Implementation of UK Eel Management Plans (2017–2020)

Progress report prepared for the Department for Environment, Food & Rural Affairs, December 2021

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Executive summary

This report outlines the monitoring, effectiveness and outcome of the Eel Management Plans (EMPs) implemented within the 14 UK River Basin Districts (RBDs). This is in accordance with the EU Withdrawal Act in relation to Article 9 of Regulation No. EC 1100/2007. The transboundary EMP shared with the Republic of Ireland (North West International) is not reported here because it is included in the report from the Republic to the European Commission.

EMPs and assessment procedures vary according to different management structures in England, Wales, Scotland and Northern Ireland. Data are tabulated and described for all 14 EMPs together where appropriate, but in some circumstances where methods differ, data are tabulated and described separately for each nation. Annexes A to C describe these assessment methods.

UK escapement biomass and mortality rates cannot be measured directly at the RBD scale. Therefore, we present results derived from extrapolations of yellow eel survey data (England and Wales), counts of silver eel in index rivers (Scotland and Northern Ireland) or silver eel mark-release-recapture studies (Neagh Bann – Northern Ireland). These approaches require a number of assumptions about the life history and production of eel, and there is natural variation (spatial and temporal) inherent within the input data used in the analyses. Hence, the outputs are described as 'best available estimates' and should be treated as such.

Mean annual silver eel escapement during the reporting period was greater than the long-term objective of 40% of B_0 in only two RBDs: Neagh Bann and Scotland. Specifically, Neagh Bann achieved 54.1% B_0 and Scotland 59.8% of B_0.

A range of management measures have been implemented to increase and/or protect silver eel production across the UK. In summary, these measures include restrictions on fisheries ranging from changes in quotas and closed seasons to outright bans, the stocking of glass eels, provision of additional eel habitat via removal of barriers to upstream migration or installation of fish passes, and entrainment reduction measures such as screening and "trap and transport".

The losses from commercial fishing increased in six RBDs during this reporting period, despite the decrease or minimal change in fishing effort for glass, yellow and silver eel across majority of the RBDs during the reporting period. The main glass eel fisheries operate in the Severn and South West RBDs, where fishing effort has fluctuated over the time series, but rates in the period 2017–2019 were similar to those in 2008 (prior to EMPs). Fishing effort for yellow and silver eel is reported more widely across RBDs in England and Wales, and the Neagh Bann in Northern Ireland. Effort fluctuates from year to year but comparing the period 2017–2020 with 2008, yellow and silver eel fishing effort was lower in six RBDs and higher in three. There are no recreational landings, so no change was reported.

Impacts from other human factors (e.g. turbines and pumps, habitat loss, stocking, etc) decreased in four RBDs during the reporting period, with the others showing very small variations. The consequent estimated mortality rates are influenced by the underlying changes in eel abundance and therefore it can be difficult to attribute changes to specific events or management actions. However, in addition to the measures previously put in place in England and Wales (100% catch and release in recreational fisheries, closed season, restrictions on methods and gear, installation of eel passes and screens and the prohibition of eel fishing in Scotland) new measures have been implemented in 2017–2019 to diminish the impact of fisheries. These included decrease in fishing season, increase in available eel habitat (99 new eel passes installed restoring access to over 1100 ha of river habitat) and reduction of entrainment impacts by installing 24 new screens.

1. Introduction

This report outlines the monitoring, effectiveness and outcome of the UK EMPs during the most recent three-year reporting period, as required by the EU Withdrawal Act (HMSO, 2019) in relation to Article 9 of Regulation No. EC 1100/2007 (EC, 2007).

Tables in this report summarise the best available estimates of silver eel escapement biomass, mortality rates due to fisheries and other anthropogenic factors, and quantities of glass eel used for stocking for the 14 RBDs of the UK during the most recent three-year period of the EMPs (2017 to 2019 for England and Wales; 2018 to 2020 for Northern Ireland and Scotland).

1.1 The UK EMP framework

The 14 UK EMPs are set at the RBD level, as defined under the Water Framework Directive (WFD; EC, 2000), covering England, Wales, Scotland and Northern Ireland (Figure 1). The RBDs in Northern Ireland deviate slightly from those defined for the WFD, owing to their transboundary nature.

Fisheries management is a devolved policy area in the UK and as such EMPs were drawn up by the relevant UK authorities within each of the nations. The implementation of EMPs is managed by different regional agencies: Environment Agency for England; Natural Resources Wales (NRW) for Wales; Marine Scotland Science (MSS) for Scotland; and the Department for Agriculture, Environment and Rural Affairs (DAERA) for Northern Ireland. The North Western International EMP is a transboundary plan with the Republic of Ireland (RoI). Its assessment and management are the responsibility of the RoI, and progress with this plan is therefore reported in the Irish Progress Report to the European Commission. The Irish Standing Scientific Committee for Eel (SSCE) was established by the respective Ministers from the Department of the Environment, Climate and Communications (RoI) and DAERA (NI). Consultation with the DAERA in Northern Ireland ensures the co-operation with Northern Ireland agencies to cover the specific needs of the trans-boundary North Western International River Basin District EMP. The SSCE comprises scientific advisers drawn from the Marine Institute (MI), Inland Fisheries Ireland (IFI), the Electricity Supply Board (ESB), The Loughs Agency, and the Agriculture, Food and Biosciences Institute for Northern Ireland (AFBINI). Although the scientists are drawn from these agencies, the advice from the SSCE is independent of the parent agencies and all data/analyses are jointly agreed before onward submission.

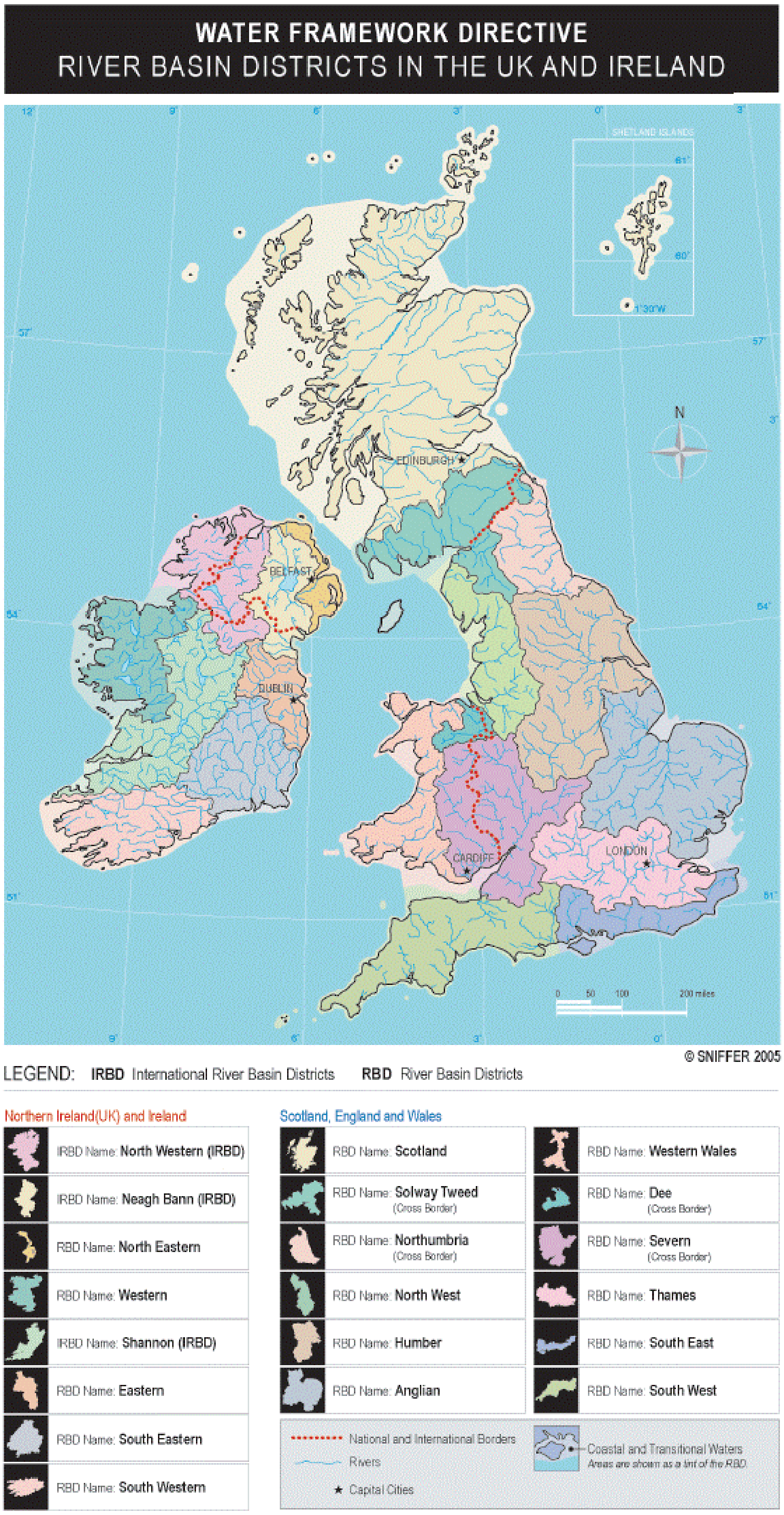

Figure 1. Schematic map of the River Basin District (RBD) layout across the UK, which forms the basis of the associated Eel Management Plans (EMPs).

1.2 The stock indicators

Nations are required to report the status of their eel stocks in each EMP in terms of best available estimates of the following stock indicators:

- $B_{current}$: the amount of silver eel biomass that currently escapes to the sea to spawn;
- B_0: the amount of silver eel biomass that would have existed if no anthropogenic influences had impacted the stock;
- B_{best}: the amount of silver eel biomass that would have existed if no anthropogenic influences had impacted the current stock;
- B_x: the amount of silver eel biomass, or equivalent, that is lost to anthropogenic factor 'x' on an annual basis;
- $\sum F$: the fishing mortality rate, summed over the age-groups in the stock;
- $\sum H$: the anthropogenic mortality rate for the combined non-fishery factors impacting on eel.
- $\sum A$: the sum of anthropogenic mortalities, i.e. $\sum A = \sum F + \sum H$;
- $R_{(emu)}$: the amount of eel less than 12 cm in length caught, and used for stocking, consumption, or aquaculture, within or out of the EMU (or RBD).

1.3 Reporting format for 2021

Following the UK exit from the EU, the Withdrawal Act (HMSO, 2019) brought Regulation EC 1100/2007 (EC, 2007) into the UK law, ensuring that its requirements are still met. In line with the EU Withdrawal Act, UK is no longer required to report to the EU Commission. However, Northern Ireland remains within the EU under the Northern Ireland Protocol (NIP) with regards to trade, which should include eel trade. In addition, fisheries administrations in the UK are still obliged to publish the EMP reports, in line with their international requirements, such as triennial reporting on eel biomass and mortality indices to the International Council for the Exploration of the Sea (ICES).

The differing management structures within the UK mean that EMPs and assessment procedures vary between England, Wales, Scotland and Northern Ireland (see original EMPs, and information describing updates in assessment methods in Annexes A, B and C of this report). As a consequence, there are some key differences in the manner in which assessments are reported here for the four nations of the UK.

Although assessments are updated annually for the Scotland and Northern Ireland EMPs, the input data for the EMPs of England and Wales are derived from a six-year rolling programme of electric fishing surveys and therefore can only be fully updated every six years. For reporting to the three-year cycle of the ICES data call, however, assessments of B_{best} for England and Wales are based on data from surveys that have been conducted within each reporting period. Differences reported in $B_{current}$ within a reporting period are due to differences between years in the amount of commercial eel catch, or reductions in other anthropogenic mortalities due to improved screening, pump design or eel passage implemented during the reporting period. It is problematic to draw conclusions from apparent trends or otherwise within three-year reporting periods. It may be more informative to compare mean values between three-year reporting periods, but the survey cycle must be taken into consideration in interpreting any apparent trends.

The timeframe of reporting eel population survey data in England and Wales is such that data for 2020 were not available in time to be included in the assessments to meet the original deadline of 30 June 2021 for this report. Therefore, and to retain the three-year reporting schedule followed in previous reports, the biomass and mortality rate estimates for England and Wales are reported for 2017, 2018 and 2019.

