The Thames European Eel Project Report




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Acknowledgements

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The Impact of COVID-19 on The Thames European Eel Project

The World Health Organization declared the outbreak of COVID-19 a pandemic on the 11 March 2020 just as ZSL staff were finalising the details of the 2020 eel monitoring training programme. The subsequent lockdown meant that we were unable to recruit and train citizen scientists in 2020. Monitoring of the eel migration was restricted to one site, Thames - Molesey Lock and many of the other elements of the TEEP were delayed or cancelled. We have added 2020 catch data, The results of our study on yellow eel in the Thames and other recent updates to the project in this report. In 2021 we will be back with updated training and volunteering protocols and look forward to working with project partners back out on our rivers.

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Executive Summary

- The numbers of glass eels arriving each year, termed glass eel recruitment, has decreased by over 90% in the North Sea compared to the 1960-1979 average (ICES, 2019). In 2008, the International Union for the Conservation of Nature (IUCN) classified the European eel as Critically Endangered.

- In response to this reported decline, in 2005, ZSL established a monitoring project to determine the recruitment of elvers (juvenile eels) into the River Thames Catchment and found a similar reduction. The study established that there were up to 99% fewer eels arriving than in the 1980's into the River Darent catchment.

- In 2011 the project expanded, incorporating citizen science, to become the largest elver monitoring scheme within a single catchment in the UK. 18 sites have now been monitored for more than 3 years. This has only been possible through collaboration with local partners, and the recruitment and training of citizen scientists.

- The goals of the TEEP are to monitor recruitment of the European eel into the Thames River Basin District (RBD), to identify barriers to upstream migrating eel and to build capacity for delivery of conservation impact for eel.

- The monitoring data and subsequent barrier investigations have enabled an evidence-based assessment to inform management measures and prioritise barrier mitigation action, such as eel passes. Barriers to migration are identified as one of the major threats to eel populations in the Thames RBD.

- This report summarises key findings from the monitoring data collected from 2005 to 2020.

- Catch per unit effort (CPUE) was calculated for each trap (number of elver caught per day) to assess changes in elver recruitment. The CPUE shows high variability, with large annual fluctuations and differences observed between sites.

- With five or more years of data for multiple sites, it is now possible to identify trends in the annual CPUE. At sites where trapping methodology and downstream barrier conditions remain unchanged, these patterns reflect what is being seen across Europe.

- Data from sites where eel passes have been installed downstream provides evidence of the impact of conservation work for eel in the region.

- In 2020, new installations include updating the eel passes at Lea Bridge Sluice (TQ 35644 86568) from a pumped pass to a more reliable gravity system. Over the duration of the project, ZSL and partners have installed eel passes which have improved access to an additional 138.95 hectares of habitat in the Thames RBD.

- To date, 981 volunteers and 22 partner organisations have been involved with the project. Multiple educational and outreach benefits have resulted through the training and empowerment of large numbers of individuals and organisations.

- This project is an example of the numerous benefits citizen science initiatives can provide for freshwater conservation. The TEEP demonstrates that continued two-way communication between conservation practitioners and volunteers can sustain volunteer engagement to provide cost-effective, reliable and robust data that can be used to guide environmental management decisions.

Contents

1. Introduction

1.1. Background

The European eel, *Anguilla anguilla* (L.), has been listed as 'Critically Endangered' on the IUCN Red List since 2008 due to dramatic declines in abundance recorded across all stages of its life cycle and much of its natural range (IUCN, 2014). In 2007, the European Commission Regulation (EC no. 1100/2007; EC 2007) *'Establishing measures for the recovery of the stock of European eel'*, was enacted. This requires Member States, with habitat supporting the European eel, to develop mandatory Eel Management Plans for their river basin districts (RBD). In addition to this, the European eel is included within Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and Appendix II of the Convention on Migratory Species (CMS).

The stages of the European eel life cycle are shown in Figure 1. Juvenile eels arrive on the coast as glass eels having drifted on ocean currents as leptocephali from the Sargasso Sea. The glass eels then pigment to become elvers during the early stages of their upstream migration. The nature of freshwater eel movements are non-linear, with their upstream migration into freshwater systems as glass eels being complex and poorly documented. Some individuals have been known to colonise the first suitable habitat they arrive at, while others may migrate to the upper boundaries of freshwater systems. Individuals may settle in an established area for several months or years but, have also been found to perform upstream shifts as they search for more suitable areas to forage or settle. These varied behaviours are not mutually exclusive with eels shifting from one behaviour to another depending on a variety of ontogenetic attributes such as age, experience, morphology and physiological state (Feunteun et al., 2003). During their growth lifecycle stage they develop into yellow eels before metamorphosing into silver eels prior to commencing their migration back to the Sargasso Sea where they breed.

