grown eel	Y, S	EMP	Fulfilled	

Annex III: Management Authorities

Table III.1: Table of management authorities and their respective responsibilities/jurisdiction per country

Country	Authority	Responsibility/Jurisdiction
Belgium	Regional entities of Flanders, Wallonia and Brussels	Implementation and evaluation of EMPs
Czech Republik	Ministry of Agriculture	Implementation and evaluation of EMPs, responsible/enforcement authority for eel management, fisheries, aquaculture
	Ministry of Environment	Responsible/enforcement authority for ecological status, species and environmental protection (e.g. implementation of most non-fishery realted measures EMPs)
	Nature Conservation Agency	Realization of protection and conservation within Ministry of Environment (assistance on implementation of non-fishery related measures of EMPs)
	T.G. Masaryk Water Research Institute, public research institution (Ministry of Environment)	strategical a methodological support (e.g. development of Eel Management Plans), monitoring activities (e.g. silver eel escapement), evaluation and reporting and eel conservation consultancy
	Czech Environmental Inspectorate (in cooperation with Customs Administration of the Czech Republic)	Control Institution of Ministry of Environment (e.g. control of import and export of „live“ eels in and outside of EU (CITES), any given control within competence of Ministry of Environment
	Czech Anglers Union	Public interest association that is involved/responsible for realization of freshwater fisheries management/recreational fishing (e.g. stocking, fishery controls, except national parks and military areas) concerning EMPs (under the competence of Ministry of Agriculture)
Denmark	Ministry of food, agriculture and fisheries	Implementation and evaluation of EMPs
Estonia	Central Government	Implementation and evaluation of EMPs
	Ministry of Environment (Fisheries Department)	Stocking, local services
	Ministry of rural Affairs	fishing licences

Finland	Ministry of Agriculture and Forestry of Finland	responsible for managing and supervising fisheries and management activities
	Natural Resources Institute Finland	research, monitoring, data collection, scientific advice
	The Centres for Economic Development, Transport and Environment	regional implementation and development of environment and natural resources
France	Ministrère de l'écologie, du développement durable, transports et du logement	Implementation and evaluation of EMPs, management, control, freshwater fisheries.
	Minstère de l'alimentation de l'agriculture et de la pêche	In charge of management of marine ressource and fisheries in mariine areas
Germany	Ministry of Food and agriculture (Federal Government)	Data collection
	State governments and associated ministries	Implementation and evaluation of EMPs
Greece	Ministry of Rural Development and Food, Directorate General of Fisheries	application of management plan and implementation of legislation
	Ministry for the Environment and Energy - Special Secretaria for Water	implementation of legislation
	Hellenic Coastguard	enforcement in sea and estuarine areas
	Regional Authorities, Department of Fisheries	implementation of legislation
Ireland	Department of Communications, Climate Action and Environment	inland fisheries policy, management, control and enforcement
	Department of Culture, Heritage and Gaelteacht (DCHG)	protection and presentation of heritage and cultural assets
	Marine Institute	Provision of scientific advice, data collection, evaluation
	Inland Fisheries Ireland (IFI)	protection, management and conservation of inland fisheries resources and sea angling
	National Parks & Wildlife Service	management of conservation responsibilities (e.g. designation and protection of conservation areas)
	Electricity supply board	Implementation of silver eel/recruitment trap & transport on Shannon, Erne and Lee
	The Loughs Agency	conservation, protection, management, promotion, development of fisheries and marine resources of Foyle and Carlingfold Area
	Department of Agriculture Environment & Rural Affairs (DAERA)	Implementation of EMPs in Northern Ireland, Supervision and Protection of associated fisheries
	Agri-Food and Biosciences Institute for Northern Ireland	Employed by DAERA to provide scientific basis/advice
	Standing Scientific Committee on Eel	Independent scientific advice for IFI
Italy	Ministry of Agricultural, Food and Forestry Policy, Directorate-General for Sea Fishing and Aquacultur (Central government)	sea fisheries up to estuaries
	Regional entities	Inland fisheries, including eel
Latvia	Ministry of Agriculture	fisheries policy, management of fisheries in inland and marine waters, data collection, management of fish resource research, fish processing and marketing