The assessment of emigrating biomass and mortality rates for England and Wales since implementation of the EMPs has been estimated for the following time periods:

- 2008–2010
    - Used to assess emigrating biomass and mortality indicators for 2009 and 2010, the first period since the implementation of the EMPs;
- 2011–2013
    - Used to assess emigrating biomass and mortality indicators for 2011, 2012 and 2013.
- 2014–2016
    - Used to assess emigrating biomass and mortality indicators for 2014, 2015 and 2016.
- 2017–2019
    - Used to assess emigrating biomass and mortality indicators for 2017, 2018 and 2019.

In contrast, new data supporting the biomass and mortality rate estimates for Scotland and Northern Ireland are available annually, and are reported here for 2018, 2019 and 2020, and trends from year to year discussed.

1.4 Changes in the assessment method since the 2018 report

The positive effect of stocking on mortality rate calculations has been excluded where previously applied, to avoid it compensating for high anthropogenic mortalities as per ICES (2020) recommendations, leading to slight changes in previously reported data. This method has been used to revise the calculations for mortality rates since 2009 in England, Wales, and Northern Ireland. There is no stocking in Scotland, thus no change was applied for mortality rate calculations there.

Please see Annex D for the most up to date biomass and mortality rates for previous reporting periods as a result of the most recent changes in the assessment reported under this Section.

England and Wales

The assessment method applied across England and Wales is described in Annex A. There was no major change in this assessment method for this latest report. Minor changes were as follows:

The number of eel index rivers used to estimate B_{best} and $B_{current}$ was reduced from 42 (in 2018) to 41 (in 2021). There was one less index river in the South West RBD compared to the previous assessment, as the limited survey data available from the River Parrett (not all sites were surveyed and not all surveys caught eel) was considered insufficient to produce a representative estimate. Analysis was therefore based on ten index rivers for this RBD.

Owing to an apparent anomaly in the 2018 yellow eel and silver eel catch data for Humber RBD, a three-year mean catch figure was calculated. This mean value was then used in the estimation of $B_{current}$, and mortality rates, alongside annual data for non-fishery impacts.

The effect of new eel passes was modelled as the additional wetted area in hectares (ha) made available to eel by each pass installed, multiplied by the silver eel escapement (B_{best}) from the relevant RBD for the year of installation and thereafter.

The assessment protocols for estimating impacts of water abstraction, hydropower, pumping stations and cooling water intakes did not change but numbers of installations were updated to reflect installation of new screens, less damaging pumps and decommissioning of facilities.

<u>Emerging data on the Severn EMU and implications for the assessment</u>

Several studies have shown eel density to be an important determinant of their mortality, especially at early stages (e.g., Bevacqua *et al*., 2011; ICES, 2016; Aprahamian *et al*., 2021). As a result, it could be argued that when eel density surpasses a habitat’s carrying capacity, there will be a surplus which would not have contributed to the production of silver eel (and their associated escapement) because of elevated density dependent natural mortality. Walker *et al*. (2019) used these assumptions with a very precautious exploitation level (i.e. set at 75%) to show that there is a potential glass eel recruitment to the River Severn in excess of its carrying capacity, thus yielding a surplus that might be exploited by the fishery without detriment to silver eel production.

A new study by Aprahamian and Wood (2021) estimated the total glass eel recruitment and fisheries exploitation levels for the River Severn and suggested a recruitment level higher than the carrying capacity proposed by Walker et al. (2019). Consequently, it was concluded by Aprahamian and Wood (2021) that the glass eel fishery in the River Severn is exploiting a surplus that would otherwise have suffered mortality from natural causes and as such has a minor impact on the eel population in the Severn and the subsequent escapement.

The conclusions made by Aprahamian and Wood (2021) imply that the relative impact of the glass eel fishery in the Severn may be lower than the estimate used in the assessment (∑F), with other non-fisheries impacts (∑H) likely having a relatively greater contribution to the overall mortality (∑A). Similarly, the assumption made by Walker et al. (2019) would indicate that the recruitment to the Severn is not a limiting factor, thus best available silver eel production (Bbest) should be higher than currently estimated from yellow eel surveys. The potential consequences of this new research are currently under consideration for inclusion in future assessments and reporting. Depending on the outcomes of these considerations, this might affect the way biomass and mortality indicators are calculated in the future.

Scotland

The assessment method applied to the Scotland RBD is described in Annex B. There was no change in the assessment method for this latest report, but the length-weight relationship for eel that is used for certain calculations has been updated, leading to slight changes in previously reported data.

Northern Ireland

The assessment methods applied to the Northern Ireland RBDs are described in Annex C.

Since the previous EMP Review of 2015, the assessment method used to monitor silver eel production and escapement estimates for the Neagh Bann RBD has changed with these changes described in Annex C. Since 2018, the calculation for estimated escapement has been changed and further improved by the development of a model combining daily river flow metrics with daily silver eel catch against which daily tag recaptures are assessed. This method has been used to hindcast and revise the calculations for escapement from

2009.The method for the North Eastern RBD was updated in 2017 to provide new estimates of current ($B_{current}$) and potential (B_{best}) silver eel escapement, by the establishment of a glass eel index site (*in situ*; five years of data) and the direct assessment of silver eel migration in 2017 onwards by netting. However, the direct escapement assessments in this RBD were heavily impacted by flooding (2019) and Covid-19 restrictions (2020).

2. Best available estimates of stock indicators and associated information

2.1. Summary results

The best available estimates for the 14 RBDs in the UK during this reporting period are provided for silver eel escapement biomass, mortality rates due to fisheries and other anthropogenic factors, and quantities of glass eel used for restocking (Tables 1–3).

Escapement biomass and mortality rates for the UK cannot be measured directly at the RBD scale. Therefore, we present results derived from extrapolations of yellow eel survey data (England and Wales), counts of silver eel in index rivers (Scotland and Northern Ireland) or silver eel mark-release-recapture studies (Neagh Bann – Northern Ireland). These approaches require a number of assumptions about the life history and production of eel, and there is natural variation (spatial and temporal) inherent within the input data used in the analyses. Hence, the outputs are described as ‘best available estimates’ and should be treated as such.

2.2. Biomass

Mean annual silver eel escapement during the reporting period was greater than the long-term objective of 40% B_0 in two RBDs: Neagh Bann and Scotland. Specifically, Neagh Bann achieved 54.1% B_0 and Scotland 59.8% of B_0.

Trends in biomass

For England and Wales, trends in silver eel escapement ($B_{current}$) are compared with the period estimates (Figure 2), which are expressed as a percentage of B_0, for 2009–2010, 2011–2013, 2014–2016 and 2017–2019. Since the last reporting period, escapement has decreased in six RBDs, increased in three and remains unchanged in two. Most changes since the 2018 report have been relatively minor, but significant reductions have been recorded in Anglian and South East RBDs, dropping from 18.7% to 6.7% and 34.6% to 19.7%, respectively. In Thames RBD there was a significant increase from 5.6% to 22.4%, returning to levels reported for 2011–2013 and 2014–2016. The reductions in modelled silver eel escapement from Anglian and South East RBDs are due to reductions in yellow eel densities recorded in surveys (e.g. River Welland in Anglian – over 85% fall; River Ouse in South East – over 75% fall). The increase in modelled silver eel escapement from Thames RBD is a result of changes in distribution and size structure recorded in the Medway and Thames surveys.

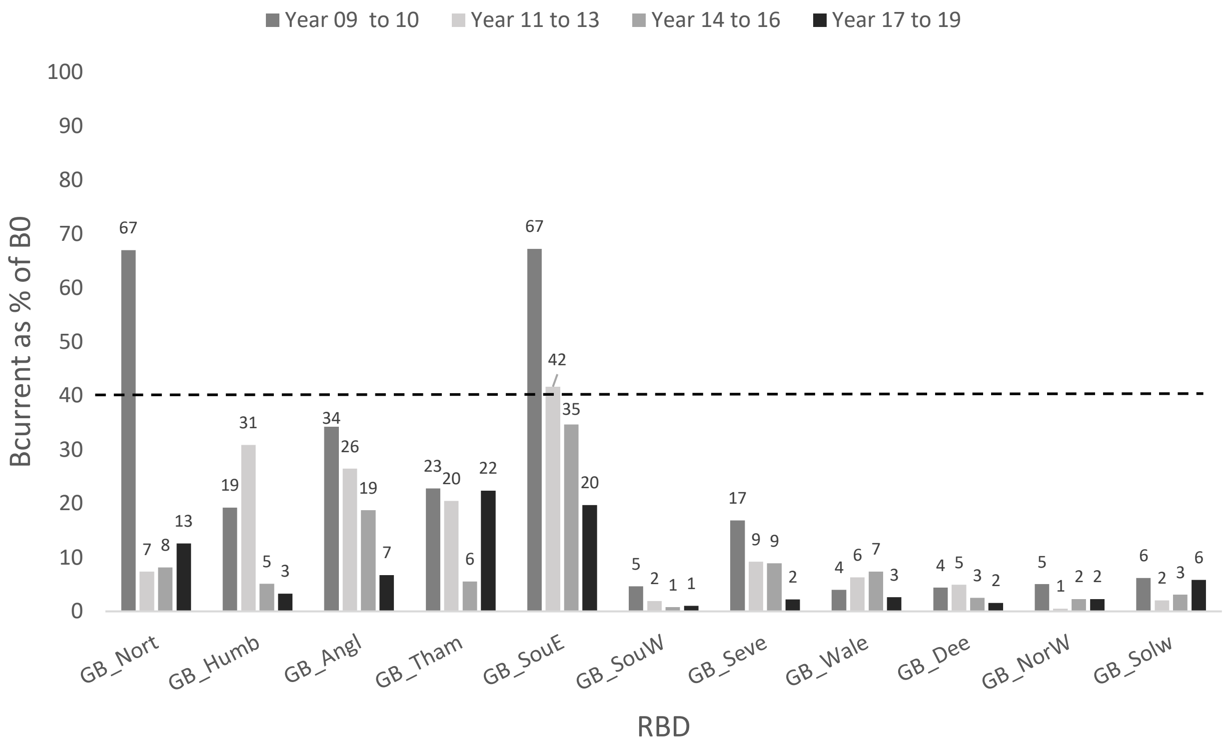

Figure 2. Compliance with the long-term objective of 40% B_0. From left to right, RBD codes correspond to Northumbria, Humber, Anglian, Thames, South East, South West, Severn, Western Wales, Dee, North West and Solway Tweed RBDs.

For the Scotland RBD, as the assessment is conducted separately for each year, a fuller trend analysis is appropriate. $B_{current}$ expressed as a percentage of B_0 declined from 2009 to 2011 but has since increased, returning above the long-term objective each year from 2013 to 2020 (Figure 3). The 2014 $B_{current}$ estimate at 140% of B_0 is due to 2014 being an exceptionally good year for silver eel escapement in the Scotland RBD and the B_0 reference value being a mean of several years of historic data.