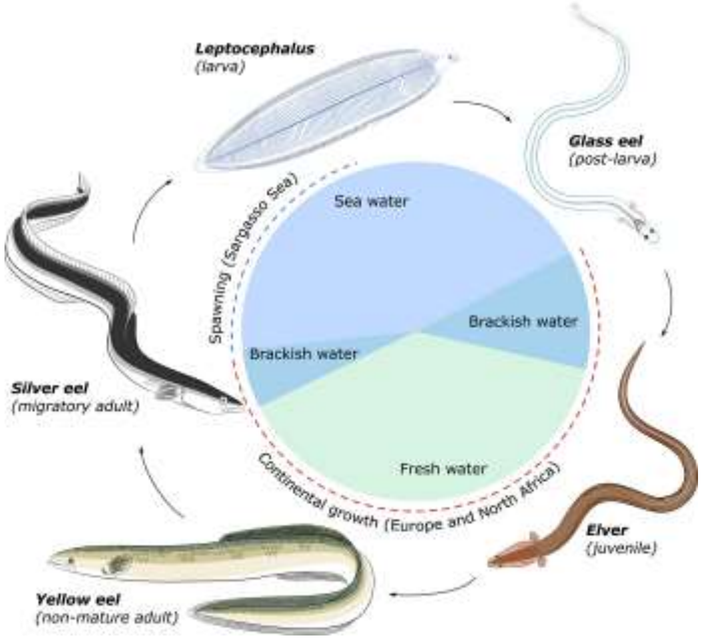


Figure 1: The life cycle of the European eel (Cresci, 2020).

The Working Group on Eels (WGEEL); which is a partnership of the European Inland Fisheries and Aquaculture Advisory Commission, International Council for the Exploration of the Sea and General Fisheries Commission for the Mediterranean (EIFAAC/ICES/GFCM), collates data from the monitoring of European eel populations across Europe and provides advice to support development and implementation of EC Regulation No. 1100/2007 for eel stock recovery. Whilst the recruitment levels have remained extremely low compared to the 1960's, from 2012 to 2014 an increase was observed, peaking in 2014 (Figure 2). This period saw recruitment in the North Sea increase to 3.3% of the 1960-1979 level from what had been less than 1%; and elsewhere in Europe saw an increase to 14.6% (ICES, 2014). Since 2014 however, recruitment levels have again been declining with the annual recruitment of glass eels across the North Sea in 2019 at just 1.4% of the 1960-1979 level (provisional). This is a further decline from the 1.6% level recorded in 2017; despite an increase from 2017-2018 to 1.9% of the 1960-1979 level. Such levels are below safe biological limits and therefore the population status of the European eel remains critical (ICES, 2016 & ICES, 2017).