Lithuania	Ministry of Agriculture	fisheries policy, management, data collection and conservation in maritime waters
Luxembourg	Ministry of Environment, Climate, and Sustainable Development National water management agency	Fisheries policy, conservation, management and control of fisheries in inland water, including recreational fisheries
	Ministry of Environment	Conservation, management and control of fisheries in inland water, including recreational fisheries
Netherlands	Ministry of Agriculture, Nature and Food Quality	Conservation of fish stocks and management of anthropogenic impacts. Delivery of EMPs
Poland	Ministry of Agriculture	inland fisheries and use of marine resources
	Ministry of the Environment	management, protection, use of natural and water resources
	National Board of Water management (NBWM)	administrative organ of central government responsible for water management
	Regional Boards of Water Management	administrative organ responsible for water management, subordinate to NBWM
	Marshals of the Voivodeships (and officer of regional governments)	revoking and limiting water use permits, monitoring fisheries, protection and development of aquatic resources
	Voivodes	regulations by National Fisheries Guards
	National Fisheries Guard	subordinate to voivodes, ensure fisheries regulations
	Directors of National Parks Directors	implementation of plans protecting national parks
	District Inspectors for marine fisheries	monitoring marine fisheries
	National Marine Fisheries Institute Gdynia and Stanislaw Sakowicz Inland Fisheries Institute Olsztyn	research & development, scientific supervision of implementation of EMPs
Portugal	General Directorate of Natural Resources, Maritime and Safety Services (Ministry of Sea)	coastal waters
	Institute of Conservation of Nature and Forests (Ministry of Agriculture, Forestry and Rural Development)	inland waters, national authority for CITES
	Standing Transboundary Comission of the River Minho	management of international section of the Minho RBD
	Portuguese Environment Agency and regional entities (Ministry of Environment)	management of waterbodies (e.g. Water Framework directive and thus river obstruction)
Spain	Spanish Ministry of the Environment and Rural and Marine Affairs	management of RBDs extending over different autonomous regions, submission of EMP
	Regional entities	management of RBDs that lie within a single region
Sweden	Swedish Agency for Marine and Water Management	fisheries and stock management
	Swedish University of Agricultural Science, Department of Aquatic Resources	data and advice for management

UK	Environment Agency (England)	management of eel including human impacts
	Natural Resources Wales (Wales)	management of eel including human impacts
	Marine Scotland (Scotland)	management of anthropogenic impacts, conservation and delivery of Scotland EMP
	Department of Agriculture, Environment and Rural Affairs (DAERA, Northern Ireland)	supervision, protection, establishment and development of eel fisheries
	Agri-Food and Biosciences Institute of Northern Ireland	scientific basis/advice for DAERA

Annex IV: Methods

Annex IV.1: Transformation of glass and yellow eel catches into silver eel equivalents

Corresponding chapter: 2.2.2

As natural mortality occurs between the glass eel and silver eel stages, landings of different stages cannot be used directly to assess the effect of each of the fisheries on the stock. Thus to compare the effects of fishing on different eel stages, all of the landings should be in the same units. For that reason, we have converted glass and yellow into silver eel considering natural mortality and obtained the Silver Eel Equivalents (SEE).

To do so, first we transformed the catches into individuals, dividing catches by the average weight of each stage. We have used the average landings of the last three seasons (2015-2017) from the WGEEL 2018 report (table IV.1).

Table IV.1. Eel landings for the 2015-2017 period (ICES 2018)

Year	Glass eel catches (kg)	Yellow catches	Current silver catches (Kg)(F plateada)	Mixed catches Y+ S (kg)
2015	63000	702000	795000	846000
2016	51000	772000	907000	1157000
2017	60000	682000	705000	1003000
Average	58000	718667	802333	1002000

Once we know the number of individuals for each stage, we have to apply an instantaneous mortality to the glass eel and a yearly natural mortality rate later. In addition, in the case of the mixed yellow and silver fishery we have to take into account the percentage of yellow and silver eel of the catches. In this way, we need to choose average weights and ages for each of the stages. Also, we need to decide what is the settlement and the natural mortality and the percentage of yellow and silver eel of the catches. This is very complicated, since the conversion is made at the stock level, and there is a great geographical variability in those parameters. Thus, we have created different scenarios (Table IV.2):

