Investigation of eel restocking practices in the Baltic Sea region

– A BALTEEL-RECO report

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»Investigation of eel restocking practices in the Baltic Sea region«

BALTEEL-RECO project partners:

Niki Sporrong, Senior Policy Officer & European Eel Project Manager, The Fisheries Secretariat
Lina Birgersson, The Fisheries Secretariat
Joonas Plaan, Estonian Fund for Nature, Estonia
Jürgen Karvak, Estonian Fund for Nature, Estonia
Elza Štrausa, Pasaules Dabas Fonds, Latvia
Magda Jentgena, Pasaules Dabas Fonds, Latvia
Matīss Zagars, Latvian Institute of Aquatic Ecology, Latvia
Arvydas Švagždys, Klaipeda University, Lithuania
Robertas Staponkus, Lithuania Fund for Nature, Lithuania

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Tegelviksgatan 40, SE-116 41 Stockholm, Sweden
+46 8 25 07 90 | e-mail: info(at)fishsec.org | www.fishsec.org

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Summary

The European eel has been in decline for decades and is listed as Critically Endangered on the IUCN and EU Red lists. In 2007, a regulation establishing measures for eel recovery was agreed but it has not yet led to any overall improvements of the population status.

This report is focused on restocking of European eel in four EU countries around the Baltic Sea: Estonia, Latvia, Lithuania and Sweden. The report was produced as part of the collaborative project Baltic Sea eel recovery from an ecosystem perspective (BALTEEL-RECO), which aims to promote a more coordinated approach to eel recovery in the Baltic Sea region.

In this report we assess the national restocking practices in the four countries. The national information is based on eel management plans, national reports, personal communication and scientific papers. All four countries adopted Eel Management Plans (EMPs) in 2008 or 2009 and restocking measures are a key part of the plans in each country and the practice is directly linked to reaching the objective of the EU recovery plan for European eel (EC Regulation 1100/2007) - silver eel escapement at 40% of estimated pristine levels.

Eel restocking is not a new management measure, however. It has a long history in the Baltic region and has been used in the four countries for decades. Restocking efforts were refocused under the EMPs and combined with efforts to reduce eel mortality. Most of the restocking efforts are taking place in lakes and rivers inland, though there are limited coastal releases as well. Estonia is the only country to report that they have reached the 40% escapement target, largely because of restocking efforts in Lake Võrtsjärv. In Latvia and Lithuania, restocking has mainly been restricted to waters with free migration routes.

Sweden was found to have the most complex organisation of eel restocking, as there are both national and private restocking, as well as legally required compensatory restocking carried out by the many hydropower companies. In Estonia it is carried out by the fishing sector in collaboration with the authorities, whereas in Latvia and Lithuania the government is responsible for all restocking.

Key scientific recommendations on quarantine procedures, the marking of eels for future evaluations and habitat quality considerations are not uniformly applied. In general, there is also a lack of an ecosystem perspective.

While an adaptive management framework is applied in all four countries, the reasoning behind changes in restocking practices over time are not always transparent and details on the exact locations and amount of eels released are not readily available. Importantly, restocking in Sweden and Estonia still takes place above migration barriers contributing to increased eel mortalities. However, both Latvia and Sweden are currently reassessing their national restocking programmes and meanwhile all government releases have been paused.

Recommendations

With the European eel population listed by IUCN as Critically Endangered and showing no signs of recovery, the scientific advice (ICES, 2022a) is zero catches of all life stages and in all habitats, including catches for restocking and aquaculture, as well as zero anthropogenic mortality. As long as restocking of eel relies solely on wild glass eels, it is our view that this advice should be followed and all fishing for glass eel and all restocking programmes should be halted until a significant improvement in the European eel population has been documented.

In addition, EU Member States need to refocus their efforts to improve and facilitate natural recruitment through long-term improvements in water quality, effective mitigation of migration barriers and habitat protection rather than relying on restocking. There are win-win solutions with other environmental benefits, such as the recreation of wetland areas important for eels that will support wider biodiversity as well as lessen the effects of climate change.

If restocking continues in the face of the scientific advice and contradictory to the objectives of the EU:s Common Fisheries Policy (Art. 2, Regulation 1380/2013), the following principles should be applied:

- Quarantine procedures under a common EU standard should apply to ensure that the spread of parasites and diseases is prevented.
- Monitoring of the glass eels condition and quality before restocking is vital in order to avoid unnecessary mortality.
- All restocked eels should be marked to facilitate evaluation of the restocking practices.
- Relocation of eel upstream of migration barriers should be prohibited and cannot be considered a conservation measure.
- Public funds should not be used for restocking purposes without proper assessment of the efficiency and appropriateness of the measures.

BALTEEL-RECO

Baltic Sea eel recovery from an ecosystem perspective

This report is one of the products of a project set up to explore the degree of regional coherence in eel recovery efforts under the EU eel regulation. The collaborative project *Baltic Sea eel recovery from an ecosystem perspective (BALTEEL-RECO)* started in 2021 and is a partnership between FishSec in Sweden, Eestimaa Looduse Fond in Estonia, Pasaules Dabas Fonds in Latvia and Lietuvos gamtos fondas in Lithuania. In order to promote a more coordinated approach to eel recovery in the Baltic Sea region, we have analysed the national eel management plans and restocking practices in each of the four countries.

The main activities in the project have been analysis and discussion of the national eel management plans and restocking practices in the format of national roundtables, a policy brief and this report, as well as raising public awareness. The project is funded by the Swedish Institute together with additional funding from the Swedish Authority for Water and Marine Management (SwAM) and the Waterloo Foundation.

This report is focused on restocking of European eel in four EU countries around the Baltic Sea: Estonia, Latvia, Lithuania and Sweden. In order to explore the potential effects of restocking on European eel recovery, we have looked at numerous scientific papers as well as materials from ICES, including reports from the Working Group on Eels (WGEEL) and the Workshop on Eel Stocking (WKSTOCKEEL). We have also collected more specific information on eel restocking practices in Estonia, Latvia, Lithuania, and Sweden and made a comparison between the four countries. The national information is based on eel management plans, national reports, personal communication, and scientific papers.

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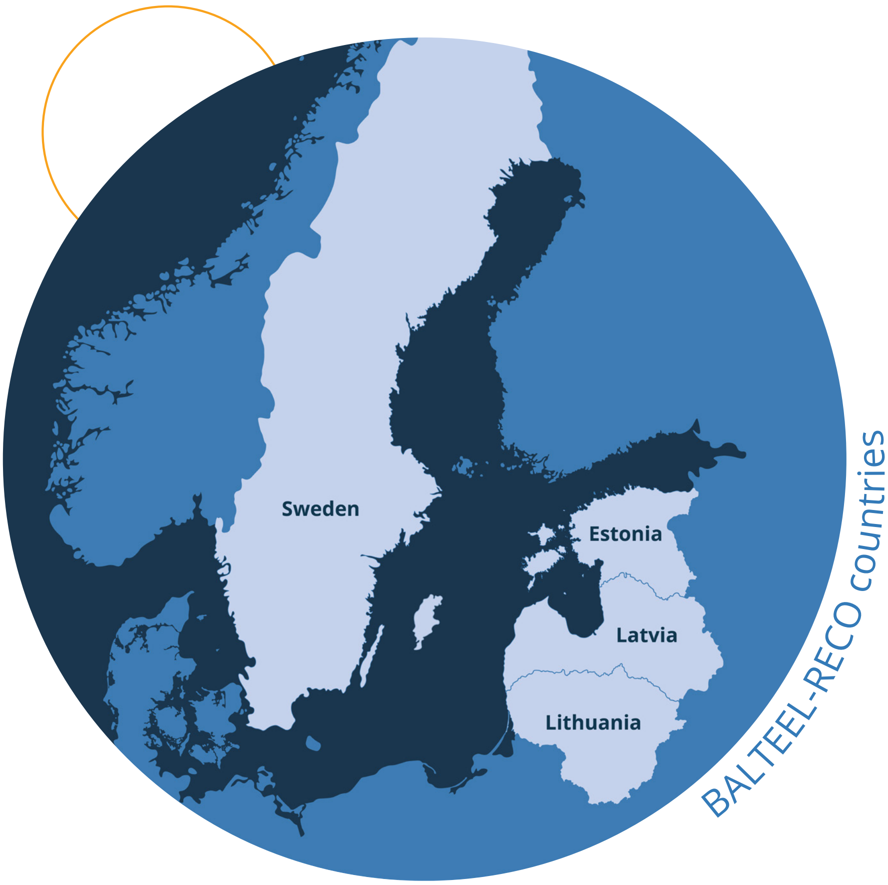


Background

For centuries, the European eel (*Anguilla anguilla*) has played an important role in the cultural and economic life of many European countries. Today, it is listed as critically endangered by the International Union for Conservation of Nature (IUCN, 2020a). European eel belongs to the Anguillidae family and is among the most commercially important species of anguillid eels, together with the Japanese eel (*Anguilla japonica*) and the American eel (*Anguilla rostrata*), which are also in poor condition (IUCN, 2020b; IUCN, 2017). The dramatic decline of European eel in recent decades raises concerns about the species' long-term survival.