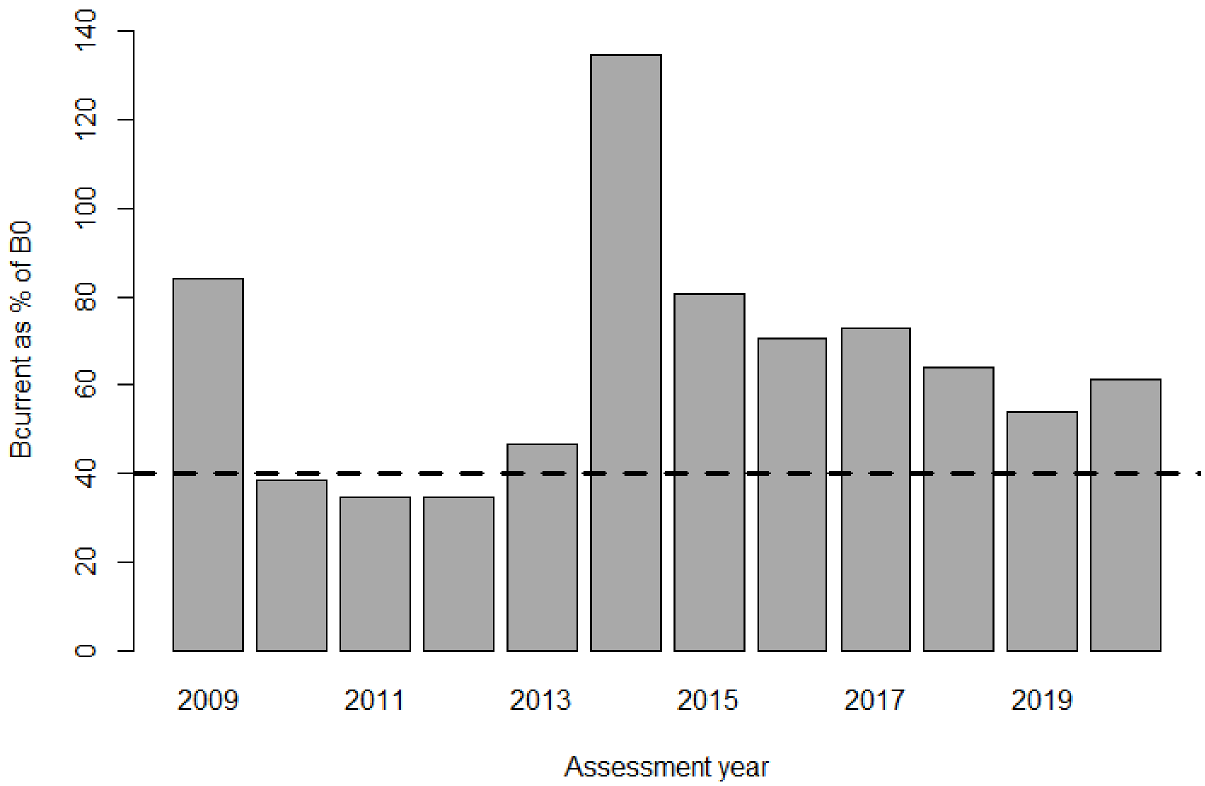

Figure 3. Change in $B_{current}$ as a percentage of B_0 in the Scotland RBD between 2009 and 2020. The dashed line represents the long-term objective of 40% B_0.

For the Neagh Bann RBD in Northern Ireland, $B_{current}$ expressed as a percentage of B_0 increased from 2015, but has been decreasing again since 2018 (Figure 4). Estimates of $B_{current}$ and B_{best} for the North Eastern RBD are only available for limited years, after a new direct capture method was developed and implemented, but is often hampered by flood events (Figure 5). Therefore, no analysis of trend is possible. However, as this is a natural system with minimal anthropogenic impacts for eel, trends are expected to be reflective of recruitment history.

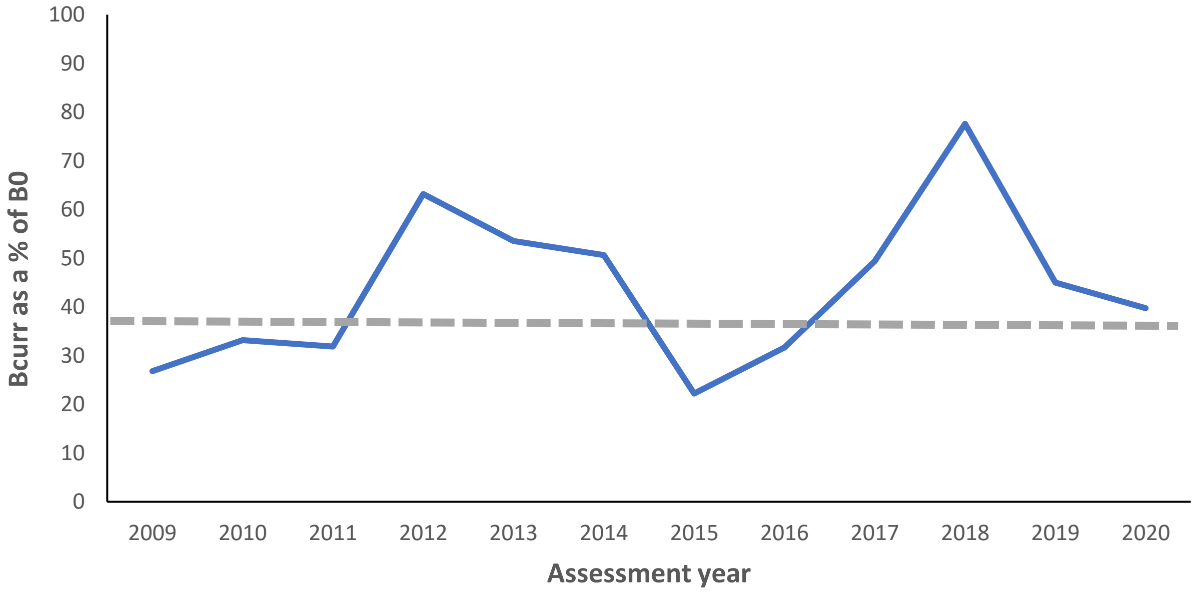

Figure 4. Change in $B_{current}$ as a percentage of B_0 in the Northern Ireland Neagh Bann RBD between 2009 and 2020. The dashed line represents the long-term objective of 40% B_0.

Table 1. Best estimates of silver eel biomass (kg) across England and Wales RBDs during 2017–2020, and across Scotland and Northern Ireland during 2018–2020. Note these estimates are based on period means for some data inputs. Key for terms provided below.

RBD code	B_0	$B_{current}$				B_{best}				Mean compliance (%) in most recent 3 years
	Pre-1980	2017	2018	2019	2020	2017	2018	2019	2020	
Northumbria	60876	7628	7690	7667	ND	14074	14074	14074	ND	12.6
Humber	137859	3838	4545	5305	ND	43534	43534	43534	ND	3.3
Anglian	341084	25580	19797	23628	ND	58385	58385	58385	ND	6.7
Thames	251699	56034	56196	56760	ND	161730	161730	161730	ND	22.4
South East	121340	23807	23969	23989	ND	36575	36575	36575	ND	19.7
South West	1327684	15630	13198	13426	ND	145072	155588	213997	ND	1.1
Severn	899687	21233	21227	20237	ND	138538	189225	265071	ND	2.3
Western Wales	429944	11169	11070	11769	ND	15360	16386	16405	ND	2.6
Dee	636166	9478	10390	9752	ND	17832	20812	20222	ND	1.6
North West	865449	19859	20065	19915	ND	42003	43915	46258	ND	2.3
Solway Tweed	1473755	85611	85611	85611	ND	110991	110991	110991	ND	5.8
Scotland	267717	194955	171501	144052	164395	244780	212134	177145	201519	59.8
North Eastern	4000	989	1453	539	ND*	989	1453	539	ND*	24.8
Neagh Bann	500000	247000	388000	225310	198900	542000	717000	492310	361900	54.1

Where:

- B_0 The amount of silver eel biomass that would have existed if no anthropogenic influences had impacted the stock.
- $B_{current}$ The amount of silver eel biomass that currently escapes to the sea to spawn.
- B_{best} The amount of silver eel biomass that would have existed if no anthropogenic influences had impacted the current stock.
- ND "No Data", where there are insufficient data to estimate a derived parameter (for example where there are insufficient data to estimate the stock indicators, or where data were collected but not available in time to be used in this report).
- ND* "No Data" due to Covid-19 impacts.

2.3. Anthropogenic impacts

Estimates of annual anthropogenic mortality rates for eel attributed to fishing (ΣF), non-fishing human impacts (ΣH) and both combined (ΣA) for each RBD are provided (Table 2). Where impacts have been on glass or yellow eel, these rates are estimated by converting the eel stage affected to silver eel equivalents (see Annexes) and then expressed as a proportion of present-day silver eel escapement. In the following discussion, any variation in mortality rate of <0.05 during the reporting period is described as 'no change'.

Although results for England and Wales are derived in part from mean potential eel escapement estimates (B_{best}) for the period 2017–2019, the loss rates from anthropogenic factors are year-specific and therefore it is reasonable to examine trends across the reporting period. Data for Scotland and Northern Ireland are annual and therefore support examination of trends.

Fishing (F)

There are no recreational landings of eel across the UK. Commercial fishing occurs in nine of the eleven RBDs across England and Wales, and in one RBD in Northern Ireland, but not in Scotland.

Across the reporting period, the impact (mortality rate: ΣF) of commercial fishing increased in six RBDs (Anglian, North West, Severn, South West, Dee and Western Wales) and did not change in the others. The increased rates in the Severn and North West RBDs were mainly due to an increase in the glass eel catches, from 1705 and 84 kg in 2017 up to 3835 and 156 kg in 2019, respectively. A minor increase in glass eel catches was evident for the Western Wales RBD in the same time period. In the South West and Dee RBDs, glass, yellow and silver eel catches increased during the reporting period, with a substantial increase in glass and yellow eel catches evident for the South West RBD (by 1160 and 1846 kg, respectively). Yellow eel catches increased in the Anglian RBD from 6129 kg in 2017 to 11796 and 7432 kg in 2018 and 2019, respectively (see Tables A3–A5).

Non-fishing (H)

Across the reporting period, the impact (mortality rate: ΣH) of non-fishing anthropogenic factors decreased in four RBDs (Humber, Severn, Dee, Western Wales), with the others showing very small variations. As these rates are estimated as eel losses in proportion to potential eel production, the results are influenced by the underlying changes in eel abundance: a smaller loss can still produce a higher mortality rate if the underlying potential has declined. Therefore, it can be difficult to attribute changes to specific events or management actions.

Overall (A)

The overall impact of anthropogenic mortality factors (ΣA) increased in five RBDs (Anglian, North West, Severn, South West, Dee), decreased in one (Humber) and showed little change in the others. These changes were mainly due to changes in fishing mortality rates, except in the Humber where there were substantial decreases in mortality rates due to hydropower and habitat loss.

Table 2. Best estimates of anthropogenic mortality rates across UK RBDs, during 2017 to 2019 for England and Wales, and 2018 to 2020 for Scotland and Northern Ireland. Note that minor differences in A versus F+H are due to rounding to two decimal places.

RBD code	ΣF				ΣH				ΣA			
	2017	2018	2019	2020	2017	2018	2019	2020	2017	2018	2019	2020
Northumbria	0.00	0.00	0.00	ND	0.61	0.60	0.61	ND	0.61	0.60	0.61	ND
Humber	0.17	0.17	0.16	ND	2.25	2.09	1.95	ND	2.43	2.26	2.10	ND
Anglian	0.21	0.39	0.27	ND	0.62	0.69	0.64	ND	0.83	1.08	0.90	ND
Thames	0.02	0.02	0.02	ND	1.04	1.04	1.03	ND	1.06	1.06	1.05	ND
South East	0.01	0.01	0.01	ND	0.42	0.41	0.41	ND	0.43	0.42	0.42	ND
South West	1.97	2.21	2.56	ND	0.39	0.42	0.41	ND	2.23	2.47	2.77	ND
Severn	1.65	2.01	2.39	ND	0.26	0.26	0.21	ND	1.92	2.24	2.57	ND
Western Wales	0.05	0.12	0.12	ND	0.27	0.27	0.21	ND	0.32	0.39	0.33	ND
Dee	0.07	0.25	0.26	ND	0.56	0.45	0.47	ND	0.63	0.69	0.73	ND
North West	0.19	0.24	0.31	ND	0.56	0.54	0.53	ND	0.75	0.78	0.84	ND
Solway Tweed	0.00	0.00	0.00	ND	0.26	0.26	0.26	ND	0.26	0.26	0.26	ND
Scotland	0.00	0.00	0.00	0.00	0.23	0.21	0.21	0.20	0.23	0.21	0.21	0.20
North Eastern	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Neagh Bann	0.79	0.61	0.78	0.60	0.00	0.00	0.00	0.00	0.79	0.61	0.78	0.60

Where:

- ΣF The fishing mortality rate, summed over the age-groups in the stock.
- ΣH The anthropogenic mortality rate outside the fishery, summed over the age-groups in the stock.
- ΣA The sum of anthropogenic mortalities, i.e. ΣA = ΣF + ΣH.
- ND "No Data", where there are insufficient data to estimate a derived parameter (for example where there are insufficient data to estimate the stock indicators, or where data were collected but not available in time to be used in this report).