- First, we have used a base scenario (Scenario 1), using what the experts of the project consider to be an average situation for the whole exploited stock area. For the glass eel weight 3 gr has been used taking into account the weight variation along the fishing season. The average weight for yellow eel for commercial fishery is 227 gr in France, 103 gr in Spain and 350 gr in Germany. As catches are dominated by northern countries 300 gr has been used as an average weight for yellow eel. The same criteria has been applied to choose the silver eel weight that has been set at 800 gr. There is a latitudinal gradient in the yellow and silver eel age and 8 and 12 years have been chosen respectively as the average age. Settlement mortality has been set at 80% (Briand, 2009) and an annual mortality rate of 0.138 has been considered (Dekker, 2000). For the mixed yellow and silver fishery in highly exploited fyke nets areas (i.e Netherlands) the yellow catches reach the 80% of total catches. However, those countries having the highest mixed catches, do not carry out this kind of exploitation, so it has been considered that yellow catches represent 70% of the catch.

- Scenario 2 includes a higher settlement mortality (90%)
- Scenario 3 uses a shorter life cycle for eel (6 and 10 years for yellow and silver eel respectively)
- Scenario 4 considers that in mixed fisheries half of the catch is yellow
- Scenario 5 assumes that yellow eel are younger and have a lower weight
- Scenario 6 considers that yellow eel have a higher weight

Table IV.2. Glass eel fishery contribution to the total cacth in terms of Silver eel equivalents, under different scenarios.

	average glass eel weight (gr)	Average yellow weight (gr)	Average silver weight a (gr)	Yellow age (y)	Silver age (y)	Settelement mortality at glass eel stage (%)	Natural mortality (y)	% of yellow eel in the mixed Y+S catches	**% of glass eel catches SEE/total catches SEE**
Scenario 1	0,30	300	800	8	12	80	0.138	70	**64.2**
Scenario 2	0,30	300	800	8	12	90	0.138	70	**47.4**
Scenario 3	0,30	300	800	6	10	80	0.138	70	**70.2**
Scenario 4	0,30	300	800	8	12	80	0.138	50	**64.9**
Scenario 5	0,30	200	800	6	12	80	0.138	70	**62.1**
Scenario 6	0,30	350	800	8	12	80	0.138	70	**66.4**

According to the base scenario, glass eel catches would be 64.2% of the total catches in SEE but if other scenarios are considered, it would vary between 47.4 and 70.2 %. Although we recognize that there is a great uncertainty about these equivalencies, since average values have been used for the whole stock and also mortality assumptions are made based on theories; we consider that they are still useful as an illustrative comparison.

Annex IV.2: EDA2 calculation Spain

Corresponding chapter: 4.2.1.5

The density of silver eels has been extrapolated using France EDA2.2 model results. The EDA2.2 model predicts eel density according to a variable joining the distance to the sea and the cumulated height of dams, the river width and the Eel Management Unit (Briand et al. 2018). Here we have only used the distance to the sea (*dsea*) to build a regression of the average production of silver eel per m^2 according to the distance. According to this simple model the density can be expressed as

$$Density_{silver} = e^{(-3.09*0.004\,dsea)}$$

which simulates a well know log decrease of eel densities according to the distance upstream (Ibbotson et al. 2002).

To predict the silver production from densities, the surface area of rivers is also needed. As no estimates are currently available for Spain, as a first approach, we have derived river surface from the surface of basin upstream from each drain. This is also derived from the French model.

$$W = -0.2 + 0.007914\sqrt{s}$$

From the water surface, and eel density, the number of silver eels per segment is calculated. The total number of eels migrating from upstream reaches are calculated using routing algorithms.

Annex IV.3.1: Identification of main economic stakeholders

Corresponding chapter: 5

The main economic stakeholders impacting eels at various stages of their lifecycle were identified from a number of sources. Hydropower companies were identified through trade journals and government publications. Further research was done through publications of the identified hydropower companies to determine if their hydropower dam installations were located on eel migratory routes. Hydropower companies whose dams were not on eel migratory routes were not included in this research.

Eel experts from the four case study countries were asked to provide names of companies engaged in eel catching, processing and aquaculture in their relevant countries. The names were then cross-checked using trade journals and publications of eel-related initiatives, and the lists were adjusted adding more companies and removing companies that had ceased operations.