The brackish Baltic Sea region, with tens of thousands of lakes and many rivers has historically been an important growth area for eels. The population decline began before the 1970s and was noticeable in the Baltic region already in the 1960s (Svärdson, 1976). Glass eel recruitment across the population has now been reduced to 1–10% of previous levels, and is lower in the North Sea area, including the Baltic (ICES 2022a; Dekker & Beaulaton, 2016; Aarestrup et al., 2009).

The deteriorating status of the eel is also reflected in the decreasing catches. Reported glass eel landings, as well as the total catches of yellow and silver eel around the Baltic Sea region, have declined by more than 90% during the last 50 years (ICES, 2022a; Dekker & Beaulaton, 2016).

Due to its complex life cycle, straddling various types of habitats across a great geographic range over a long period of time, and its high body fat, eels are perhaps particularly susceptible to negative impacts of anthropogenic activities. Several factors are thought to have contributed to the decline. The reductions in mature eels are mainly attributed to fishing, habitat loss and degradation, and pollution, while larvae are assumed to mainly be affected by changes in oceanic conditions (e.g., ICES, 2017; Righton et al., 2021; Dekker, 2004; Wickström & Sjöberg, 2014; Drouineau et al., 2018).

A recovery plan for eel was adopted by the EU in 2007, as a response to scientific advice and concern from stakeholders regarding the decline of the stock (EC, 2007). The recovery plan provides a joint management framework across the EU, which includes mandatory national eel management plans (EMPs) for all Member States within the geographical span of the population. The Black Sea countries and some inland Member States, such as Austria, have been exempt.

Among other things, it is stated in the eel recovery plan that "*Special measures to increase the numbers of eels less than 12 cm in length released into European waters as well as for the transfer of eel less than 20 cm in length for the purpose of restocking should therefore be implemented as part of an Eel Management Plan*" and that 60% of the glass eels caught (<12 cm) should be reserved for restocking efforts. Restocking does not have to be part of the national Eel Management Plans, but it is one of the most commonly used management measures across the EU.

Despite the EU regulation and subsequent management measures, 16 years later, there are no signs that the eel population is recovering, and glass eel recruitment remains very low (ICES, 2021; 2022a). In fact, a scientific evaluation of the implementation of the national eel management plans carried out in 2022 showed that so far, no overall progress has been made in reaching the EU recovery objective (ICES, 2022b). According to the most recent advice on possible fishing opportunities by the International Council for the Exploration of the Sea (ICES), the European eel population is still so depleted that all fishing, including glass eel fishing, should stop (ICES, 2022a).

What is restocking?

Fish restocking (or stocking) is a management strategy used to supplement or enhance the population of fish in a given area. This approach can be used to support fisheries, increase recreational fishing opportunities, or in efforts to restore populations of threatened or endangered fish species. While smaller scale restocking in, for example, ponds date back further, the practice became more widespread in Europe during the late 19th and early 20th centuries. Restocking of European eel began in France in the 1840s, followed by Germany in the early 1900s (Dekker & Beaulaton, 2016) and is still ongoing today. Throughout the years, eel restocking has been carried out for diverse purposes, such as extending or sustaining fishery, lessening the impact of migration barriers, compensating for other kinds of anthropogenic mortalities, or aiming to support the recovery of the stock (Dekker et al., 2021; Dekker & Beaulaton, 2016). In Europe, restocking of European eel to supplement fisheries (commercial and recreational) has been a common practice for over a century, while restocking for stock recovery or stabilisation started more recently due to the poor state of the stock.

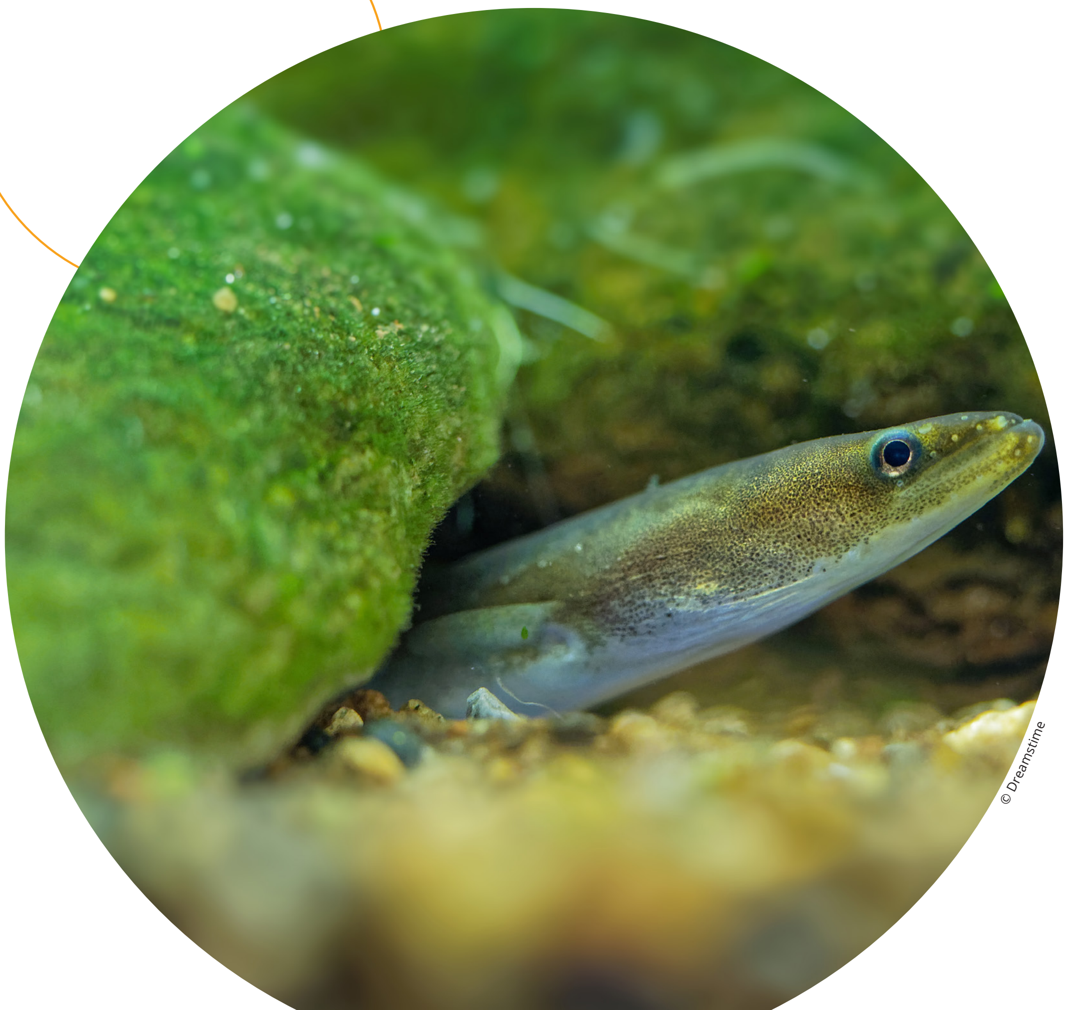
While restocking of other fish species is often done by releasing young fish that have been raised in captivity, eel restocking relies on the relocation of natural born recruits – i.e. young eels captured in the wild. The reason for this is the complexity of the eel's reproduction and life cycle, which - to date - makes it unviable to breed in captivity. The selected recipient areas are usually habitats where eels have occurred before. The European eels used for restocking in Northern Europe are normally sourced from other regions, such as the Bay of Biscay, where glass eels are still more abundant. Prior to Brexit, eels from the British River Severn were also used.

Eels used for restocking are either glass eels released shortly after capture and transport (national quarantine rules apply) or ongrown eels - yellow eels which were captured as glass eels and then kept in aquaculture to a larger size. The life stage used for restocking varies by country and there is no unified definition for ongrown eels.

Restocking in European inland waters often takes place above migration barriers, such as locations above hydropower plants, dams and in ponds. In many cases, for example in Sweden, restocking is an obligatory measure that the hydropower companies are obliged to take in order to compensate fishers for the loss of migratory fish. In some countries, there is also a discourse on restocking and "productivity" in inland waters with good water quality and/or little competition that would provide good growth in eel - and the natural occurrence and biology of European eel is not properly considered. EU Member States around the Baltic Sea use eel restocking as a measure to compensate both for the stock's decline and for the low immigration levels of eel to the region (Rohtla et al., 2021; Shiao et al., 2006). Even today, much of the restocking is in support of commercial and/or recreational fisheries.

The eel regulation states that "*the objective of each Eel Management Plan shall be to reduce anthropogenic mortalities so as to permit with high probability the escapement to the sea of at least 40 % of the silver eel biomass relative to the best estimate of escapement that would have existed if no anthropogenic influences had impacted the stock*" (EC No 1100/2007). Restocking has become a commonly used tool - perhaps the most common management measure across the EU - to meet the EMP objective of 40 % escapement of the silver eel biomass. However, several studies have questioned the net benefit of restocking, particularly from a conservation point of view (e.g., Westin, 2003; Marohn et al., 2013; Rohtla et al., 2021).