Stocking

Stocking is a relatively minor activity in England and Wales, with only 17 kg stocked in 2017 and 2018 in the Severn RBD and negligible stocking reported from Eels in the Classroom Programme in 2019 (Table 3). These stocking practices are predicted to result in 2020 kg of silver eel equivalents in total (note that potential anthropogenic impacts on these eels have not been taken account of in these estimates).

There has been no eel stocking in Scotland for many years.

Eel stocking is important to the Neagh Bann RBD in Northern Ireland, with 4537 kg of glass eels stocked in total in the Lough Neagh during the reporting period (2017–2020; Table 3). French glass eels comprised 1576 kg (34.8%) of the total biomass stocked, the remainder being sourced from the UK fishery.

Table 3. The amount of glass eel (kg) stocked into UK RBDs, during 2017–2020. Data for 2021 were not available (ND) at the time of the writing for some RBDs. There are no stocking practices (NP) in North Eastern and Scotland RBDs.

RBD code	Year			
	2017	2018	2019	2020
Northumbria	0	0	0	ND
Humber	0	0	0	ND
Anglian	0	0	<0.1	ND
Thames	0	0	0	ND
South East	0	0	0	ND
South West	0	0	0	ND
Severn	17	17	<0.5	ND
Western Wales	0	0	0	ND
Dee	0	0	0	ND
North West	0	0	<0.1	ND
Solway Tweed	0	0	0	ND
Scotland	NP	NP	NP	NP
North Eastern	NP	NP	NP	NP
Neagh/Bann	817	754	1252	1714

The amount of glass eel caught per annum, as declared to the Environment Agency and Natural Resources Wales, is presented (Table 4) along with the proportions of this catch used for stocking, aquaculture or direct consumption ($R_{(emu)}$), based on declarations at first sale.

Table 4. Percentage of glass eel caught in the UK and sold for stocking, aquaculture or direct consumption ($R_{(emu)}$), according to dealer's reports. [Note these percentages may not add up to 100% because of mortality and weight loss after capture]. Data for 2020 were not available (ND = no data).

Year	Catch (kg)	Percentage used for:		
		Stocking	Aquaculture	Direct Consumption
2009	422	100.0	0.0	0.0
2010*	1890	55.4	3.5	0.0
2011+	3641	34.8	63.9	0.0
2012	3819	88.8	11.2	0.0
2013	8659	50.4	49.5	0.0
2014	11600	62.6	30.9	6.8
2015	2800	72.7	27.2	3.6
2016	4279	54.0	45.7	0.3
2017	3530	56.3	43.7	0.0
2018	4660	80.5	19.5	0.0
2019	6950	72.2	27.7	0.0
2020	ND	ND	ND	ND

*40.9% of exports were not declared, so could have been either restocking or aquaculture.
+1.22% of exports were not declared, so could have been either restocking or aquaculture.

The evolution of the market price of glass eel, based on the price paid by the Lough Neagh Fishermen's Cooperative Society for eels for stocking Lough Neagh is presented (Table 5).

Table 5. Cost of purchasing glass eel (€ /kg).

Year	Cost (€) /kg
2009	525
2010	497
2011	353
2012	475
2013	400
2014	225
2015	284
2016	ND
2017	275
2018	250
2019	250
2020	190

2.4. Fishing effort

The time series of fishing effort for commercial eel fisheries in the UK (noting no commercial fishing in Scotland) are presented (Tables 6, 7 and 8) per nation and eel life stage.

Given that fishing effort for yellow and silver eel has only recently been disaggregated for England and Wales, it is reported as combined fishing effort (Table 6).

Fishing effort for glass eel is reported for five RBDs during the 2017–2019 period. The main glass eel fisheries operate in the Severn and South West RBDs, where fishing effort has fluctuated over the time series but rates in the 2017–2019 period were similar to those in 2008 (data for 2020 not available at time of writing). Commercial fishing for glass eel is no longer undertaken in the South East RBD.

Table 6. Time series of annual fishing effort for glass eel in RBDs of England and Wales, during 2008–2019. Effort expressed as dip net nights. Data for 2020 were not available (ND = no data). There have been no fisheries authorised (NP = not pertinent) in the South East RBD for several years.

Year/RBD	North West	Dee	Western Wales	Severn	South West	South East
2008	194	10	18	4060	2064	0
2009	142	14	16	3020	1344	16
2010	82	14	22	2271	1178	NP
2011	95	23	14	3903	3141	NP
2012	108	32	9	5390	4026	NP
2013	101	12	17	4660	4301	NP
2014	153	0	7	8360	9371	NP
2015	266	39	0	10297	8032	NP
2016	121	8	21	4623	2877	NP
2017	118	17	36	4324	2755	NP
2018	118	27	50	3935	2491	NP
2019	141	27	100	4344	2826	NP
2020	ND	ND	ND	ND	ND	NP

Fishing effort for yellow and silver eel is reported more widely across RBDs in England and Wales, and the Neagh Bann in Northern Ireland. Effort fluctuates from year to year but comparing rates in the 2017–2019 period with 2008, effort was lower in six RBDs (Humber, Thames, South East, Western Wales, Dee and Neagh Bann) and higher in three (Anglian, South West and North West). Severn and Northumbria RBDs were not included in this comparison given yellow and silver eel fisheries have not been authorised in these RBDs for a number of years.

Table 7. Time series of annual fishing effort (trap nights) for yellow and silver eel (combined) in England and Wales RBDs, and yellow eel in Neagh Bann, during 2008 to 2020. ND = data not available to report, ND = no data due to Covid-19 impacts, NP = not pertinent (no fishery authorised in that year).*

Year/RBD	Northumbria	Humber	Anglian	Thames	South East	South West	Severn	Western Wales	Dee	North West	Neagh Bann
Effort Units	Trap nights										Boat days per season
2008	186	17898	54163	24811	13296	28999	185	186	5102	5909	9650
2009	168	16157	41561	13610	30277	11494	5330	2458	210	548	10860
2010	66	6991	52358	13940	7898	17728	366	331	144	533	10490
2011	NP	19346	99418	18305	6783	17483	1980	557	5184	14604	10440
2012	NP	17380	83572	10267	19315	27885	0	5703	4423	27574	9880
2013	NP	24545	75430	21796	13381	48437	10	302	884	9305	9810
2014	NP	20362	101315	11859	2680	21825	NP	0	5670	251	9590
2015	NP	11510	135164	13656	7987	47654	NP	54	804	397	8850
2016	NP	808	93343	13602	25010	41575	NP	13729	892	1071	8785
2017	NP	5642	89417	11466	6350	45648	NP	2	3426	8727	8698
2018	NP	7883	80440	8561	6847	41019	NP	10	2302	6075	8641
2019	NP	2075	77792	5656	3904	38387	NP	0	3888	9163	8657
2020	NP	ND	ND	ND	ND	ND	NP	ND	ND	ND	ND*

Table 8. Time series of annual fishing effort for silver eel in the Neagh Bann RBD, during 2008–2020. Effort expressed as numbers of fishing weirs.

Year/RBD	Neagh Bann
2008	3
2009	3
2010	3
2011	3
2012	2
2013	2
2014	2
2015	2
2016	2
2017	2
2018	2
2019	2
2020	2

3. Implementation of management measures

3.1. Describe the measures implemented since the adoption of your eel management plan, including the year of implementation and, where practical, realised or anticipated effect on silver eel escapement biomass.

In summary, actions implemented in England and Wales since the adoption of eel management plans have delivered:

- 100% catch and release for eel by angling (introduced 2009)
- Close seasons for net and trap fishing for eel (introduced 2010)
- Limits on the geographical extent of the eel fishery (introduced 2010)
- Restrictions on eel fishing methods and gear (introduced 2010)
- New legislation to require the installation of eel passes and eel screens at structures impacting safe eel passage (introduced 2010)
- 99 new eel passes in 2017–2019 restoring access to over 1100 ha of river habitat (totalling 885 passes restoring access to over 9300 Ha since 2009)
- 24 new screens at water intakes during 2017–2019 (totalling 52 eel screens since 2009)
- 2 Fish Recovery and Return/bywash systems at water intakes
- A reduction in the 2018 fishing season in territorial waters by 40 days (compared to pre-EMP) as a result of EC Regulation 2018/120 (EC, 2018)
- A reduction in the 2019 fishing season in all fisheries by 10 days (compared to pre-EMP) as a result of EC Regulation 2019/124 (EC, 2019)

In Scotland, the principal management measure of the EMP was to prohibit fishing for eels, by any method, without a licence, via legislation introduced in 2009. To date, no licences have been issued to fish for eels in Scotland (with the exception for some small-scale scientific sampling).

In Northern Ireland, actions implemented in 2009 have continued as described in the 2015 and 2018 EMP Reviews, and additional actions are reported as follows:

National measures

- Removal of fyke net as a legal fishing engine in 2010
- Raising of Minimum Landing Size (MLS) for yellow eel from 300 to 400 mm in 2010

- Ban on the taking of eel by recreational fishing for eel in 2010, all NI RBDs
- Establishment of yellow and silver eel commercial traceability system in 2009

Neagh Bann RBD

- Closure of one silver eel fishing weir in the River Bann since 2012
- Lough Neagh Fishermen’s Co-operative Society (LNFCS) direct funding of PhD project investigating male eels, their silver phase and run timings, differential capture rates and parasite burdens to provide biological information used in the stock assessment method.
- Initiatives to reduce capture of undersized eels (<400 mm total length) in long line harvest, by (i) increase in commercial long line hook size (from size 4 to 3), and (ii) MRes research project into the development of an alternative eel fishing bait derived from marine discards
- LNFCS commissioned an investigation into the prevalence of eel viruses in the Neagh Bann RBD
- Refurbishment of eel passes within the Neagh Bann RBD
- Improvement and modernisation of LNFCS fisheries enforcement vessels.

North Eastern RBD

- Creation of glass eel monitoring site from 2012: now established as a new annual index site and reported to ICES from 2017
- Glass eel stocking of this RBD in 2014 (funded by LNFCS)
- Assessment of recruitment, yellow eel population and migrating silver eel within one region (Killough) of the RBD in 2017

Anticipated effect of UK measures on silver eel escapement biomass

With the exception of the large-scale stocking in the Neagh Bann RBD, it is not yet possible to predict when these measures will achieve the required additional silver eel production across the UK. Investment in scientific research continues alongside implementation of management measures to improve our understanding of the situation. However, the timing of the recovery of the eel stock in the UK depends in part on the recovery of the international stock as a whole to provide increased eel recruitment to UK waters, and this trend cannot be predicted at this point in time.

3.2. Provide an explanation for any planned measure not implemented.

There are no specific measures planned in the original EMPs that have not yet been implemented. However, some of the generic measures (e.g. installation of eel passes and screening of water intakes) are ongoing.

3.3. List any difficulties encountered in the implementation of the plan

England and Wales

The main difficulties encountered in implementing the measures in England and Wales were those of:

1) Identifying the owner or person responsible for some in-river obstructions. Under these circumstances it is difficult to obtain permission to resolve eel passage at that site, or to apply powers under the Eels (England and Wales) Regulations 2009;

2) Obtaining the necessary resources to improve access to suitable habitat or to prevent entrainment;

3) The costs of eel screening installations at intake structures can be prohibitive for some operators (up to several million £) and are subject to cost benefit analysis constraints. The Environment Agency has spent two years working with operators to agree how to address such affordability issues. A new approach is now in the process of being implemented. In addition, implementation of the Eels (England & Wales) Regulations is via scheduled maintenance and/or capital investment programmes. This should mean that delivery of eel measures is more cost effective for operators, but it will mean a slower delivery rate for these improvements.

Scotland

None.

Northern Ireland

The stocking target for the Neagh/Bann RBD was not achieved in 2018 or 2019 because of a disconnect in timing of supply with demand.