Annex IV.3.2: Company level data collection

Corresponding chapter: 5

Company level data for the identified economic stakeholders was collected using a number of sources. For larger stock-listed hydropower companies, company level data was collected from annual reports and other company publications. For private companies, this research referred to relevant company registries and utilized company data service Orbis. Financial data collected included: turnover, profit, total assets, and proportion of business that is eel related. For hydropower companies, additional information their installed capacity and generation was collected.

Annex IV.3.3: Fisheries data gathering and analyses, Spain

Corresponding chapter: 5.1.4

Each Autonomous Community in Spain has exclusive competences on eel fisheries. In this way, Spanish government does not compile eel catches at a national level as it does for other stocks and data is recorded in the different autonomous regions. This causes great differences in the eel fishery information available among the autonomous regions. AZTI compiles eel fishery information for the WGEEL. However, the economic information is not compiled in this working group. Also, as eel fishery in Spain does not take place in the maritime Waters, it is not compulsory to compile this information within the DCF. For that reason, in the framework of the current project a survey was sent to the Autonomous Communities in Spain having an eel fishery (Galicia, Cantabria, Asturias, Murcia, Cataluña, Valencia, Andalucía). This survey contained questions about fishery description, boats description, number of fishers, number of involved companies (and names), dependency data, prices and some economic data of fisheries. All of the Autonomous Communities answered to the survey, although in many cases they did not have information regarding some of the questions.

The obtained information was used in combination of the data compiled by AZTI for the WGEEL to produce the Spanish Fishery description.

Annex IV.4: Data collection on fisheries, aquaculture & processing

Corresponding chapter: 6

For Chapter 6 we have collected public available information on the eel fisheries in France, Germany, Greece and Spain. This includes catch statistics for silver, yellow and glass eel and the number of licences issued for fishers. In addition information on aquaculture and fish processing production was collected and the aquaculture production for Europe and the focused countries listed. In the chapter on trade and markets available information is presented, especially on eel products and the glass eel market. In a deeper analysis eel value chains are presented.

Annex IV.5 Impacts on fisheries, aquaculture and processing

Corresponding chapter: 7.2.3

In Chapter 7 the aim was to assess economic impacts of eel management measures. A deeper impact assessment was not possible as the economic data for fishing companies is very limited. A description of the necessary data for an improved impact assessment is included. Due to the limited data for fisheries only the change in revenues of a total closure of eel fisheries could be calculated and reported. For the analysis of impacts on aquaculture and fish processing companies the available data was collected and possible impacts on the selected companies from chapter 5 reported. The EMFF data on funding for eel stocking measures for Germany were collected and reported.

Annex IV.6: Impacts on hydropower companies

Corresponding chapter : 7.3

In order to assess the impact of possible eel migration measures on each of the hydropower companies that were identified in section 5.4, the initial plan was to assess the impact of three different migration measures: a seasonal shutdown of hydropower facilities, installing upstream and downstream migration equipment, and trapping and transporting the eels. However, when assessing the available data, it turned out that only the first two measures could be (partly) properly analysed. Below, for each of these measures the methodology is discussed. For the trap and transport measure it is explained why a proper assessment was not possible.

Annex IV.6.1: Seasonal shutdown of hydropower facilities

For each of the hydropower companies identified in section 5.4, the impact of a seasonal closure of certain hydropower facilities on the total revenue (in EUR), net profit (in EUR) and power generation in (Terawat hours (TWh)) was assessed. The data used to make this assessment consisted of individual company data averaging the two most recent available years. For most companies this translated into averages of the financial years 2016 and 2017. Since the literature study showed that the eel migration peak has an average duration of one to two months and differs from year to year (usually somewhere between August and December, depending on climate and region), our estimations assessed the impact of a seasonal closure ranging from two to ten weeks. We assume that the hydropower generation is equally divided over each week within the year, to account for the different migration peaks within each year.