Ultimately, these practices may greatly reduce the potential and ability of mature eels to contribute to the spawning migration as silver eels, and reproduction. There is also a high risk that eels restocked above hydropower plants will die when they attempt to return to the sea.



Scientific literature on eel restocking

Based on the EU management objectives under the Common Fisheries Policy (Article 2, Regulation 1380/2013), the current scientific advice on fishing opportunities and conservation of European eel concludes that no fishing for eel can be considered sustainable, including catches of glass eels used for restocking. The annual ICES advice on eel for 2023 states that "*when the precautionary approach is applied, there should be zero catches in all habitats in 2023. This applies to both recreational and commercial catches and includes catches of glass eels for restocking and aquaculture*" (ICES, 2022a). The same advice was given the previous year (ICES, 2021b). Anthropogenic mortalities not related to fisheries should also be zero and eel habitat restoration should be done in order to increase the quality and quantity of habitats. ICES has also recommended in previous advice sheets that for eel restocking, "*a precautionary approach should be applied in assessing risk when the outcome of stocking is uncertain*" (ICES, 2006, 2007, 2008. 2009, 2011).

Previous ICES WGEEL evaluations of restocking (2006, 2008, 2009 and 2011) state that in local studies stocking has clearly "*been beneficial by enhancing the yellow and silver eel stocks in a number of water bodies*". However, in order for restocking to be considered a conservation measure the relocation of eels needs to improve the escapement in comparison with a situation where the eel had not been translocated. The ICES workshop WKSTOCKEEL defines a net benefit of restocking as "*where the stocking results in a higher silver eel escapement biomass than would have occurred if the glass eel seed had not been removed from its natural (donor) habitat in the first place*" (ICES, 2016).

While several restocking studies have given some idea of escapement, the eels need to reach the Sargasso Sea in order to contribute to reproduction – and this is more difficult to study. ICES states that the contribution of eel restocking to the population's reproductive potential remains unknown and that information on factors such as "*carrying capacity estimates of glass eel source estuaries, detailed mortality estimates at each step of the restocking process, and the spawning potential of stocked vs. non-stocked eels*" is lacking (ICES, 2022a).

Reliance on a glass eel surplus for restocking

Restocking depends on wild caught glass eels, and does not increase the actual amount of eels in the population. Instead, the classification of eel restocking as a recovery measures is based on the assumption that transferring individuals from areas with higher abundance to those with lower abundance could enhance the eels survival (e.g. Righton et al., 2021) – that more of the glass eels would die unless they are translocated to other areas. Essentially, the practice relies on there being a considerable surplus of eels at the donor site – mainly the Bay of Biscay - for which the survival rate would improve if they are translocated to another place, perhaps a place with less competition and better water quality. One objection to the practice of restocking is the fact that the previous local "surplus" of eels in the Bay of Biscay has disappeared due to the declining influx of glass eels from the Atlantic (Svedäng & Gippert, 2011).

Considering the dire state of the stock, it is uncertain whether such a "surplus" of glass eels still exists. The recent assessment by the ICES questions this and states that we don't know enough about the carrying capacity at source and that the net benefit of restocking is unknown. Over the last decades, glass eel recruitment has declined significantly (ICES, 2021a). This decrease is further evidenced by reduced catches of glass eels, indicating a considerable drop in the overall supply. Furthermore, while silver eel quantities and escapement has been shown to increase after restocking, there is currently no evidence that restocking of eels contributes to the spawning stock (ICES, 2011b, 2016). In fact, restocking may not contribute to the recovery of the eel population as a whole (ICES, 2021a).

Risks associated with eel restocking

Aside from the uncertainty around the net benefit of restocking for the eel population, the effects of restocking efforts can be influenced by a number of different factors such as the condition of the glass eels, the habitat at the recipient site that eels are translocated to, and restocking density (Simon & Dörner, 2014; Dekker, 2015; Marohn et al., 2013). There are also a number of potential risks associated with restocking of European eel listed in scientific literature as well as ICES reports (ICES, 2016; ICES, 2011b), including:

- *Biosecurity*: introduction of pathogens (Kullmann et al., 2017; Danne et al., 2022; Pratt et al., 2019; Delrez et al., 2021) and non-native species (Marohn et al., 2014) to the recipient area.
- *Migration*: effects on spawning migration in translocated eels (Durif et al., 2022; Westin, 2003; Sjöberg et al., 2017).
- *Mortality*: glass eel mortality during capture, handling and transport of glass eel in commercial fisheries (Simon & Dörner, 2014; Stacey et al., 2015; Simon et al., 2022).
- *Genetics*: potential effects on genetic structure (Als et al., 2011; Pavey et al., 2015).
- Altering *sex ratios* and *growth* (Côté et al., 2009; ICES, 2011).

There is currently no scientific consensus on the wider benefits of European eel restocking and the degree to which restocked eels contribute to the spawning stock; only that restocking increases the eel stock at a particular location. The following sections will expand on some of the possible risks associated with European eel restocking based on our review of scientific literature.

Biosecurity

The health status of fish used for restocking needs to be taken into account as it is important to prevent the spreading of diseases or parasites caused by eel restocking (Kullmann et al., 2017; ICES, 2016). Apart from the potential spread of eel-specific diseases and parasites, such as *Herpesvirus anguillae*, *Anguillicola crassus*, and the rhabdovirus "Eel Virus European X", there is also a risk of spreading other fish diseases as well as a potential risk of introducing non-native flora and fauna, which could be invasive and negatively impact local ecology (ICES, 2016).

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Biosecurity is harder to control when wild-caught fish with an unknown health status are used than it is for other species that, unlike eels, can be bred in captivity (Delrez et al., 2021). In trade and aquaculture, eels are kept at higher than natural densities for varying periods of time and there is a risk of pathogens spreading during this time. Knowledge of the impact of restocking on the spread of viral diseases in eels is still lacking, and in general the impact of glass eel usage is less studied than the impact of using adult eels. A recent study by Danne et al., (2022) examined the levels of virus infections in glass eels intended for restocking in Germany. The study found infections with anguillid herpesvirus 1 (AngHV1) and rhabdovirus Eel Virus European X (EVEX) and stated that restocking practices need to be controlled in order to minimise the potential spread of pathogens (Danne et al., 2022).

Kullmann et al. (2017) studied anguillid herpesvirus 1 in eels used for restocking in a fjord in northern Germany and stated that the eels were found to be "*heavily contaminated with AngHV 1 and that there is an obvious coherence with stocking activities*". The effect of the anguillid herpesvirus on spawning ability is still not determined but *"it is recommended to apply the precautionary approach and avoid stocking of diseased eels."* Kullmann et al. suggest that virus screening should be mandatory before restocking and "long-term diseases monitoring and a stock monitoring programme" are needed to comply with the precautionary approach. Measures or control mechanisms are vital in order to ensure that the restocking does not lead to a spread of diseases in the eel population (Kullmann et al., 2017).

Another example of likely introduction of pathogens through eel restocking was found in a study by Pratt et al. (2019), which showed that infestation of the swim bladder nematode *Anguillicoloides crassus* in American eel (*Anguilla rostrata*) in the upper St. Lawrence River occurred for the first time after translocation of glass eels to the area as part of a conservation stocking research project. In European eel, *A. crassus* is suspected to affect the spawning migration by compromising the function of the swim bladder.

Delrez et al. (2021) examined quarantine conditions for glass eels after capture and before restocking. The study found that because eels are kept at a higher density in captivity than the natural state in the wild, the contact between eels is greater and the risk of pathogen transmission higher. Artificial translocation of fish from one area to another "is also a major cause of pathogen introduction and spread between regions" (Delrez et al., 2021). They recommend implementation of a short (15 days) pre-release quarantine period for glass eels to reduce the risk of pathogen spread with a limited negative impact on the eels.

Migration

Of all eel species, the European eel travels the longest distance and also has the most complex migration (Aoyama, 2009). Mature eels travel thousands of kilometres to breed in the open ocean in the Sargasso Sea. After spawning, the eel larvae are transported by the Gulf Stream and North Atlantic Drift to coastal and freshwater habitats in Europe and Northern Africa, where their growth habitats are located (Tesch, 2003; Aarestrup et al., 2009). The spawning migration is impacted by factors such as temperature, light conditions, moonlight and water turbidity (Kjærås et al., 2022). Scientific knowledge about this journey has been limited and only recently did a study provide the first *direct* evidence of European eel spawning migration published (Wright et al., 2022).