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Annex A: Methods and data used in the 2017–2019 assessment of England and Wales

A1. Introduction

The assessment approach can be summarised as follows: the best achievable present-day silver eel escapement in the absence of human impacts (B_{best}) is estimated for index rivers within each River Basin District (RBD), using an eel life history model to extrapolate yellow eel density data from surveys across a river basin to whole river estimates of yellow eel numbers at length class, converted to numbers of silver eel at length class and then to silver eel biomass using a length-weight regression, all using the Scenario-based Model of Eel Production II (SMEP II) (Aprahamian *et al.*, 2007; Walker *et al.*, 2013). Silver eel biomass for the river habitat is converted to a mean silver eel production rate across the wetted area of modelled river (i.e. kg·ha^{-1}). This production rate is then applied to all wetted area of rivers, lakes, estuaries and lagoons (where present) across the RBD, and finally losses that would have impacted the yellow eel population before they are electro-fished (e.g. glass eel (GE) fishing and barriers) are accounted for to estimate the B_{best} (Equation 1). The losses from various anthropogenic factors are estimated as silver eel equivalent biomass, and these are subtracted from B_{best} to estimate the present-day silver eel escapement to the sea ($B_{current}$) (Eq. 2). The silver eel escapement from the historic pre-1980s reference period (B_0) was estimated using the same approach as for $B_{best,}$ using historic survey data. The remainder of this section describes these analyses in greater detail.

$$B_{best} = Silver\ eel\ production\ rate + \ Barriers\ impact + GE\ catch \qquad \text{Equation 1}$$

$$B_{current} = B_{best} - Fishing\ mortality - Non\text{-}fishing\ mortality + Gains\ from\ installed\ passes + Gains\ from\ stocking \qquad \text{Equation 2}$$

A2. B_{best}

Estimates of B_{best} were made for the time periods as follows:

- 2005–2007
    - Used to assess emigrating biomass and mortality indicators for “Pre EMP”.
- 2008–2010
    - Used to assess emigrating biomass and mortality indicators for 2009 and 2010;
- 2011–2013

    - Used to assess emigrating biomass and mortality indicators for 2011, 2012 and 2013.
- 2014–2016
    - Used to assess emigrating biomass and mortality indicators for 2014, 2015 and 2016.
- 2017–2019
    - Used to assess emigrating biomass and mortality indicators for 2017, 2018 and 2019

The assessments were based on yellow eel data stored on the National Fish Population Database (NFPD). Only quantitative density and biomass data were included and therefore the following survey types and data were excluded:

- Fishing methods:
    - Fyke netting
    - Fixed traps fishing
    - Portable traps fishing
    - Trapping
    - Dip netting
    - Gill netting
    - Kick sampling
    - Trawl netting
    - Timed surveys
- Where the fished area was less than 10 m^2.
- Where the biomass recorded was greater than 3000g per 100 m^2.
- Where the length of eel recorded was <50 mm.

B_{best} was estimated for 41 rivers across the eleven RBDs (Table A1), for the 2021 report. Survey data from multiple index rivers were analysed for each RBD and extrapolated to the whole wetted area of the RBD, except for Humber and Dee RBDs where data from all river surveys within each RBD were analysed such that extrapolation was not necessary. The estimate of B_{best} was based on modelled data from the rivers sampled in that RBD. Mean values for each reporting period are provided (Table A2).

Table A1. Silver eel production outputs from SMEP II (kg·ha⁻¹) for the rivers analysed for the periods 2005–2007, 2008–2010, 2011–2013, 2014–2016 and 2017–2019. Please note that for Humber and Dee, only mean values are shown due to a large number of rivers included in the analysis.

RBD	River	2005–2007	2008–2010	2011–2013	2014–2016	2017–2019
Northumbria	Coquet	0.00	0.35	0.38	0.37	0.02
	Wear	1.41	6.96	0.77	0.86	1.67
Humber	Humber	0.57	0.79	1.14	0.41	0.36
Anglian	Great Ouse	1.91	0.43	0.63	0.56	0.49
	Suffolk Stour	2.85	2.58	1.27	0.55	0.91
	Wensum	1.70	1.29	1.30	0.82	0.87
	Witham	4.27	4.41	2.88	0.89	0.88
	Welland	5.37	4.36	5.28	7.18	0.96
	Chelmer & Blackwater	11.4	4.26	3.48	1.23	0.85
	Nene	3.90	1.27	0.97	0.17	0.42
Thames	Lee	3.60	1.18	1.94	1.35	1.08
	Medway	0.99	1.80	1.21	0.12	2.29
	Thames	1.95	2.05	1.40	0.22	1.16
South East	Ouse	2.41	1.03	2.24	2.81	0.65
	Itchen	6.17	12.63	7.83	6.36	5.56
	Test	3.60	12.35	6.14	4.32	1.63
South West	Dorset Stour	0.14	5.02	0.53	0.16	0.34
	Exe	0.04	0.78	0.04	1.27	0.09
	Fowey	0.67	1.47	0.24	0.24	0.07
	Frome	4.54	8.46	3.18	1.86	1.1
	Hampshire Avon	1.70	3.00	2.76	0.84	2.4
	Otter	0.16	0.76	0.63	1.66	0.07
	Parrett	0.04	0.21	1.08	0.02	No estimate
	Plym	3.34	1.81	2.95	0.62	3.73
	Tamar	0.11	0.35	0.06	0.24	0.3
	Taw	0.00	0.03	0.01	0.21	0.89
	Teign	0.01	0.05	0.11	0.15	0.07

Severn	Severn	1.18	1.48	1.33	0.51	0.42
	Wye	0.07	0.28	0.58	0.23	0.18
	Usk	0.09	4.42	1.49	2.51	0.25
Western Wales	Clwyd	No estimate	0.05	0.07	0.5	0.2
	Teifi	No estimate	0.89	2.44	1.69	0.8
	Tywi	No estimate	0.97	0.03	1.02	0.05
	Wnion	No estimate	1.15	2.04	1.91	0.87
Dee	Dee	0.35	2.15	2.44	1.27	0.81
North West	Bela	No estimate	4.80	0.54	1.1	2.18
	Derwent	0.05	0.31	0.29	0.23	0.3
	Ellen	3.40	0.01	0.06	No estimate	0.02
	Mersey	0.00	0.11	0.16	0.4	0.04
	Ribble	0.44	1.33	0.72	0.81	0.45
	Weaver	1.12	0.03	0.00	0.4	No estimate
Solway Tweed	Border Esk	0.13	1.65	0.37	0.59	1.67
	Eden	0.10	0.20	0.09	0.46	0.29
	Tweed	No estimate	1.28	0.57	No estimate	No estimate

Table A2. Silver eel production outputs from SMEP II (kg·ha^{-1}) for the periods 2005–2007, 2008–2010, 2011–2013, 2014–2016 and 2017–2019 for each River Basin District. Note: with the exception of the Humber and Dee the estimates for each RBD are means of two to ten index rivers. For Humber and for Dee all available survey data from the RBD were used to produce the mean values.

RBD	2005–2007	2008–2010	2011–2013	2014–2016	2017–2019
Northumbria	0.71	3.66	0.58	0.62	0.85
Humber	0.57	0.79	1.14	0.41	0.36
Anglian	4.49	2.66	2.26	1.63	0.77
Thames	2.18	1.68	1.52	0.56	1.51
South East	4.06	8.67	5.40	4.50	2.61
South West	0.98	1.99	1.05	0.66	0.91
Severn	0.45	2.06	1.13	1.08	0.28
Western Wales	No estimate	0.77	1.15	1.28	0.48
Dee	0.35	2.15	2.44	1.27	0.81
North West	1.00	1.10	0.30	0.59	0.60
Solway Tweed	0.12	1.04	0.34	0.53	0.98

A3. Anthropogenic mortality factors and $B_{current}$

The impacts of the anthropogenic (human-induced) mortality factors have been summarised according to four categories as follows:

1. Fishing mortality, relates to the catch of all life stages;
2. Entrainment and mortality at water intakes, includes mortality from pumping stations, critical surface water abstractions, power stations and hydropower facilities;
3. Habitat quantity and quality, relates to the impact of manmade obstructions (including tidal gates); and
4. Stocking, reflects the benefit of stocking and has been reported as a negative impact.

A3.1. Fishing mortality

Recreational catch

It has been illegal to kill eel caught by recreational fishing in England and Wales since 2009. Anyone who does catch an eel on rod-and-line (the only legal recreational instrument) must return it alive to the water from where it was taken. Therefore, it is assumed that there is no recreational catch of eel.

Commercial catch

Catch data were available from the glass eel and from the yellow and silver eel fisheries. In 2009, legislation was introduced to improve the traceability of eel caught, such that there are now three sources of glass eel exploitation data:

1. Catch returns to the Agency – this provides a breakdown of catch by RBD but may underestimate the total catch (C_i)
2. The quantity of glass eel bought by the dealers from the fishermen (consignment notes) – this is the total amount of glass eel caught (C_t)
3. The quantity of glass eel exported from the UK or stocked within the UK – this is the total amount of glass eel caught minus mortality and weight loss post-capture.

For the period 2009 to 2019, the glass eel catch in RBDi was calculated as follows, using the nomenclature 1, 2 and 3 above:

$$G_i = C_t \cdot \left(\frac{C_i}{\sum_{c=0}^{n} C_i}\right)$$

For the years 2006–2008 the estimate of the total glass eel caught in each RBD was:

$$G_i = C_i \cdot \frac{\overline{C}_{t\,(2009-2011)}}{\sum_{c=0}^{n} \overline{C}_{i(2009-2011)}}$$

For 2005 and the early 1980s (Pre 1980 in Table A3) the estimates for both glass and yellow and silver eel (combined) were derived from the import export figures published in the country report (ICES, 2014: Table 2 [page 830] and Table 26 [page 855], respectively). The partition of the catch to individual RBDs was based on the current split in the total catch based on the mean proportions between 2005 and 2013.

The catch for the Solway Tweed RBD prior to the ban on eel fishing in Scotland was assumed to be 10% of the total Scottish catch as the Scottish part of the Solway Tweed represents ≈10% of the freshwater habitat of Scotland.

Yellow and glass eel catches were converted to silver eel equivalents, as follows:

The biomass of yellow eel caught was considered to be the equivalent of the potential silver eel escapement as the instantaneous mortality rate of 0.14 yr^{-1} (Dekker, 2000) approximated to the instantaneous growth rate of 0.2 yr^{-1} (95% CI ± 0.03) (Aprahamian, 1986).

For the glass eel catch, 1kg of glass eel was considered equivalent to 59.4 kg of silver eel. This was determined assuming:

1. a settlement instantaneous mortality of 0.00915 day^{-1}, (95% CI ± 0.00149 day^{-1}) based on an extrapolation from the study of Bisgaard and Pederson (1991) to a glass eel of 80 mm;
2. a settlement period of 50 days (Briand, 2009) assuming a water temperature of 9 ^{o}C;
3. an annual instantaneous mortality following settlement of 0.14 yr^{-1} (Dekker, 2000);
4. a 50:50 sex ratio; and
5. males maturing at 11.9 (95% CI ± 0.6) (@ 89.9g [95% CI ± 3.7g]) and females at 17.8 (95% CI ± 0.8) years (@ 568.9g [95% CI ± 57.1g]) (Aprahamian, 1988).

Thus, the losses due to commercial fishing were estimated with the following formula:

$$Banthro_{fi} = \sum_{g=0}^{n} G_i \,.\, 59.4 + \sum_{y=0}^{n} Y_i + \sum_{s=0}^{n} S_i$$

Where:

- $Banthro_{fi}$ is the biomass (kg) of eel in terms of silver eel equivalents that is estimated that would be produced in RBD_i if no fishing was present.
- G_i is the biomass (kg) of glass eel caught in fishery g in RBD_i (Table A3).
- Y_i is the biomass (kg) of yellow eel caught in fishery y in RBD_i (Table A4).
- S_i is the biomass (kg) of silver eel caught in fishery s in RBD_i (Table A5).

Table A3. Glass eel catch (kg) by River Basin District (RBD), including the information from the dealers and catch returns to the Environment Agency. NP = not pertinent (no fishery authorised in that year).

RBD	Pre-1980	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Northumbria	0	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
Humber	0	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
Anglian	0	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
Thames	0	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
South East	0	0	0	0	0	0	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
South West	17919	3225	722	999	521	282	1079	2033	2161	4536	5624	1365	2069	1721	1898	2881
Severn	24454	4055	944	1750	554	111	759	1460	1586	3947	6010	1295	2084	1705	2558	3835
Western Wales	1998	457	55	39	6	0	2	4	0	34	33	0	39	10	27	28
Dee	795	202	8	9	3	1	7	21	23	22	0	17	5	10	60	50
North West	4827	860	174	299	137	28	43	123	49	119	133	123	83	84	116	156
Solway Tweed	0	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP

Table A4. Yellow eel catch (kg) by River Basin District (RBD). Note: due to an apparent anomaly with reported catch figures for Humber in 2018, a three-year mean catch was applied for biomass and mortality calculations (in brackets). NP = not pertinent (no fishery authorised in that year).