To come to impact assessments on total revenue, net profit and power generation, first the hydropower facilities of each company that would be affected by a seasonal closure had to be mapped. Therefore, for each of the hydropower companies we assumed that the hydropower facilities that would likely be affected by eel migration measures are located within 250 km from the sea, since presumably most of the natural eel migration does to reach more inland destinations. This does not hold for Germany, which, unlike the other selected Member States, has various upstream river sections that are heavily stocked. However, we limited the analysis for Germany to the 250 km range as well for the results to be comparable over the four selected Member States. Nearly all identified hydropower companies publish the location and installed power generation capacity of each of their hydropower facilities. Actual power generation per hydropower facility is often not provided. Thus, for each hydropower company the percentage of installed hydropower capacity within a Member State that would be affected by a seasonal shutdown of hydropower facilities located within 250 km from the sea could be estimated. We assumed that pumped storage facilities do not pose severe risks for eels on their migration routes, since these types of facilities are usually not (completely) obstructing the river flow and mostly work through artificially created reservoirs next to the river. Therefore, pumped storage capacity was not included when assessing which hydropower facilities would be impacted by a seasonal shutdown. For some companies, the pumped storage capacity could not be isolated, but since it represented such a small part of the total hydropower capacity it was considered negligible. Some hydropower companies do not publish information with respect to the installed hydropower capacity, but only provide the location of the hydropower facilities. In these cases, the amount of hydropower facilities located within 250 km from the sea compared to the total amount of hydropower facilities within the Member State was used as an estimate for the installed hydropower capacity that would be affected by a seasonal shutdown.

Although hydropower companies usually do not publish yearly power generation data per hydropower facility, they do publish aggregated yearly hydropower generation data on a country level. This country specific hydropower generation data, in combination with the earlier identified percentage of affected hydropower capacity, generates the following formula to estimate the **average** annual **loss in power generation** for each hydropower company in a specific Member State (where hydropower is abbreviated to 'HP'):

$$Closure\ (years) \times Average\ yearly\ HP\ generation\ (TWh) \times \frac{HP\ capacity\ <\ 250km\ of\ sea\ (GW)}{Total\ installed\ HP\ capacity\ (GW)}$$

Next, we wanted to assess the impact of a seasonal shutdown on the total revenue and net profit. We assumed that the amount of generated power per year is the variable that will most directly influence total revenue and net profit. Therefore, it was necessary to assess the importance of each company's hydropower generation activities in relation to the company's other power generation activities within the respective Member State. This was done by comparing the yearly hydropower generation with the total power generation in the respective Member State.

After the above assessment provided an insight in the importance of each companies' hydropower generation as a part of the total power generation within a specific Member State, it was necessary to separate other business activities (e.g. infrastructure, trading, etc.) from the total revenue and net profit within the specific Member State. When this was done, the amount of total revenue and net profit that was derived from power generation related activities within the specific Member State was known. This so-called segment revenue and segment net profit can usually be derived from the segment/geographic reporting notes accompanied with each companies' financial statements. Using this segment revenue, the **average yearly loss in total revenue** could be estimated:

$$Closure\ (years) \times \text{segment revenue (EUR)} \times \frac{HP\ generation\ (TWh)}{Total\ power\ generation\ (TWh)} \times \frac{HP\ capacity < 250km\ from\ sea\ (GW)}{Total\ installed\ HP\ capacity\ (GW)}$$

Similarly, using the segment net profit the **average yearly loss in net profit** could be estimated:

$$Closure\ (years) \times \text{segment net profit (EUR)} \times \frac{HP\ generation\ (TWh)}{Total\ power\ generation\ (TWh)} \times \frac{HP\ capacity < 250km\ from\ sea\ (GW)}{Total\ installed\ HP\ capacity\ (GW)}$$

All estimations of the identified companies were also aggregated at a Member State level, to give an indication of the estimated impact within each Member State. For France and Spain, the identified hydropower companies accounted for more than 90% of each country's total installed hydropower capacity. The remaining part of the installed hydropower capacity was held by unidentified small private sector hydropower companies. Therefore, for these two countries we extrapolated the estimations of the identified hydropower companies to account for the impact of a seasonal closure on unidentified small private sector hydropower companies. For Germany and Greece, the identified hydropower companies accounted for less than 90% of the total installed hydropower capacity. Therefore, for these two countries we did not extrapolate the estimations to account for possible unidentified small private sector companies, since the uncertainty would be too high and would not reflect each countries' identified hydropower distribution (i.e. location and type of hydropower facilities). Therefore, the aggregated Member State estimations for Germany and Greece have not accounted for unidentified small private sector companies.