Some scientific studies suggest that the current restocking practice where juvenile eels are translocated to other areas (often long distances) could disrupt the eels' spawning migration and consequently their contribution to stock recovery. While some suggest that relocated eels may not be able to migrate as well as the wild recruits (e.g., Westin, 1998; Westin, 2003; Svedäng & Gippert, 2011; Durif et al., 2022), other studies did not find that migration was impacted in restocked eels compared to natural eels. Westerberg et al. followed natural and restocked eels migrating from the Swedish west coast (i.e. outside the Baltic Sea basin) for 2,000 km in a telemetry study and did not find differences in swimming route, speed or depth between the restocked or natural eels (Westerberg et al., 2014). An older study by Westin (1990) suggested that the Baltic Sea can act as a trap for the eels used in stocking programmes, and that they might not be able to find their way out in the silver eel stage. Westin (2003) also found that eels restocked in a freshwater lake on the island of Gotland in the Baltic Sea displayed confused escapement behaviour and concluded that they likely lacked the imprinting needed to migrate and contribute to recruitment. A tagging study on the Swedish east coast (Sjöberg et al., 2017) found that most of the eels restocked in Lake Mälaren did not manage to migrate out of the lake into the Baltic Sea.

Eels that are unable to migrate as normal may loose fat content and energy reserves that are necessary to successfully complete the long migration to the spawning grounds. The restocking site is assumed to be important for spawning migration. For instance in Sweden, restocking on the west coast is prioritised (Dekker et al., 2021).

A recent study by Durif et al. (2022) compared migratory routes of five species of temperate anguillid eels and suggested that eels, like other migrating animals, might need to imprint their migratory route. Once the geomagnetic parameters have been imprinted by larvae at the spawning grounds, adult eels could use this information to retrace their route and find their way back to the spawning ground years later. The authors state that "*translocated glass eels are not exposed to the magnetic cues needed for successful navigation back to the spawning area*" (Durif et al., 2022).

Apart from navigation, timing may also be important for the eel's migration success and delays caused by migration barriers may be costly for the eel (Trancart et al., 2020). Tambets et al. (2021) found unusual migration behaviour, where 21% of the restocked eels travelled from the Estonian Narva River reservoir to the Baltic Sea and then temporarily returned to the freshwater before moving back to the sea. However, others have stated that the "false start" to the migration observed by Tambets et al. could be "*a behaviour which is already well known throughout the range—yellow eel inter-habitat shifting between saline and freshwater habitats*" rather than silver eel migration (Rohtla et al., 2022) and more studies are needed to confirm this phenomenon.

No existing studies directly prove that restocked eels contribute to recruitment, as no one has been able to follow tagged eels all the way to the Sargasso Sea. In fact, the first study with direct evidence that adult European eels do migrate to the Sargasso Sea was published just last year. That study followed European eels from the Azores to the spawning site in the Sargasso Sea but did not analyse effects of eel restocking on the migration (Wright et al., 2022).

Mortality

Mortality during the capture, storage and transport of glass eels for restocking is one of the major risks listed by ICES. The WKSTOCKEEL report notes that "*some glass eel fisheries and their associated gears impart significant mortality and post-capture stress while other gear types and methods are relatively benign*" (ICES, 2016). Mortalities caused by fisheries can be both direct (during fishing) and indirect through, for example, skin lesions. Large lesions may be lethal immediately, whereas smaller lesions can kill the glass eels after some time unless they are healed. The mortality of glass eels in fisheries are dependent on factors such as mesh size of the nets used for capture, speed of the boat and subsequent storage of the eels (Simon et al., 2022).

Efforts have been made to examine approaches to reduce mortality of glass eel fishing (ICES, 2016) but studies of mortality in glass eels are still limited in geographic coverage. Glass eel fisheries in France use a few different types of gear including hand scoop nets and various push nets (with different mesh sizes and shapes) (Beaulaton & Castelnaud, 2009). Push nets are nets which are pushed over the bottom in shallow waters, either ahead of a small boat or by hand (FAO). Relatively few studies have explored mortalities in push net fisheries of glass eels so far.

A study by Briand et al. (2012) monitored mortality in glass eels after fishing and found that in push net fisheries the mortality varied greatly in the two days after fishing, from 2–82%. Long fishing periods or high speed during push net fishing led to mucus loss and the mortalities were significantly correlated with body injuries. Higher mortality was seen for fishing with push nets, compared with fishing using hand nets (which are used in French, Spanish and UK glass eel fisheries) and compared with collection using trapping ladders. Both trapping ladder and hand net fishing led to no or very low mortality in the experimental study (Briand et al., 2012).

More recently, Simon et al. (2022) examined mortalities in the French push net fisheries for glass eels. Direct mortality was found to be low (ranging from zero to 3.1%). They found that skin lesions occurred in on average 31% of the eels fished in the examined French fisheries but that there was a wide range of variation between 4–98%. According to this study, glass eel mortality can be limited by fulfilling specific criteria, including regulating the net's mesh size (maximum 1 mm at the cod-end), controlling the boat's speed (maximum 1,5 knots), limiting the haul duration (not exceeding 30 minutes), and appropriately storing the eels after capture (Simon et al., 2022).

Mortality may also differ if ongrown eels (glass eels reared in eel farms until they reach a specific size, around 5–8 g) are used for restocking instead of glass eels. The assumption has been that the survival and growth rate is higher if ongrown eels are used but this has not been proven (ICES, 2008). However, Simon and Dörner (2014) compared survival in glass eels and ongrown eels jointly restocked in five German lakes and found that "*stocked farm eels have no general advantage in survival and growth compared with glass eels after 3–5 years in small lakes when stocked at an optimal time in spring*". Restocking with farm eels is more expensive but does allow for greater planning of the restocking activities, so that they can be carried out at optimal conditions, when water temperature is high enough and prey available, for example.

Restocking in the Baltic Sea

Historically, the Baltic Sea region has been an important growth area for eels, and the stock consisted mainly of large, female eels. According to Svärdson (1976), eels were incredibly widespread in the region. Sampling of 1,670 lakes in southern and central Sweden recorded eels in 73%. A decline in eel recruitment in Scandinavia has been observed since the 1940s, but the most significant reductions in eel recruitment across Europe have taken place since the early 1980s.

Natural recruits of European eel still occur in the Baltic Sea even though they are much less prevalent today. Rohtla et al. (2021) used otoliths to study the proportion of natural and restocked eels caught in coastal waters of Estonia and Finland. They found that for Estonia, 74% of the eels caught were natural recruits while 26% had been restocked. A study in Latvia found that approximately 36.7% eels in the mouth of River Daugava and 31.2% in the nearby freshwater Lake Ķīšezers came from restocking. At a coastal sampling site 7.1% came from restocking (Lin et al., 2012). In an earlier Lithuanian study, which also used otoliths to separate the eels, 20% of the eels from the Curonian Lagoon and only 2% in the coastal waters of the Baltic Sea came from restocking while the rest were natural recruits (Shiao et al., 2006). For Sweden, around 73% natural and 27% restocked eels were found in an older study with eels from different places in the Baltic Sea, Skagerrak-Kattegat, and the Swedish west coast (Limburg et al., 2003). A more recent study using eels from Lake Mälaren in Sweden and four sites in the Baltic Sea found that approximately 90% were natural and 10% restocked (Sjöberg et al., 2017).

The success of eel restocking efforts – from a conservation point of view – in the Baltic Sea likely depends on several factors, such as the availability of suitable habitat, the presence of migration barriers, and the quality of the water - and whether there is a targeted fishery in the restocking area. In addition, restocking efforts can be complicated by the eel's complex migratory behaviour, which can make it difficult to determine the most effective release locations and release timing.

Traceability of restocked eels

Marking the eels used for restocking is important in order to be able to identify stocked eels and distinguish them from naturally occurring eels in studies of translocation and to assess success of restocking (Righton et al., 2021). The Joint EIFAAC/ICES Working Group on Eels has recommended that "*all stocked eel should be marked and thereby separable from wild eel in subsequent sampling*" (2011). Eels used for restocking in Sweden have, for example, been marked using a strontium solution since 2009. Several studies around the Baltic Sea (e.g. Limburg et al., 2003; Shiao et al., 2006; Lin et al., 2012; Marohn et al., 2013) have used the Strontium and Calcium profiles (or Sr:Ca ratios) in otoliths of eels to distinguish (unlabeled) restocked eels from natural recruits because of the difference in their saltwater experience. Rohtla et al. (2021) used three otolith microchemical parameters (ratios of Sr:Ca, Ba:Ca and $^{87}Sr:^{86}Sr$) to separate restocked and natural recruits from sites in Estonia and southern Finland and stated that the distinction between natural and restocked eels is quite straightforward in most cases. Wickström & Sjöberg have suggested that restocking evaluation requires international collaboration and recommended the use of different methods for labelling the eels in different countries/restocking locations around the Baltic Sea to ensure that these can be separated during later evaluations

(2014). ICES has also advised that "*internationally coordinated research is required to determine any net benefit of restocking on the overall population*" (2020). Traceability of glass eels is also an important measure for counteracting illegal trade.

Impact on ecology

Studies assessing the ecological impacts of eel restocking on the ecosystem and other biological communities are very limited to date. One example is a pilot study by Félix et al. (2020), where the ecological impact of glass eel restocking on other species was analysed in the form of predation and competition. A selected area of the Mondego River in Portugal was monitored before and after restocking to detect changes in fish assemblage for seven local species and through sampling of macro-invertebrates to assess competition between species and predation impact, respectively. It was found that the restocking event did not have a significant effect on the tested local fish (structure or abundance) at the three sampling locations. However, the density of elvers recaptured one year later was around 10 times lower than the authors' estimations at time of release, which could be explained by, among other things, dispersion to other sites or early mortality (Félix et al., 2020).