RBD	Pre-1980	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Northumbria	93	5	1	0	0	45	60	NP	NP	NP	NP	NP	NP	NP	NP	NP
Humber	17970	1295	1160	2138	1429	411	3033	4857	3267	3865	151	1678	155	1542 (2468)	4838 (2468)	1023 (2468)
Anglian	76619	13065	6282	3739	9903	6616	10708	16478	15335	9351	11000	8082	12273	6129	11796	7432
Thames	39920	7175	5688	6963	5548	4745	5655	6082	1815	3991	3222	2696	2473	2264	1971	1682
South East	15600	406	3069	1807	602	7029	1432	1879	2116	286	284	12143	825	364	216	200
South West	35960	3787	6788	2019	6626	2546	2722	3792	5966	8688	10117	5642	10261	11168	13347	13014
Severn	1113	565	170	68	27	0	150	350	0	0	NP	NP	NP	NP	NP	NP
Western Wales	2070	240	475	273	118	22	345	252	647	100	0	0	1345	0	0	0
Dee	2146	34	28	23	642	70	53	1082	478	152	415	74	73	333	123	608
North West	7484	1619	1250	211	474	114	150	1477	2972	669	87	93	187	326	154	247
Solway Tweed	0	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP

Table A5. Silver eel catch (kg) by River Basin District (RBD). Note: due to an apparent anomaly with reported catch figures for Humber in 2018, a 3-year mean catch was applied for biomass and mortality calculations (in brackets). NP = not pertinent (no fishery authorised in that year).

RBD	Pre 1980	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Northumbria	82	0	0	0	90	10	0	NP	NP	NP	NP	NP	NP	NP	NP	NP
Humber	5007	243	323	2188	865	110	199	257	1627	259	81	742	49	22 (393)	1115 (393)	41 (393)
Anglian	16538	6659	2417	198	1974	592	739	2006	2980	2486	1483	3759	3664	2109	2258	2808
Thames	3408	1067	971	484	404	119	67	513	200	308	384	202	152	14	134	4
South East	15939	3594	4104	2621	1650	3198	823	694	650	1991	754	895	252	30	79	60
South West	5433	1886	1896	228	552	303	172	68	533	950	1167	119	947	1117	1342	1459
Severn	2052	396	146	124	117	1224	100	380	0	0	NP	NP	NP	NP	NP	NP
Western Wales	207	10	31	140	10	43	9	9	0	0	0	0	150	0	0	0
Dee	180	10	6	9	15	14	15	119	0	31	30	31	24	21	19	173
North West	2178	202	1103	85	263	80	72	270	462	105	28	56	33	254	220	277
Solway Tweed	250	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP

A3.2. Entrainment

Pumping stations

In 2015, 336 of the 946 pumping stations in England and Wales were identified as having the greatest potential to impact eel, based on the distance from head of tide and the predicted prevalence of eel. The predicted prevalence was estimated using a non-parametric geostatistical model (Wyatt, 2005; Wyatt, *et al*., 2007) that related the prevalence of eel to environmental variables (distance from the tidal limit and altitude), and geographic location. The model was used to predict the expected prevalence of eel for a given river type under reference conditions, the pressure variables being set to zero (WFD-UKTAG, 2008a).

To estimate the impact across the RBD, it was assumed that all the area upstream of each of the 336 most impacting pumping stations was lost to eel production (Table A6). The total annual loss in terms of silver eel biomass for RBD (i) was estimated as follows:

$$Banthro_{ji} = \sum_{j=0}^{n} (Bsmep_i \, . A_{ji})$$

Where:

- $Banthro_{ji}$ is the biomass (kg) of silver eel that is estimated would be produced in catchment j in RBD_i if no pumping station was present.
- $Bsmep_i$ is the silver eel production from RBD_i (kg ha^{-1}) estimated by SMEP II.
- A_{ji} is the wetted area (ha) upstream of the pumping station in catchment j in RBD_i.

Table A6. Area of habitat lost to eel production (ha) from those pumping stations with the greatest potential to impact eel

RBD	Area of habitat lost to eel production (ha)
Northumbria	5
Humber	3897
Anglian	5234
Thames	28
South East	797
South West	1621
Severn	119
Western Wales	0
Dee	0
North West	366
Solway Tweed	0

In the period 2017–2019, no eel measures were installed at any of the 336 key pumping stations, so the estimated area of habitat lost to eel production remains the same as in the

2018 report (Table A6). It should be noted, however that eel measures have been implemented at a number of pumping stations not used in the original impact calculation.

Surface water abstractions

In 2015, it was determined that surface water was abstracted at 23,106 sites in England and Wales. A total of 530 sites were identified as posing the greatest threat to eel using the following criteria: distance from head of tide, size of the abstraction, predicted presence of eel, the sensitivity of the water body to abstraction (WFD-UKTAG, 2008b). These identifications were also quality assured by consultation with local experts.

Information on eel entrainment and mortality was available from 10 surface water abstraction sites (APEM, 2007; APEM, 2010; Frear and Axford, 1991). The annual number of eel entrained at these 10 sites ranged from zero to 3261 with a mean of 613.8 (95% CI ± 613.8) eel per year. The mean age of those eel was assumed to be two years, which equates to about 150 mm total length. The equivalent in terms of silver eel biomass (calculated as above) was estimated to be 0.03 kg per entrained eel, equating to 19.2 (95% CI ± 19.2) $kg \cdot yr^{-1}$ entrained per abstraction.

The total annual loss in terms of silver eel biomass for RBD_i (Table A7) was therefore estimated as follows:

$$Banthro_{ki} = \sum_{k=0}^{n} K_i \,.\, 19.2$$

- $Banthro_{ki}$ is the biomass (kg) of silver eel that is estimated that would be produced in RBD_i if no surface water abstraction was present.

- K is the number of surface water abstractions in RBD_i.

In the 2017–2019 period, 24 more eel screens were installed at high priority/critical intakes, resulting in a reduction in the ongoing impact, with 483 critical abstractions remaining (Table A7).

Table A7. Number of critical abstractions and estimated loss of emigrant biomass.

RBD	Number of High priority abstractions still impacting in 2019	Estimated biomass of silver eel entrained (kg·yr^{-1})
Northumbria	11	211
Humber	15	288
Anglian	131	2515
Thames	39	749
South East	37	710
South West	80	1536
Severn	16	307
Western Wales	12	230
Dee	11	211
North West	124	2381
Solway Tweed	7	134

Cooling water intakes at Power Stations

Information on eel impingement and/or entrainment at cooling water intakes of power stations was available from five sites. At three sites, only impingement data were available and to account for the quantity of eel that passed through the screens, the catch was raised by x300 for glass eel and x4.3 for yellow eel (APEM, 2012). There was no correction factor applied for silver eel. For the two sites where no size information was available, it was assumed that those eels caught between 1 February and 30 April 30 were glass eel, with yellow eel being caught at all other times. A survival rate of 36% was assumed for glass eel and 75% for yellow eel entrained by the power station (APEM, 2012; Jacobs, 2008). The conversion of glass eel and yellow eel entrainments into silver eel equivalents was as described for the commercial catch (above). The estimated annual biomass of silver eel equivalents entrained by a power station was 697.6 kg·yr^{-1} (95% CI ± 724.2 kg·yr^{-1}).

The total annual loss in terms of silver eel biomass for RBD$_i$ (Table A8) was estimated as follows:

$$Banthro_{li} = \sum_{l=0}^{n} L_i \,.\, 697.6$$

$Banthro_{li}$ is the biomass (kg) of silver eel that is estimated that would be produced in RBD$_i$ if no power station was present.

L is the number of power stations in RBD$_i$.

In 2016, it was estimated that there were 51 power stations across England and Wales where cooling water intakes were impacting eels. By 2019, this number had fallen by seven as those stations had been decommissioned in the 2017–2019 period and no longer pose an entrainment/mortality risk to eels. The loss of emigrant biomass has therefore reduced accordingly (Table A8).

Table A8. Number of power stations and estimated loss of emigrant biomass.

RBD	Number of Power Stations impacting in 2019	Estimated biomass of silver eel entrained ($kg \cdot yr^{-1}$)
Northumbria	3	2092.8
Humber	15	10464
Anglian	2	1395.2
Thames	8	5580.8
South East	4	2790.4
South West	2	1395.2
Severn	1	697.6
Western Wales	1	697.6
Dee	1	697.6
North West	7	4883.2
Solway Tweed	0	0.0

In-river Hydropower facilities (turbines)

The impact of each in-river hydropower facility was estimated according to the B_{best} production ($kg \cdot ha^{-1}$) for the relevant RBD, the area of habitat upstream, the presence or absence of screens (preventing eel entrainment) and the type of turbine.

For those sites with screens (α), the proportion of eel entering the turbine(s) was assumed to be: zero, if the spacing between the bars/mesh was <15 mm; 50%, if the spacing was between 16–29 mm; and 100%, if >30 mm: 27.6% of hydropower schemes (excluding Archimedes screws) are adequately screened to prevent the entrainment of eel (i.e., spacing was <15 mm).

The estimates of turbine mortality (β) were taken from ICES (2011), and these were: Archimedes screw = 0%, Francis Turbine = 32%, and Kaplan turbine = 38%. All hydropower facilities have some form of bypass channel that provides an alternative route for fish around the turbine. On this basis, it has been assumed that ≈ 50% of the silver eels produced upstream of a turbine will become entrained therein whereas the other 50% use the bypass.

On those river systems where there is more than one hydropower facility, the loss of production from the upstream turbine(s) has been accounted for in estimating the potential impact of turbines further downstream, i.e. the cumulative impact of all turbines has been calculated (Table A9).

$$Banthro_{hi} = \sum_{h=0}^{n}((Bsmep_i \, . A_{hi}) - ((Bbest_i \, . A_{h_u i})\alpha_{h_u}\beta_{h_u}))\alpha_h\beta_h$$

Where:

- $Banthro_{hi}$ is the biomass (kg) of silver eel that is estimated that would be produced in RBD_i if no hydropower facilities (h) were present.
- h_u represents the hydro scheme upstream of hydropower station h.

Table A9. Estimated loss of emigrant biomass due to hydropower stations (kg·yr^{-1}).

RBD	Estimated loss of emigrant biomass (kg·yr^{-1}) 2005–2007	Estimated loss of emigrant biomass (kg·yr^{-1}) 2008–2010	Estimated loss of emigrant biomass (kg·yr^{-1}) 2011–2013	Estimated loss of emigrant biomass (kg·yr^{-1}) 2014–2016	Estimated loss of emigrant biomass (kg·yr^{-1}) 2017–2019
Northumbria	10	53	8	9	9
Humber	575	592	619	507	507
Anglian	0	0	0	0	0
Thames	3	2	2	2	2
South East	63	135	84	70	70
South West	862	867	863	195	195
Severn	8	27	17	16	16
Western Wales	33	37	56	62	62
Dee	2	10	12	6	6
North West	79	84	47	54	54
Solway Tweed	0	1	0	1	1

A3.3. Habitat loss

Barriers

There are about 19,000 potential barriers (partial and complete barriers) to eel migration across England and Wales. The impact of barriers (including tidal gates) was estimated using a general linear model derived from eel data in 27 rivers from 2008 to 2013 (r^2 = 0.196):

$$\gamma_b = e^{(-2.6545-(0.302Log_e(\delta+1))-\left(0.0401Log_e(\varepsilon+1))-(55.3Log_e(\zeta+1))-(0.2906Log_e(\eta+6))+(1.7152Log_e\theta)\right)-1}$$

Where:

- γ_b is density (# 100m^{-2}) of eel in the presence of barriers downstream
- δ is distance (m) upstream of tidal limit
- ε is the number of barriers downstream of the site to the tidal limit
- ζ is the gradient (m m^{-1}) to the site
- η is the longitude (°East) of the site
- θ is latitude (°North) of the site.