Annex IV.6.2: Installation of upstream and downstream migration equipment

The actual cost of the installation of upstream and downstream migration equipment differs per precise location. Therefore, in order to estimate the average costs per hydropower company we used an approximate minimum and maximum cost. These were then used in conjunction with the number of hydropower dams located on relevant eel river migration routes to estimate the financial impact on the identified hydropower companies.
Of the four selected Member States, it was only possible to do the impact assessment for France. In France, we were able to use precise information on dams delivered by the ROE database. For the other Member States, this type of information was not available. Similar to estimating the impact of a seasonal shutdown of hydropower facilities, for the France estimation we again assumed that the affected hydropower dams were located within 250 km from the sea. Dams that are used to directly flow to cooling units were removed from the dataset. The dataset was further split between hydropower dams located on small and large rivers according to a flow limit of 50 m^3/s. The cost of installing upstream and downstream migration equipment differs, and therefore separate estimations were made for upstream and downstream. The dataset of relevant hydropower dams within 250 km from the sea consisted of 1,185 hydropower dams (of in total 28,737 dams that are located in this area), 64 of which were hydropower dams on large rivers and 1,121 were hydropower dams on smaller rivers.

As for estimating the costs of installing **downstream** migration equipment, specific information about the flow of the river was derived from the RHT (Pella et al. 2012). We used costs based on two publications giving costs ranging from EUR 20,000 per m^3/s to EUR 50,000 per m^3/s (LUWG 2008, Ebel 2018). These costs were considered too low for the large dams, so we increased those costs to EUR 50,000 to EUR 150,000 per m^3/s for dams on large rivers (>50 m^3/s). Dams that are not used for hydropower generation or are already equipped with downstream passages (14 large dams and 56 small dams) have been removed from the dataset. The analysis assumed that the information in the ROE database is correct. It must be emphasised that the cost of installing downstream migration equipment can vary according to the condition for setting up the construction work (sometimes it is possible to isolate the powerplant), whether it is necessary to modify the dam structure to enlarge or deepen the water intake, and according to the design of the downstream migration pathway for fishes. These elements can account for a one to five factor in the total cost, and this estimation requires site specific elements which are not possible to gather at a large scale. Therefore, the estimated cost range of installing downstream migration equipment should only be considered as a rough indication of the final possible costs.

The cost of **upstream** migration has been assessed by using specific information about the flow of the river from the RHT (Pella et al. 2012) and using cost data for equipment of multi species fishways. Figures on cost were collected from Baran et al. (2015), giving the price of a fishway according to the equipment flow in the fishway and the height of the dam. Another figure given by Luwg (2011) has also been used in a first assessment. However, this work was giving a dam cost about one tenth of the cost provided by Baran et al. (2015)[3], and we chose to use the French assessment, but this large difference illustrates the difficulty in finding the right costs. Missing values on dam height have been replaced by the average height in the small and large dam datasets. Those dams equipped with any kind of upstream migration fishway (Fish sluice, lift, pool fishway, Denil fishway, artificial river or eel specific ladder) have been removed from the dataset (31 large dams and 192 small dams). Finally, the figure for final cost has been reduced by 20% as Baran et al. (2015) indicate that the cost is overall lower on hydropower dams.

To get to company specific estimates for the costs of installing upstream and downstream migration equipment, we have divided the total Member State costs among the identified companies based upon the installed hydropower capacity. This means 79.5% of the total costs have been contributed to EDF, 15% to Engie and 5.5% to unidentified other hydropower companies.

Annex IV.6.3: Trap and transport

The costs incurred when eels are trapped and transported vary per location. Currently, there is no countrywide data available to analyse the costs of this measure for each of the Member States. Also on a company level, the trap and transport measure requires more analysis on possible costs and effectiveness. Like already mentioned earlier in this report, in certain cases it is highly debatable whether trap and transport helps to solve the eel migration issue. Because of these considerations the costs of trap and transport have not been estimated in this report.

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[3] 0.8 x (51.41(±33.6) x Water denivelation(m)+4.95(±1) x Module(m3.s-1))

The diversity of detrimental factors impacting the European eel and the number of involved stakeholders pose a challenge for an effective stock management. Knowledge on the economic consequences of single management measures is required to better assess their implications for the involved sectors. This study summarizes the current knowledge on threats and provides economic data from hydropower generation, fisheries and aquaculture impacting the European eel in order to evaluate management measures and estimate their repercussions for stakeholders.

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