Eel restocking as a conservation measure

While in the past, restocking was done in order to aid inland fishing, compensate for a loss of fish after migration barriers were created and to preserve biodiversity in upstream areas, it is now mainly used as a conservation strategy to enhance the silver eel escapement, as per the guidelines of the EU Eel Regulation and the Member States' Eel Management Plans.

As stated in Article 7(8) of the Council Regulation establishing measures for the recovery of the stock of European eel (European Commission, 2007):

> *"Restocking shall be deemed to be a conservation measure for the purposes of Article 38(2) of Regulation (EC) No 1198/2006, provided that:*
>
> *— it is part of an Eel Management Plan established in accordance with Article 2,*
>
> *— it concerns eels less than 20 cm in length, and*
>
> *— it contributes to the achievement of the 40 % target level of escapement as referred to in Article 2(4)."*

By defining restocking of eel as a conservation measure, the regulation also ensures that public funding under the then European Fisheries Fund (EC 1198/2006) could be accessed to pay for this management measure. In 2014, this regulation was repealed and replaced by the European Maritime and Fisheries Fund (EU 508/2014), but funding for restocking of eel remained under Article 11 (f). This regulation was also repealed in 2021, and replaced by the European Maritime, Fisheries and Aquaculture Fund, but the provision of funds for restocking of eels remains – now under Article 13 (h).

Since the establishment of the EU recovery plan for eel, tax payers' money has been used to fund public restocking programmes in most Member States. Exactly how much money has been spent is very difficult to ascertain, as the EU reporting on its funding programmes is not detailed enough. In light of the scientific advice for the eel population and the fact that the conservation benefits of restocking have repeatedly been questioned, this level of public spending is problematic.

However, the suitability of eel restocking as a conservation measure remains under debate in scientific literature.

Knowledge gaps

In 2016, the ICES WKSTOCKEEL report (ICES, 2016) listed a number of knowledge gaps regarding eel restocking based on previous reviews. Many of these have still not been fully addressed today:

> *"1) Translocated and stocked eel can contribute to yellow and silver eel production in recipient waters, but evidence of their contribution to actual spawning is limited by the general lack of knowledge of the spawning of any eel.*
>
> *2) In addition to investigations on the value of stocking for the enhancement of silver eel escapement in distinct EMUs, it was recommended that internationally coordinated research is required to judge the net benefit of stocking for the overall population.*
>
> *3) Assessments of carrying capacity estimates of glass eel donor estuaries are absent.*
>
> *4) Detailed mortality estimates along glass eel trade channels are required.*
>
> *5) The impact of holding and maintenance feeding of elvers in aquaculture with regard to a possible adaptation to culture conditions (as known from other fish species like salmon and trout) is unknown.*
>
> *6) Ongrown eels exhibit no advantage in growth and survival compared to stocking with glass eel: The only benefits conferred were allowing temperature conditions to become suitable in the recipient waters, and the facilitation of veterinary observations during quarantine.*
>
> *7) The most frequent shortfall in early life history mortality and development assessments was the absence of controls in the studies.*
>
> *8) Analyses of the life histories of those glass eels "left behind" at the donor estuaries is a prerequisite to any net benefit assessment and does not feature in any of the studies reviewed."*
>
> (ICES, 2016)

In order to get a full understanding of the impact of eel restocking it is important that long(er) term studies of the fate of restocked eels, and studies of the ecological impacts of restocking should be performed, as these aspects are still largely unevaluated. The ecological status after eel restocking, including competition and predation should be monitored over longer periods of time as prey and diet of the eel changes with increasing size. Continued monitoring and management efforts are also necessary to ensure the long-term sustainability of the eel population and to address the underlying factors contributing to the decline. In order to fill many of the identified knowledge gaps and more easily distinguish between naturally recruited and restocked eels, as well as restocked eels from different locations, eel tagging should be performed on all glass eels intended for translocation.

According to ICES, it is important that methods that enable us to assess whether different restocking practices are successful are developed (ICES, 2016). This would also allow for feedback to be taken into account in the eel management plans (Righton et al., 2021).

Restocking information by country

Estonia

The majority of Estonian restocking takes place in the country's largest inland water body, Lake Võrtsjärv, which is also the centre of Estonian eel fishing today – over 90% of eel landings. A very high proportion of the catch consists of restocked eels. Restocking of Lake Võrtsjärv began in 1956 – before then, eel fishing in the lake was limited.

Strategy, adaptivity and scientific basis for restocking

There has been no official national eel restocking strategy in Estonia since the start in 1956, but the main focus has been on Lake Võrtsjärv. Even with all the political changes – independence, EU membership, EU eel recovery plan – the practice has stayed more or less the same over time. Restocking under the EU recovery plan corresponds to historical restocking which began during Soviet times.

Estonia's Eel Management Plan (EMP) partially describes the national restocking plans but there is no separate publicly available restocking strategy. While most of the restocking takes place in Lake Võrtsjärv, lesser amounts are released into smaller lakes and waterways in the East Estonian basin. Restocking mainly takes place above the hydropower plant in the Narva river basin - which is large and constitutes a major barrier for migrating eels. However, according to Ministry staff (in person comm., 2022), the turbines in the Narva dam are more passable than other types of turbines and have higher survival rates. In the past, there has been small-scale restocking in lakes in the West Estonian basin, such as Lake Ermistu, where eels have open access to the sea. Overall, however, there has been no significant restocking in the West Estonian basin or the Baltic Sea.

Estonia uses glass eel and pre-grown yellow eel (over 2 years old) for restocking. Until 1987, glass eel was imported from France and later from England. In 1988 and 1995, yellow eels were imported from Germany. Yellow eel came from the local aquaculture sector between 2002 and 2008. Between 2000 and 2020, glass eel has been imported mainly from France and yellow eel from local aquaculture. Lately, the import country is determined by market conditions.

Restocking mainly takes place in the spring (April, May) and summer (July), but in 2020, restocking also took place during the winter (January, February). The amount of restocked eel has varied, partially depending on the price of glass eel each year. Over the years 2010–2019, after the adoption of the EMPs, glass eel restocking varied between 0 and 3.25 tonnes. For yellow eel, it varied between 0 and 0.25 tonnes.

Estonian restocking is in line with the national EMP, which states that it is sustainable to restock eels in the East Estonian basin. The EMP also states that the measures to limit fishing effort in the West Estonian Basin and the Baltic Sea are sufficient and that no restocking is needed there.

Restocking in Lake Võrstjärv and the smaller lakes in the East -Estonian basin is organised by the regional fishery association MTÜ Võrtsjärve Kalanduspiirkond. In recent years, there have been a few restocking projects in the Baltic Sea (2019), organised by MTÜ Saaremaa Kalavaru, but they do not have long-term funding or a plan.

It should be noted that eel restocking practices are under debate within the Estonian scientific community. According to researchers from the Estonian University of Life Sciences, restocking the East Estonian basin, including Lake Võrtsjärv, is sustainable, supports eel conservation, and follows the aims set in the national eel management plan. In contrast, studies at the University of Tartu, have found that restocking in Lake Võrtsjärv does not support conservation measures. If restocked, Rohtla et al. (2021) recommend doing so along the Baltic Sea coast or in larger rivers with dams removed, such as the rivers Pärnu and Kasari.

Tracing and quarantine

In Estonia, there are no quarantine rules for glass eels intended for restocking. Neither are the restocked eels marked in a way that makes them distinct from naturally recruited eels and eels restocked in other locations (as mentioned in the section on *Traceability of restocked eels*, studies have also separated restocked and natural eels through looking at microchemical parameters in otoliths such as Sr:Ca ratios).

Responsibility and funding for restocking

The restocking in Lake Võrstjärv, and the smaller lakes in the East Estonian basin is organised by the regional fishery association MTÜ Võrtsjärve Kalanduspiirkond. The process is part-funded by the national Environmental Investment Centre, which collects licence fees from fishers. These licence fees are based on the number of eel fyke nets used by each fisher.

Until 2020, 50% of the cost was paid through the European Maritime and Fisheries Fund (EMFF), which replaced the European Fisheries Fund (EFF) in 2014, but since the new EU funding programme – the European Maritime, Fisheries and Aquaculture Fund (EMFAF) – was launched in 2021 no public funding has been available for restocking. This decision was taken by the Ministry of Rural Affairs.

Availability of restocking data:

Official European eel restocking statistics are publicly available from the Estonian Ministry of Environment from 1991 to 2020. The most accessible information about restocking is published by the Fisheries Information Centre in the yearly Estonian fisheries report.

Is the restocking strategy publicly available? It is partially described in the EMP.

Life stages used for restocking: Glass eel and pre-grown yellow eel (over 2 years old).

Origin of restocked eels: mainly from France, but determined by market conditions. Yellow eel ongrown in local aquaculture; previously imported from Germany.