The anthropogenic effect of barriers was estimated by setting ε in the above equation to zero and comparing the ratio of density as estimated from the above equation in the presence and absence of barriers. The mean of all these site ratios was applied to the RBD as a whole, as follows:

$$Banthro_{bi} = \frac{Bcurrent_i}{\overline{\gamma_{bi}/\gamma_i}} - Bcurrent_i$$

$Banthro_{bi}$ is the biomass (kg) of eel in terms of silver eel equivalents that is estimated that would be produced in RBD_i if no barriers were present.

$\overline{\gamma_{bi}/\gamma_i}$ is the mean proportion of eel density in the presence of barriers against no barriers present (ε = 0) at sites within RBD_i.

In the 2017–2019 reporting period, a total of 99 eel passes were installed at eel barriers. We can adjust the estimated impact of barriers accordingly by calculating the amount of upstream habitat made available by each eel pass and its corresponding production in terms of silver eel biomass. Hence our estimate of the impact of barriers is reduced.

A3.4. Stocking

Stocking was undertaken using glass eel (Table A10) and converted into silver eel equivalents as described for commercial catch (above). The impact of stocking was considered in the estimation of total anthropogenic mortality when calculating $B_{current}$, but was not included in the estimation of mortality rates (see below A3.5)

Table A10. Amount of glass eel stocked (kg), by RBD from 2009–2019. Note that these glass eels all originated in the RBDs of England and Wales.

RBD	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Northumbria	0	0	0	0	0	0	0	0	0	0	0
Humber	18.50	38.00	0.00	10.00	3.00	3.80	0	0	0	0	0
Anglian	4.60	15.20	11.30	1.50	9.10	0	0	0	0	0	0.07
Thames	0	0	0.01	1.20	2.00	14.00	0	0	0	0	0
South East	0	0	0	0	7.00	7.50	0	0	0	0	0
South West	0	0	0	0.19	12.80	8.70	0.33	0.55	0	0	0
Severn	0	0.40	38.83	9.75	21.10	21.50	17.00	17.00	17.00	17.00	0.40
Western Wales	0	0	0	0	0	0	0	0	0	0	0
Dee	0	0	0	0	0	0	0	0	0	0	0
North West	0	0	0	0	0	0.03	0	0	0	0	0.03
Solway Tweed	0	0	0	0	0	0	0	0	0	0	0

A3.5. Estimation of mortality rates

The sum of lifetime anthropogenic mortalities (∑A) is calculated as:

$$\sum A = -\ln\left(\frac{Bcurrent}{Bbest}\right)$$

Fisheries (∑F) and non-fisheries mortalities (∑H) were assumed to operate during the whole continental life and at the same time, and therefore estimated as:

$$\sum \mathrm{F} = \frac{\mathrm{Ct}}{\mathrm{Ct} + Ht} * \sum \mathrm{A}$$

$$\sum \mathrm{H} = \frac{Ht}{\mathrm{Ct} + Ht} * \sum \mathrm{A}$$

where C_t represents total fisheries catch in silver eel equivalents and H_t total non-fisheries loss of silver eel equivalents.

Stocking was not considered in mortality calculations to avoid incautious situation where anthropogenic mortalities could be compensated by large restocking programmes. Therefore, stocked eels (as silver eel equivalents) were subtracted from $B_{current}$ prior to estimating lifetime anthropogenic mortalities and from total non-fisheries loss prior to calculating fisheries and non-fisheries mortalities.

A4. Estimation of B_o

The target level of escapement (B_0) was determined using two out of three options specified under Article 2(5) of EC Regulation 1100/2007 (EC, 2007). Where available, historic data collected were used to produce the B_0 target values for those river basins. These were then applied to river systems with limited or missing data, while considering ecology and hydrography of those systems. The approach is described in more detail below.

There are few historic eel surveys available across England and Wales that provide the density, length frequency and sex ratio data necessary to apply the SMEP II approach to estimate RBD-specific B_0. The rivers and survey years available are presented in Table A11.

Complete data are only available from the Severn (1983), Dee (1984) and Thames (1992–1994). These data were applied directly in the SMEP II model to estimate historic potential production (~B_{best}), applying the same approach as described for estimating current B_{best}, above.

As no length data were recorded for the Anglian rivers Stour and Chelmer, the mean eel length for a site was estimated from other rivers as follows:

*Mean total length (mm) = 281.0 (±15.54) + 0.9879 (±0.245) * Distance from tidal limit (km)* $P<0.001$; $r^2 = 0.23$

The length distribution was estimated using a random number generator based on the mean length (calculated above), a standard deviation (SD) of 102 (the mean SD of all sites where length had been recorded), and assuming a binomial distribution.

As only the mean length and SD were available for the South West rivers (Frome, Fowey Teign, Axe, Otter and Plym), the length distribution was estimated using a random number generator, assuming a binomial distribution.

Table A11. Estimates of silver eel potential escapement ($kg \cdot ha^{-1}$) for various rivers between 1979 and 1994.

RBD	River (Year)	Potential escapement ($kg \cdot ha^{-1}$)
Anglian	Suffolk Stour (1983)	0.73
	Chelmer (1986)	0.88
Thames	Thames (1992–1994)	2.35
South West	Frome 1990	82.54
	Fowey 1981 &1983	3.06
	Teign 1979	2.20
	Axe 1979	56.78
	Otter 1978	27.24
	Plym 1982	7.17
Severn	Severn (1983)	6.84
Dee	Dee (1984)	29.89

Where potential escapement estimates were available for two or more rivers in the same RBD, the river-specific estimates were combined to provide a mean estimate for the RBD. For the South West RBD, the mean escapement was estimated based on the assumption that 14% of the production is derived from chalk streams (River Frome) and 86% from rain fed rivers (i.e. Fowey Teign, Axe, Otter, Plym) as follows:

$$SW\ RBD\ (kg \cdot ha^{-1}) = ((Frome*0.138876) + ((Fowey + Teign + Axe + Otter + Plym)/5) * (1-0.138876))$$

In the Anglian RBD, the two rivers were given equal weighting because the rivers are similar in character.

Where no historic data were available for any rivers within the RBD, the following assumptions have been made:

- The east coast RBDs (Northumbria, Humber and South East) follow a similar trajectory to that of the Anglian, where current escapement (B_{best}) is greater than “historic” and therefore current production has been taken as B_o.
- The West Wales and North West RBDs were extrapolated from the South West (excluding chalk rivers), Severn and Dee estimates, weighted according to wetted areas.
- The Solway-Tweed estimate was extrapolated from the estimates of the North West and Northumbria RBDs, weighted according to wetted areas.

These potential escapement estimates were then corrected for the impact of barriers (as above) to give an estimate of B_o for each RBD (Table A12).

Table A12. Estimates of B_o (kg·ha^{-1}) for River Basin Districts in England and Wales and for the cross border Solway Tweed RBD.

River Basin District	B_o (with barriers; (kg·ha^{-1})	B_o (with no barriers; kg·ha^{-1})	Comment
Northumbria	3.66	5.16	Based on current estimate and the rationale from Anglian that current is higher than historic and as 2008–2010 (3.25 kg·ha^{-1}) > 2011–2013 (0.63 kg·ha^{-1})
Humber	1.14	2.38	Based on current estimate and the rationale from Anglian that current is higher than historic and as 2011–2013 (1.14 kg·ha^{-1}) > 2008–2010 (0.79 kg·ha^{-1})
Anglian	4.49	6.27	Based on current estimate (2005–2007) being higher than historic (0.81 kg·ha^{-1}).
Thames	2.35	5.88	Thames (1992–1994)
South East	8.67	10.60	Based on current estimate and the rationale from Anglian that current is higher than historic and as 2008–2010 (8.67 kg·ha^{-1}) > 2011–2013 (5.40 kg·ha^{-1})
South West	28.07	37.03	Pristine production based on 1979–1990 data (28.07 kg·ha^{-1}) determined using SMEP II (assumes:14% production from chalk rivers of 82.5 kg·ha^{-1}, the remainder from rain fed rivers at 19.3 kg·ha^{-1}
Severn	6.84	11.98	Severn 1983
Western Wales	13.98	16.18	Pristine production estimated at 13.98 kg·ha^{-1} based on South West (excluding chalk rivers), Severn and Dee weighted according to area = ((19.29*31050) + (6.84*54542) + (29.89*14129)) / 99721
Dee	29.89	45.02	Dee 1984
North West	13.98	18.50	Pristine production estimated at 13.98 kg·ha^{-1} based on South West (excluding chalk rivers), Severn and Dee weighted according to area = ((19.29*31050) + (6.84*54542) + (29.89*14129)) / 99721
Solway Tweed	13.01	16.84	Based on South West (excluding chalk rivers), Severn and Dee weighted according to area and Tweed production for 2008–2010 based on the rational that current production on the east coast is higher than historic. Assumed 13.98 kg·ha^{-1} for Solway and 1.28 kg·ha^{-1} for Tweed (2008–2010)

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Annex B: Methods and data used in the 2018–2020 assessments of Scotland RBD

B1. Introduction

Eel fisheries in Scotland were banned (without licence) in 2009 as the principle management measure of the EMP for Scotland River Basin District (RBD). Prior to 2009, fisheries were not regulated, so only crude estimates of the scale of the fishery are available (Anon, 2010). Stock assessment methods for the RBD are therefore based on scientific estimates of upstream and downstream counts of eel at traps on three rivers. The estimates of B_0, $B_{current}$ and B_{best} rely on the extrapolation of data from small study areas to the whole RBD, with the inherent possibility of bias. To derive an estimate of current production and anthropogenic mortality for the RBD from the available data has required a number of assumptions; these have tended to be precautionary in nature (i.e. likely to underestimate current production and overestimate current anthropogenic mortality (see Anon, 2010 for details).

From 2013, in keeping with methods used in England and Wales, Scotland adopted the inclusion of estimates of silver eel production for transitional waters based on the simplistic assumption that this is equivalent to silver eel production in the lower lying rivers and lochs of Scotland. Pristine production for transitional waters is assumed to be equivalent to pristine production in Scottish freshwaters during the reference period. For this reason, the inclusion of transitional waters has a relatively small effect (as a percentage of pristine output) on modelled silver eel output. However, because anthropogenic mortality is assumed to be zero in transitional waters, as there are no fisheries, the inclusion of transitional waters leads to a substantial reduction in the estimate of the value of $\sum A$ for the Scotland RBD. All figures in the current report have been back-calculated to include production from transitional waters, and thus do not match equivalent figures in the 2012 report to the EU.

B2. B_{best}

Current eel production in Scottish waters is assumed to be limited only by recruitment and barriers to productive habitat. Accordingly, B_{best} is estimated in the same way as $B_{current}$, but including potential production from the habitat area currently assumed to be lost to production due to manmade barriers (including hydropower). This amounts to 42,670 ha of potential eel habitat of which: 31,545 ha are in the lower altitude band, 8,725 ha in the middle band, and 2,400 ha are in the upper band. It is worth noting that the reported area of habitat above manmade barriers is artificially increased, by an unknown extent, above the natural condition, due to the impoundment of waters above dams; accordingly, B_{best} is over-estimated by this method, which in turn leads to an overestimate of mortality due to manmade barriers and hydropower facilities.

B3. Anthropogenic mortality factors and $B_{current}$

The impact of manmade barriers on eel production was estimated in the most conservative way possible: by assuming that all barriers were total and acted to remove all production upstream of the barrier without increasing production downstream (i.e. an assumption that downstream habitat is completely saturated). Hydropower facilities were treated in the same way, even where fish passes allow eels access above the turbines: in this case the conservative assumption is that silver eel mortality moving downstream through the turbines is 100%. Thus, three assumptions are made that overestimate the impact of barriers on eel production: 1) all identified barriers completely exclude eels; 2) all hydropower sites cause 100% mortality of silver eels passing through them; 3) the wetted area of Scotland RBD is 100% saturated with eels. Thus, any wetted areas above hydropower facilities, or other manmade barriers, were removed from the productive area when estimating current production, and the production lost as a consequence was regarded as anthropogenic mortality (∑A), with the separate impacts of a) hydropower facilities and b) other manmade barriers to eels estimated according the area of production lost to each (5,574 ha lost to hydropower, and 37,096 ha lost to other manmade barriers).