When does restocking take place? It mainly takes place in the spring (April, May) and summer (July), but in 2020, restocking also took place during the winter (January, February).

How much eel is restocked: Variable, partially depending on the price of glass eel. From 2010 to 2019, between 0 and 3,25 tonnes of glass eel were restocked, and between 0 and 0,25 tonnes of yellow eel.

Where does restocking take place? Mainly Lake Võrtsjärv in central Estonia and some smaller lakes in the East Estonian basin.

Does restocking take place above barriers? Yes, restocking mainly takes place above the hydropower plant in the Narva river basin.

While there is an ongoing discussion in Estonia about its restocking efforts, and alternative strategies have been suggested, it can be argued that the continued restocking of this inland lake upstream of the country's largest hydropower station, is as much in support of fisheries as a conservation measure.

Latvia

Strategy and scientific basis for restocking

The historical scientific data on any aspects of eel population ecology is very limited. Therefore, the Latvian restocking strategy is mainly based on expert opinion. Eel restocking quantities have mainly been based on calculations combining the available habitat with stocking densities suggested by national experts. A stocking density of 100 glass eels per 1 hectare was established in the initial Eel Management Plan (EMP) from 2009. Only glass eels were used and they were stocked only in waterbodies open to migration.

During the period 2011–2014, around 2.7 million glass eels were stocked. The restocking was stopped in 2015–2016 but resumed in 2017–2019, when 2.4 million glass eels were released. The numbers correspond well with targets in the EMP restocking strategy.

The country's restocking strategy has changed over time and, to a certain extent, an adaptive approach is applied. Already in 2013, it was established that the stocking has had limited effect but it seems that no thorough discussion about the scientific basis for continued stocking took place. However, after stocking glass eels over a period of 9 years, Latvian eel restocking is currently on hold until 2024, awaiting the results of research to evaluate the previous releases.

Tracing and quarantine

The glass eels used for restocking in Latvia are not marked but the eels are quarantined for a couple of weeks prior to restocking. Detailed information on quarantine requirements is not publicly available.

Responsibility and funding for restocking

In previous years, Latvian restocking was coordinated by the Institute of Food safety, Animal Health and Environment (BIOR). BIOR also performs all the science. The actual stocking was done by a private company, based on a public procurement. Only glass eels were used and the measure was supported by the European Maritime, Fisheries and Aquaculture Fund (EMFAF) or the European Fisheries Find (EFF).

Is the restocking strategy publicly available? Yes, it is included in the latest instalment of the EMP. Both EMP`s contain reports on eel restocking, and reports on all fish restocking activities in Latvia are also publicly available.

Life stages used for restocking: Only glass eels have been used for restocking in Latvia.

Origin of restocked eels: Mostly from Great Britain, but since 2022 this is not possible due to Britain's exit from the EU.

When does restocking take place? In the month of May, when water temperatures are higher than 10°C.

How much eel is restocked? 2.7 million glass eels were stocked in 2011–2014. Stocking was stopped in 2015–2016. In 2017–2019, 2.4 million glass eels were stocked. There is currently no restocking.

Where does restocking take place? In recent years, glass eels were stocked only in waterbodies open to migration.

Does restocking take place above barriers? Not generally. Two examples of restocking above migration barriers in Latvia are above a natural waterfall in river Venta and in Lake Burtnieks above a disused papermill dam. In both cases, downstream migration is not hampered.

Latvia's restocking strategy has changed over time and, to a certain extent, an adaptive approach is applied.

Lithuania

The primary natural habitats for eels in Lithuania are coastal areas, as well as the Curonian Lagoon, which is a freshwater lagoon separated from the Baltic Sea by the Curonian Spit. The eel population in inland waters relies on restocking efforts (ICES, 2020b). Recreational fishing is still allowed in Lithuania, whereas the only commercial fishing for eel allowed is a limited licensed inland fishery that targets silver eels.

The first official eel restocking in Lithuanian inland water bodies was performed from 1928 to 1939 in the Vilnius region. About 3.2 million eels were stocked during this period. From the mid-20th to the 21st century, restocking has mainly been carried out in the eastern part of the country. Only a few percent of the total have been stocked in western Lithuania.

In 1998, restocking with ongrown eels started, after a specialised aquaculture company was built. The quantities used for restocking have decreased over time. In 1960–1986, a total of 33.2 million eels were stocked in eastern Lithuania, on average about 1.2 million glass eels annually. However, catches only amounted to 6–16 tons, indicating that the efficiency of the stocking strategy was extremely low. From 2011–2022, an annual average of 0.7 million ongrown eels were stocked.

Strategy and scientific basis for restocking

In Lithuania, the target biomass of eels has been determined based on historical catches in the Curonian Lagoon, and is applied to the entire area covered in the Eel Management Plan (EMP). Eels are kept in aquaculture for up to 6–8 weeks before being stocked in waterbodies, and at the end of this period they weigh about one gram. Such eels are already classified as "ongrown" and stocked at a rate lower than 100 eels per hectare.

Based on the results of research conducted by the Lithuanian Nature Research Centre as part of the national EMP, a feasibility study from 2016 proposed to unify the restocking rates for glass and ongrown eels. Even though there is no unified definition of what constitutes an "ongrown eel", ICES (2015) indicates that ongrown eels are considered to be eels that have been raised in aquaculture for some time before stocking and, usually, the size of such eels is at least 15 cm (ICES, 2012).

Official European eel restocking statistics are publicly available from the Lithuanian Ministry of Environment and the Ministry of Agriculture. However, there is no information about which specific water bodies are stocked, even though these are provided for other nationally stocked fish species. The Lithuanian restocking quantities do not correspond to the intended ones in the EMP.

Tracing and quarantine

Marking is partially used for restocked eels in Lithuania, as a fraction of the stocked eels are marked with the dye alizarin red. A fraction of the eels is also kept in quarantine for 3–6 weeks prior to restocking.

Responsibility and funding for restocking

Restocking is carried out by the Fisheries Service under the Ministry of Agriculture of the Republic of Lithuania. It is done with support from the EMFF and a small contribution from the national budget. More limited restocking efforts were also carried out by fishing companies and individual fishermen, but after 2014 this was prohibited and assigned to the Fisheries Service under the Ministry of Agriculture.

Is the restocking strategy publicly available? -

Life stages used for restocking: Both glass eels and ongrown eels (0.8-1.2 g).

Origin of restocked eels: Glass eel have been imported from France and, in the past, from England.

When does restocking take place? Mainly in April–May.

How much eel is restocked? On average, 0.7 million ongrown eels per year were stocked in 2011–2022.

Where does restocking take place? Lithuanian restocking mainly takes place in the eastern part of the country. Only a few percent of the total are restocked in the western part.

Does restocking take place above barriers? No. Restocking is only carried out where there are free migration routes to the coast.

During the most intense Lithuanian restocking period in 1960–1986, catches remained relatively low and amounted to just 6–16 tons per year, indicating that the efficiency of the stocking strategy was extremely low.

It should also be noted that there is no joint transboundary eel management plan with Russia for the Curonian Lagoon, even though it is the main natural eel habitat in this region. In Russia there are no restrictions on eel catches, including eels stocked by Lithuania.

Sweden

Once very common, the natural recruitment of eel today is extremely limited, and mostly occurs on the west coast. In inland areas and in the northern parts of the eel's distribution area, eel stocks are now very sparse. According to the most recent 3-year report, 90% of the total inland silver eel production in Sweden is estimated to come from restocking efforts (Dekker et al., 2021). Natural immigration of eels to inland lakes has been highly obstructed by barriers and dams.

There is a long history of both eel restocking and assisted upstream migration - or translocation - of naturally recruited eels from the Swedish west coast to the eastern lakes. It was mainly done to compensate for a lack of recruitment caused by migration barriers and to support a continued fishery. Imported eels have been used for restocking since the early 1900s, but a regular programme for restocking was started in the 1950s. Additionally, young eels (of approximately 5 g) trapped in the river Göta älv close to the Swedish city of Trollhättan (until 2005), and bootlace eels (sättål, weighing approximately 90 g) from the west coast were translocated to inland waters or to the east coast. Currently glass eels purchased abroad are being used for restocking.

Strategy, adaptivity and scientific basis for restocking

In Sweden, restocking is one of four key sets of measures outlined in the national Eel Management Plan (EMP) to increase the survival and escapement of silver eels. The plan adopted in 2009 proposed at least a doubling of earlier restocking efforts, up to around 2.5 million glass eels per year by 2012, combined with a reduction in fishing mortality and hydropower mortality, as well as increased control and enforcement measures. It suggested that restocking would contribute a 13% increase in silver eel production based on current estimated numbers.

Restocking would take place in waters with the maximum potential for eel survival in southern and middle Sweden, at densities of around 100 eels per hectare. It is also noted in the EMP that suitable waters for restocking is not a limiting factor, but rather the availability of glass eels. According to calculations underpinning the plan, restocking of more than 100 million glass eels combined with a complete fishery closure would be required to achieve a target of 50% pristine silver eel escapement from Swedish coastal waters.

The EMP does not contain a detailed restocking strategy, but emphasises restocking as a conservation measure intended to increase silver eel escapement, as well as the importance of good water quality, free migration routes and low fishing pressures when selecting suitable areas. It also lists a number of lakes and rivers, but it is unclear if these are the waters where restocking will take place.

The Swedish 3-year reports on implementation of the EU eel regulation (Dekker, 2012; Dekker, 2015; Dekker et al., 2018; Dekker et al., 2021) contain information about restocking from 1950 and onwards. The spatial distribution of restocking has varied quite a bit over the years, especially before the establishment of the national EMP. Prior to 2010, restocking took place mainly in freely accessible lakes.

In more recent years, eels have been restocked on both the west coast, the Baltic coast and in inland waters (e.g., Lake Vänern, Lake Ringsjön and many smaller lakes). Restocking is mainly performed in three regions: Västra Götaland in the southwest, Halland on the west coast, and Skåne in the south. Restocking at sites on the Swedish west coast began in 2010 and has since increased, but during the 2010–2020 period inland waters still received the majority of the glass eels.

Tracing and quarantine

Since 2009, all eels used for restocking in Sweden are bathed in a strontium solution that leaves a measurable trace in their otoliths to enable separation of restocked and natural eels (Wickström, & Sjöberg, 2014). Sweden and Finland are the only European countries with "*reported quarantined glass eel restocking*" (ICES, 2019; 2021). Glass eels are kept in indoor aquaculture facilities during the 9-12 weeks quarantine period, after which they are released as elvers. Glass eels are tested on arrival and observed by a quarantine vet throughout the quarantine period.

Responsibility and funding for restocking

Swedish restocking is complex and can be separated into three different categories. The majority of the restocking is *national restocking* – carried out by the government in inland waters and on the coast, as part of the national EMP and funded through a combination of EU (EMFF; but not in 2021) and national funds.

Secondly, *hydropower-related compensation restocking* – which hydropower companies are legally required to carry out as part of "compensation duties" for blocking the waterways - is substantial. These are funded by the hydropower companies as a result of requirements in old hydropower permits.

Finally, *private restocking* – generally smaller scale restocking activities carried out by individuals owning specific inland fishing waters or by fisheries organisations. Private restocking is controlled through an application process handled by the County Administrative Boards (regional government authorities).

Since 2021, no government-funded restocking within the framework of the national EMP has taken place, but hydropower-related compensation restocking has continued. The national restocking efforts are currently being re-assessed. A national review of all hydropower permits in Sweden to bring them in line with the EU Water Framework Directive is also pending, but will likely take many years, as there are thousands of permits - some up to 100 years old - that need to be assessed against new environmental criteria.

"Power grab for eel" - collaboration on restocking and assisted migration

In its advice on zero catch and zero anthropogenic mortalities, ICES (2022a) acknowledges that "catches for the purpose of subsequent release to improve survival may be part of temporary conservation measures – e.g., where dams exist and prevent downstream or upstream migration of silver and glass eel, transfer across barriers within the same waterbody could be considered if it is likely that the associated mortality is less than that in the absence of such measures." But ICES also states that "*upstream assisted migration should only be applied if the future escapement of silver eels is ensured*".

Under the national EMP, the Swedish authorities have been working with the hydropower sector to increase silver eel escapement. This initiative is called "Power grab for eel" (Krafttag ål) and combines research with voluntary, concrete measures to increase silver eel survival rates in downstream migration past hydropower stations. It is financed by the participating hydropower companies, with some measures co-funded by the Swedish Agency for Marine and Water Management.

The initiative funds research on technical solutions that increase silver eel survival, as well as measures such as restocking of glass eels and assisted silver eel migration. For example, restocking within the project *8+fjordar* on the Swedish west coast has been carried out annually between the years 2011–2019 and in 2022–2023 as part of the Krafttag ål initiative. A total of 330,000–400,000 eels per year were restocked until 2019, but in 2022 and 2023 the numbers were lower – around 184,000 and 170,000 eels respectively.

Hydropower companies have performed extensive so-called *trap-and-transport* to reduce eel mortality after restocking above barriers. This is done by catching silver eels in waters located above hydropower plants and transporting them to downstream locations, even the coast, to allow the eels safe passage. The trap-and-transport programme started in 2011 and is jointly organised by the Swedish government, a group of energy companies and the fishers involved. Since the start, a total of 171,134 silver eels have been translocated according to the programme coordinators. In 2022, record numbers - almost 19,000 eels, were moved from Göta älv, Motala ström and the rivers Lagan and Ätran.

Mortality during trap and transport is relatively low according to data from the Swedish Inland Fishermen's Federation (Svenska Insjöfiskarenas Centralförbund), 0.78% on average, but factors such as longer time spent in the fish-corf and high water temperature sometimes leads to mortalities up to 10% (Jacobson, 2022).

While reducing silver eel mortality, trap-and-transport is a relatively expensive way to reduce the eel mortality caused by restocking eels above barriers in the first place, as part of the "compensation obligations". The 2021 Swedish national report states that natural eel recruitment (not assisted upstream migration) has been far less impacted by hydropower, since the eels could not climb the hydropower dams (Dekker et al., 2021) – i.e., there would be few eels above the dams if we didn't put them there.

Is the restocking strategy publicly available? Yes.

Life stages used for restocking: Glass eels purchased abroad are being used for restocking.

Origin of restocked eels: Glass eels used to be sourced from the Severn in England, but with Britain leaving the EU that is no longer possible. Since then, imported from France.

When does restocking take place? During late spring/early summer (mainly May to July).

How much eel is restocked? 2.3–3 million glass eels have been released each year from 2010 until 2020. Since 2021, no national eel restocking has been carried out but compensatory restocking by hydropower companies have continued.

Where does restocking take place? On the west coast, the Baltic coast and inland waters in Västergötland, Halland and Skåne. During 2010–2020 approximately 40% of the restocking took place in coastal waters and 60% in inland waters.

Does restocking take place above barriers? Yes, almost 40% of all glass eel restocking in Sweden during the years 2010–2020 took place above hydropower plants or other barriers according to an overview by the Stockholm University Baltic Sea Centre (2022).

Since the Swedish EMP was adopted, restocking levels have increased and are close to the stated target of 2.5 million glass eels per year, if all restocking efforts are included. However, many eels are still being restocked above migration barriers - almost 40%. To some extent, the restocking efforts are ignoring the criteria set up in the plan about good water quality, free migration routes and limited fishing pressure. Today, most of the restocking takes place in other waters than those listed in the EMP and is concentrated to the south-west of the country but it is not clear when the shift happened and the reasoning behind it.

Baltic region comparison

History of eel restocking in the four countries

Eel restocking in the four countries have taken place for decades. For instance, there have been attempts at Swedish eel restocking since the early 1900s, and some lakes were restocked already during the 18th century. However, restocking was introduced as a fishery conservation measure from the 1960–70s. Lithuanian restocking has also taken place since the early 1900s but intensified between 1960–1986. In Estonia, restocking of Lake Võrtsjärv has taken place since 1956. Latvia has had a restocking plan since 1927 and restocking intensified in 1960–1988.

Types of restocking

Out of the four countries examined in this report, the organisation of eel restocking is the most complex in Sweden, with three distinct categories of actors and funding: the national/regional authorities, the hydropower companies and private interests (by application). In Lithuania and Latvia, the authorities are fully responsible and in Estonia restocking is organised by the regional fishery association MTÜ Võrtsjärve Kalanduspiirkond.

Restocking above barriers

The upstream migration of glass eels and elvers from the European coast to inland waters poses significant difficulty for eels today. During the early 1900s, industrialisation led to a massive loss of available suitable habitat and an increase in migration barriers for eels and other species. Today over 1 million barriers exist instream in Europe (Belletti et al., 2020).

The same barriers create problems for the mature silver eels migrating downstream on their journey back to the Sargasso Sea. Spawning migration from the Baltic Sea is further complicated by the geographic bottlenecks that silver eels must navigate in order to reach the Atlantic – the Danish Belt-Sea, with the narrow straits Little Belt, Great Belt, and Öresund - and the continued targeted fisheries there.

In Sweden, restocking efforts have been more focused on the west coast lately, where there are no obstacles blocking their way to the sea. In addition, eel fishing has been banned in this area for over a decade. However, over a million glass eels were still restocked in inland waters above migration barriers in 2020 (Baltic Sea Centre, 2022, based on data from the Swedish University of Agricultural Sciences (SLU)). In Estonia, the vast majority of restocked eels are released in lakes above the Narva hydropower station, mainly in Lake Võrtsjärv. In contrast, very limited restocking financed by private entities takes place in Latvian lakes that are closed to migration, and no restocking above migration barriers is done in Lithuania.

Glass eels restocked above migration barriers such as hydropower plants and other hydroelectric barriers are at risk of being killed when they mature and start their spawning migration. Removal or mitigation of these types of barriers is expensive and time consuming, but for long-term improvement, free migration routes and higher availability of freshwater habitats are of high importance for eel conservation. Restocking above barriers should be avoided as many of the eels will die while passing downstream migration barriers or hydropower dams – thus having a much lower potential to contribute to escapement.