Current silver eel output ($B_{current}$) is estimated at three whole river trap sites, with no known anthropogenic mortality, which measures production across three altitude bands: Shieldaig (0–240 m), Girnock (240–415 m), and Baddoch (>415 m). The annual production from these three bands is then calculated from the production at the relevant site and the wetted area of habitat in that altitude band in the whole RBD. The total wetted area of freshwater for Scotland RBD, after excluding habitat above manmade barriers, is 111,069 ha of which: 97,684 ha lie in the 0–240 m band, 10,853 ha lie in the 240–415 m band, and 2,532 ha lie in the >415 m band. Production in transitional waters (60,502 ha) is assumed to be equivalent to the lowest of the three altitudinal bands.

Estimates of silver eel production for pristine conditions (pre-1980), for current production in the period immediately prior to the introduction of the EMP (mean 2006–2008), and for each of the subsequent years are shown in Table B1.

Table B1. Estimates of silver eel escapement in Scotland RBD in three altitude bands based on whole-river traps at three sites ($kg \cdot ha^{-1}$)

Altitude band (m)	Pre-1980	Pre-EMP (2006–2008)	2012	2013	2014	2015	2016	2017	2018	2019	2020
0–240	1.18	1.11	0.51	0.74	2.24	1.34	1.15	1.12	1.02	0.87	0.99
240–415	1.18	0.47	0.94	0.54	0.28	0.43	0.59	1.51	0.77	0.61	0.63
>415	1.18	0.50	0.54	0.42	0.80	0.10	0.55	0.55	0.72	0.20	0.11

For the period prior to the introduction of the EMP (and the cessation of the fishery), additional mortality estimates due to the fishery were based on available estimates of the size of the fishery in 2003, yellow eel catches were scaled to silver eel equivalents after Aprahamian (1986).

B4. Estimation of B_0

The pristine production of Scottish waters was estimated in three ways: based on historical silver eel production at a single Scottish site (Girnock Burn) in the period from 1967–1981; by reference to the historical production at a similar site (Burrishoole, Ireland, 1971–79; ICES, 2008) and by reference to an Irish model (ICES, 2008) of five catchments accounting for catchment geology. All three methods gave similar estimates of silver eel production in $kg \cdot ha^{-1}$, and the mean of the three estimates was set as Scotland RBD's pristine production. This estimate of production was then applied to the wetted area of habitat in Scotland, estimated by GIS methods. Areas above natural barriers to eel migration were excluded from the pristine productive wetted area, but areas above manmade barriers (of any era of construction) were included in the pristine productive area. These methods are described in detail in the Scotland RBD EMP (Anon., 2010). Since production of the EMP however, the estimate of pristine production using Girnock Burn data was adjusted to account for a proportion of eels bypassing the trap in spate conditions, as it also was for the 2012 report to the EU. This led to a slight increase in estimated pristine production (averaged from the three methods) to 1.18 $kg \cdot ha^{-1}$.

B5. References

Anon. (2010) Scotland RBD Eel Management Plan www.webarchive.org.uk/wayback/archive/3000/https://www.gov.scot/Resource/Doc/295194/0118349.pdf.

Aprahamian MW (1986) Eel (*Anguilla anguilla* L.) production in the River Severn, England. *Polskie Archiwum Hydrobiologii*, 33: 373–389.

ICES (2008) Report of the 2007 session of the Joint EIFAC/ICES Working Group on Eels, Bordeaux, 3–7 September 2007.ICES CM 2007/ACFM:23, 534 pp.

Annex C: Best estimates of silver eel escapement for Northern Ireland RBDs

Neagh Bann RBD

For the only EMU in Northern Ireland with a fishery, the GB_Neag RBD, the estimate of pristine escapement (B_0) was determined using historic data including catch and sex ratio, input-output regression analysis and from known productivity of eel growing areas (Section 11.4 of GB_Neag EMP). Using these three methods pointed to a potential natural output in the range of 400 to perhaps 600 tonnes per annum given historical high natural glass eel supplies. This range would estimate the required 40% level at around 160 t to 240 t.

In Northern Ireland, the monitoring of silver eel migration and subsequent estimations of silver eel escapement ($B_{current}$) from the Neagh Bann RBD are carried out by direct measurement (section 11.1 of the Neagh Bann EMP). Given the geography of the RBD, in particular the single outflow point of Lough Neagh via the Lower River Bann at Toome, it was possible to initiate an annual mark-recapture programme in 2003, with the objective of estimating escapement of silver eels from Lough Neagh based on the non-recaptured proportion of those tagged silver eels taken back upstream and released. This work was further enhanced and corroborated by implementing a hydro-acoustic tracking study (a not foreseen but implemented measure) in 2011. To date, 12 098 eels have been tagged with Floy™ Tags since 2003 and recaptures recorded at both silver eel sites in the RBD.

Since 2018, the calculation for estimated escapement has been changed and further improved by the development of a model combining:

- daily river flow metrics with
- daily silver eel catch,
- against which daily tag recaptures are assessed.

This method has been used to hindcast and revise the calculations for escapement from 2009. Specific details of this mark recapture escapement assessment are outlined in Section 11.2 of the Neagh/Bann EMP (Anon. 2010) and in Aprahamian and Evans *et al.* (2021).

North Eastern RBD

The estimate of pristine escapement from the North Eastern RBD was calculated with reference to the ecology and hydrology of similar systems (as described in Section 2.4.1 of the North Eastern EMP). Historic escapement was unknown and not monitored because there are no fisheries in this RBD, but all rivers and upland lakes suitable for eels have been assessed as having no or minimal barriers to migration. As such under adequate recruitment levels and an adherence to the management actions laid down in the North Eastern EMP, this RBD should reach or better the 40% target naturally. Data relating to eel population densities and age distribution have been gathered for assessment purposes and are now included within Biomass and Mortality estimates. A glass eel index site has been established and the direct assessment of silver eel migration conducted in 2017 by netting.

C1. References

Anon. (2010) Eel Management Plan Neagh / Bann River Basin District. The Scientific Basis for the Viability of Current Management of Eel in the Lough Neagh and Lower Bann River Basin. Department of Food, Environment and Rural Affairs, Northern Ireland, 72 pp.

Aprahamian MW, Evans DW, Briand C, Walker AM, Elarney YMC, Allen M (2021) The changing times of Europe's largest remaining commercially harvested population of eel *Anguilla anguilla* L. Journal of Fish Biology, 99(4), 1201–1221.

Annex D: Updated biomass and mortality indices for previous reporting periods

Table D1. Updated best estimates of silver eel biomass (kg) across England, Wales, Scotland and Northern Ireland RBDs during 2009–2016. Note these estimates are based on period means for some data inputs. ND means "No Data", where there are insufficient data collected to estimate a derived parameter.

RBD code	$B_{current}$								B_{best}							
	2009	2010	2011	2012	2013	2014	2015	2016	2009	2010	2011	2012	2013	2014	2015	2016
Northumbria	40755	40750	4478	4478	4478	4975	4975	4975	60876	60876	9577	9577	9577	10243	10243	10243
Humber	28991	27438	42157	42971	43325	8012	5598	7814	95534	95534	137859	137859	137859	49581	49581	49581
Anglian	119084	115474	88620	88207	95137	64862	65503	61407	201850	201850	171573	171573	171573	123715	123715	123715
Thames	57862	57004	49286	53937	51699	14249	14125	14397	179581	179581	162444	162444	162444	60336	60336	60336
South East	77582	85553	50511	50318	51222	46487	34042	46003	121340	121340	75622	75622	75622	62932	62932	62932
South West	61757	61706	28545	25917	23528	8974	13999	8565	111056	158434	170603	178185	319248	353455	112330	154125
Severn	151485	152478	84841	83843	84518	81453	81185	81185	277546	315997	235791	243276	383532	499481	219402	266246
Western Wales	17235	16946	27117	26730	27277	32321	32321	30826	23522	23616	35448	35207	37231	41300	39358	41674
Dee	27961	27976	30940	31663	31958	15876	16217	16224	45802	46166	53178	53314	53223	27030	28030	27344
North West	43612	43584	4809	3121	5781	19904	19868	19797	69666	70548	25584	21188	25350	44296	43722	41304
Solway Tweed	91171	91171	29925	29925	29925	45801	45801	45801	118164	118164	38885	38885	38885	59460	59460	59460
Scotland	225202	102484	93071	92715	124429	360098	216204	189344	274984	124218	115078	118380	153555	435281	262328	232003
North Eastern	ND	ND	ND	ND	ND	ND	ND	313	ND	ND	ND	ND	ND	ND	ND	313
Neagh Bann	217300	266500	156342	219871	211231	154635	168722	230875	650300	700500	571342	595871	604231	518635	473722	544875

Table D2. Updated best estimates of anthropogenic mortality rates across England, Wales, Scotland and Northern Ireland RBDs during 2009–2016. Note that minor differences in A versus F+H are due to rounding to two decimal places. ND means "No Data", where there are insufficient data to estimate a derived parameter; NP means "Not pertinent", where no fishery has been authorised in that year.

RBD code	ΣF								ΣH								ΣA							
	2009	2010	2011	2012	2013	2014	2015	2016	2009	2010	2011	2012	2013	2014	2015	2016	2009	2010	2011	2012	2013	2014	2015	2016
Northumbria	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40	0.76	0.76	0.76	0.72	0.72	0.72	0.40	0.40	0.76	0.76	0.76	0.72	0.72	0.72
Humber	0.01	0.06	0.06	0.06	0.05	0.01	0.12	0.01	1.22	1.27	1.12	1.12	1.11	1.84	2.06	1.84	1.23	1.33	1.18	1.18	1.16	1.85	2.18	1.85
Anglian	0.05	0.07	0.15	0.15	0.09	0.14	0.13	0.18	0.48	0.49	0.52	0.52	0.50	0.51	0.51	0.52	0.53	0.57	0.67	0.67	0.60	0.65	0.64	0.70
Thames	0.05	0.05	0.07	0.02	0.04	0.12	0.09	0.08	1.09	1.09	1.12	1.08	1.10	1.39	1.36	1.35	1.13	1.15	1.19	1.10	1.15	1.50	1.45	1.43
South East	0.10	0.02	0.04	0.04	0.04	0.02	0.28	0.02	0.34	0.33	0.36	0.36	0.36	0.29	0.34	0.29	0.45	0.35	0.40	0.41	0.40	0.31	0.61	0.31
South West	0.23	0.65	1.57	1.71	2.49	3.61	1.84	2.66	0.35	0.29	0.22	0.22	0.16	0.12	0.24	0.23	0.59	0.94	1.79	1.93	2.64	3.73	2.08	2.89
Severn	0.04	0.20	0.60	0.63	1.19	1.56	0.56	0.80	0.57	0.53	0.45	0.44	0.33	0.27	0.45	0.40	0.61	0.73	1.05	1.07	1.53	1.83	1.01	1.20
Western Wales	0.00	0.02	0.02	0.02	0.07	0.05	0.00	0.11	0.31	0.31	0.25	0.25	0.24	0.19	0.20	0.20	0.31	0.33	0.27	0.28	0.31	0.25	0.20	0.30
Dee	0.00	0.01	0.06	0.04	0.04	0.02	0.05	0.02	0.49	0.49	0.48	0.48	0.47	0.51	0.50	0.50	0.49	0.50	0.54	0.52	0.51	0.53	0.55	0.52
North West	0.03	0.05	0.73	0.67	0.59	0.26	0.25	0.18	0.43	0.43	0.94	1.24	0.88	0.54	0.54	0.56	0.47	0.48	1.67	1.92	1.48	0.80	0.79	0.74
Solway Tweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Scotland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.19	0.21	0.24	0.21	0.19	0.19	0.20	0.20	0.19	0.21	0.24	0.21	0.19	0.19	0.20
North Eastern	ND	ND	ND	ND	ND	ND	ND	0.00	ND	ND	ND	ND	ND	ND	ND	0.00	ND	ND	ND	ND	ND	ND	ND	0.00
Neagh Bann	1.10	0.97	1.30	1.00	1.05	1.21	1.03	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.10	0.97	1.30	1.00	1.05	1.21	1.03	0.86