Restocking strategies

All four countries use restocking efforts extensively as a measure to reach the target escapement level for silver eel set out in the EU eel regulation (1100/2007). Generally, glass eels imported from France, and previously the United Kingdom, are used. In Lithuania, some eels are ongrown but only to around 1 gram. Estonia is the only one of the four countries that reports having reached the 40% escapement target.

Restocking mainly takes place in inland waters and to some degree in the same waters that were previously restocked but for other reasons, such as in support of fisheries or to compensate for reduced recruitment caused by hydropower, particularly in Sweden and Estonia. In Latvia and Lithuania there is a greater focus on restocking in waters with free migration routes to the sea.

Restocking strategies have been changed over time, since the adoption of the EMPs, but it is not always clear how and when. In Estonia, it has remained most unchanged, but with a different funding structure. Latvia stands out as all restocking is currently on hold and being evaluated, and not for the first time. In Sweden, national restocking efforts are on hold since 2021 and continued efforts are under assessment while private restocking, primarily by hydropower companies, continues.

Pre-release quarantine is important for glass eels that have just been translocated in order to ensure that the restocked eels do not spread diseases (Delrez et al., 2021). Sweden and Finland are the only EU Member States with "*reported quarantined glass eel restocking*" (ICES, 2019 and 2021). For glass eel restocking in Estonia, no quarantine rules apply. In Latvia, eels are quarantined for a couple of weeks prior to restocking and in Lithuania a fraction of the restocked eels are kept in quarantine for 3–6 weeks. The duration of quarantine is the longest in Sweden where it lasts for 9–12 weeks.

In order to evaluate the restocking efficiency and examine the contribution of restocked eels to the local population, marking or tagging the restocked eels is vital (Righton et al., 2021). This is recommended in scientific literature, and several methods have been developed for it including oxytetracycline, alizarin red, and strontium (e.g., Wickström & Sjöberg, 2014). However, out of the four countries, only Sweden routinely marks all eels used for restocking. In Lithuania, a fraction of the restocked eels is marked with alizarin. These restocked eels can be separated from natural eels using microchemical parameters in otoliths such as Sr:Ca ratios but not from other restocked eels (see section on *Traceability of restocked eels*).

Table 1. Comparison between eel restocking in Estonia, Latvia, Lithuania and Sweden

	Are eels currently being restocked?	Are the restocked eels marked?	Do eels intended for restocking need to be quarantined?	Are eels restocked above migration barriers?	Is public funding used for restocking?
ESTONIA	Yes	No	No	Yes	No
LATVIA	No	No	Yes	No*	Yes
LITHUANIA	Yes	Partially	Only a small proportion	No	Yes
SWEDEN	Yes**	Yes	Yes	Yes	Yes

*Very limited Latvian restocking financed by private entities has taken place in lakes that are closed to migration.

** No government-funded restocking since 2021. Compensation restocking by hydropower companies and under the "Krafttag ål" programme is still ongoing in 2023.

Conclusions and recommendations

It is clear from the most recent ICES advice (2022a) as well as evaluations by the European Commission (2020) that no significant improvement in the poor state of the European eel population has occurred. The recruitment levels seem to have levelled out since 2010, but are now at a historically low level, which means that escapement targets are difficult for Member States to meet without the use of restocking programmes. Restocking is used as a key management measure in most EMPs in the EU in order to achieve the recovery plan objective of 40 % pristine silver eel escapement – yet few actually do.

In 2021, ICES changed its advice on fishing opportunities for European eel to "*zero catches in all habitats*" and made clear that, from a precautionary point of view (in line with the CFP objectives for data poor stocks), no catches of European eel can be considered sustainable – including glass eel catches for use in restocking. ICES also states that the benefit to the reproductive potential of the eel population is still unknown and these uncertainties taken together with the possible harmful effects of restocking means that "*while following the precautionary approach, no catch for restocking should be allowed*" (ICES, 2022a). If ICES advice is to be followed, restocking of European eel should be halted.

In 2020, an external evaluation of the EU eel recovery plan (1100/2007) carried out by the fisheries consultants Poseidon and others was published. It states that eel restocking should be considered as a "*short to medium term measure*" which "*should be phased out as natural recruitment and water course connectivity improves*". Solutions which are likely to have more long-term impacts on eel stocks include "*structural measures to make rivers passable and improve river habitats, together with other environmental measures*" (European Commission, 2020).

While restocking is listed in the EU eel regulation as a conservation measure, actual evidence that it effectively contributes to future recruitment is still lacking. Despite the uncertainty, restocking, or relocation, of wild glass eels and elvers in areas where the eel has declined is one of the most common management measures used in the EU. How restocking is carried out, however, varies quite a bit across different Member States. In addition, despite the overarching argument of using restocking as a conservation measure in order to increase the escapement of silver eels to the sea, the underlying objectives and reasoning varies. Some countries focus on "*productivity*", others on compensation for biodiversity loss and fishing opportunities due to migration barriers, in addition to restocking for greater survival and escapement.

In this report, we have looked at the restocking strategies of four Baltic Member States and how they have been implemented, assessed and adjusted. What we have found is that despite very long traditions of restocking - in some cases more than 100 years - restocking does not appear to result in increased reproduction and recruitment. The eel population has not recovered and recruitment to these four countries have not significantly improved. It is, however, possible that the situation would be even more serious without the measure.

There is no doubt, however, that restocking improves the local stock of eel and supports a continued fishery and/or increased silver eel escapement from that particular waterbody. This may have positive effects in terms of biodiversity, but may also allow a fishery that is no longer viable to continue, masking the scale of decline in the population.

Of the four countries we have looked at, all still allow a targeted fishery for eel, and - with the exception of Sweden - a recreational fishery for eel. Restocking may also delay other necessary measures, such as the removal or mitigation of migration barriers, as they require much more substantial effort and investment. We can see that all four countries have focused more on restocking than dam removal or effective fish passages. Even in Sweden, close collaboration with the hydropower companies have mainly resulted in funding for research, restocking initiatives and trap-and-transport of silver eels.

In its advice on zero catch and zero anthropogenic mortalities, ICES (2022a) is more supportive of trap-and-transport and acknowledges that "catches for the purpose of subsequent release to improve survival may be part of temporary conservation measures – e.g., where dams exist and prevent downstream or upstream migration of silver and glass eel, transfer across barriers within the same waterbody could be considered if it is likely that the associated mortality is less than that in the absence of such measures." But ICES also states that "upstream assisted migration should only be applied if the future escapement of silver eels is ensured". In these four countries, only Lithuania strictly adheres to providing a free migration route when restocking - and this is not "assisted migration" but a matter of moving glass eels from a different part of the continent to the Baltic Sea region, against scientific advice.

There are also a number of other drawbacks with widespread restocking efforts:

- Relocation of eels complicates any biological assessments of the population, as it is difficult to get any reliable picture of the current natural geographical range, and natural recruitment.
- There is a high risk that it contributes to the spread of parasites and diseases, some of which may affect other fish species.
- Without full traceability of glass eels, the ongoing intra-EU trade may provide opportunities for illegal trade of this extremely valuable commodity.
- Some scientists argue that moving glass eels from one part of the continent to another disrupts the imprinting of the eels migration route and may actually have a detrimental effect on the spawning migration and subsequent recruitment, though there is no unequivocal studies that proves this or the opposite.

Recommendations

With the European eel population listed by IUCN as Critically Endangered and showing no signs of recovery, the scientific advice (ICES, 2022a) is zero catches of all life stages and in all habitats, including catches for restocking and aquaculture, as well as zero anthropogenic mortality. As long as restocking of eel relies solely on wild glass eels, it is our view that this advice should be followed and all fishing for glass eel and all restocking programmes should be halted until a significant improvement in the European eel population has been documented. There is no evidence that supports arguments that there is a "surplus" of glass eel anywhere that would be "saved" by continued restocking efforts - this is also explored by ICES and others.

In addition, EU Member States need to refocus their efforts to improve and facilitate natural recruitment by long-term improvements in water quality, effective mitigation of migration barriers and habitat protection rather than relying on restocking. There are win-win solutions with other environmental benefits, such as the recreation of wetland areas important for eels that will support wider biodiversity as well as lessen the effects of climate change.

If restocking continues in the face of the scientific advice and contradictory to the objectives of the EU:s Common Fisheries Policy (Art. 2, Regulation 1380/2013), the following principles should be applied:

- Quarantine procedures under a common EU standard should apply to ensure that the spread of parasites and diseases is prevented.
- Monitoring of the glass eels condition and quality before restocking is vital in order to avoid unnecessary mortality.
- All restocked eels should be marked to facilitate evaluation of the restocking practices.
- Relocation of eel upstream of migration barriers should be prohibited and cannot be considered a conservation measure.
- Public funds should not be used for restocking purposes without proper assessment of the efficiency and appropriateness of the measures.

»Investigation of eel restocking practices in the Baltic Sea region«

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