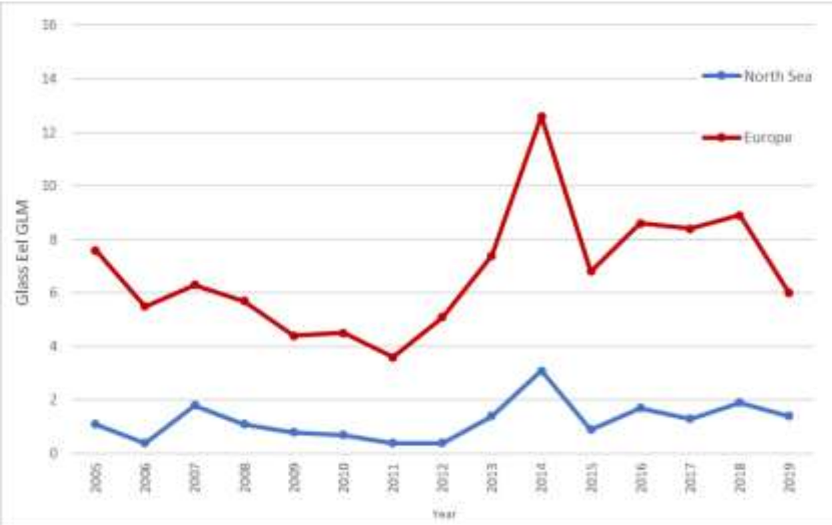


Figure 2: Glass eel recruitment indices for the European eel in the continental North Sea and 'elsewhere in Europe' from 2005 to 2019. (The data were taken from the 2019 ICES stock advice. Glass eel recruitment was predicted as a function of area, year and site giving the geometric means of estimated recruitment (GLM). This was fitted to 43 time-series', comprised of either a combination of glass eels and yellow eels or purely glass eels and was then scaled to the 1960–1979 geometric mean (ICES, 2019).

Several anthropogenic, oceanic and climatic factors have been identified as potential causes of the recorded decline in recruitment. They include the loss of habitat, pollution, barriers to migration, hydropower, and exploitation from commercial and recreational fishing (Feunteun, 2002; Dekker, 2003; Chadwick *et al.,* 2007). These pressures impact all life stages of the eel; affecting glass eel and elver survival and limiting silver eel escapement (Winter *et al.,* 2006; Piper *et al.,* 2012). Some studies have shown oceanic and climate variability impact the transport of larvae and recruitment of glass eels (Bonhommeau *et al.,* 2008; Baltazar-Soares *et al.,* 2014). These factors in-combination are likely to be responsible for the decline in eel recruitment in the UK (Jacoby *et al*., 2015).

1.2. Eels in the Thames

The Thames RBD comprises 11% of the freshwater and lake habitat in England and Wales (EA, 2010). As a result, it has historically provided an important area of habitat for the growth stage of the European eel, supporting large population stocks (Wheeler, 1979; Naismith and Knights, 1988). However, South East England is a highly developed and densely populated area, with a long history of heavily engineered waterways. Barriers to migration, in the form of flood defences and weir construction, have been identified as a major threat to eel migration (DEFRA, 2010). There are 2,412 structures which are potential barriers to upstream migration within the Thames RBD (Clifton-Dey, D., pers. comm., 2016). It is likely these structures prevent access to suitable habitat by blocking upstream migration, leading to patchy distribution and reduced eel production in the Thames RBD compared to historical records.

1.3. ZSL Monitoring Programme

ZSL began monitoring upstream elver migration in the Thames tributaries in 2005 to compare levels of elver recruitment against levels in the 1980s. The focus of the monitoring between 2005 and 2011 was at three sites on the Rivers Darent, Roding and Mole. Traps are placed at river barriers and upstream eel movement is monitored from April to October, during the elver migration season. Long term datasets from these sites have provided an insight into the decline of the European eel, identifying a 99% decrease in elver recruitment in the Darent Catchment compared to the 1980s (Gollock *et al.,* 2011). Monitoring sites on the Rivers Mole and Darent were closed in 2017 due to eel pass installations on the former and the removal of the barrier, where monitoring took place, on the latter. Monitoring on the Roding continues (although interrupted by Covid-19 in 2020) and data from the site are sent annually, via the Environment Agency, to the WGEEL. These are used, as supplementary evidence, along with other datasets to inform eel stock management advice from the WGEEL.

Since 2011, the scope of the Thames European Eel Project increased through the development of citizen science. Volunteers and the support from 22 partnership organisations have enabled monitoring of the upstream eel migration at 18 sites for a minimum of three years and five sites for less than three years, between 2011 and 2020, (Figure 3). ZSL provide training, monitoring equipment and some of the traps. Licenses and some traps have been supplied by the Environment Agency. The South East Rivers Trust (SERT), National Trust and the Thames Rivers Trust have also provided monitoring traps used within the project.

2. Method

2.1. Trap Locations

Molesey Weir was the only site that could be monitored in 2020 and is shown below in Figure 3. Molesey Weir was part of the nine sites monitored in 2019, indicated in Figure 3, along with all other sites monitored for ≥ 3 years. Previous monitoring for less than three years, has been conducted on the Rivers Ember- Island Barn Sluice, Chess-Chenies Bottom Weir, Loose- Allnutt Mill and Lea- Three Mills River and Prescott Channel. Through a close working relationship with the Environment Agency chaired Eel Management Plan Implementation Group (EMPIG), ZSL take every opportunity to monitor new passes built in the region. Monitoring can only happen, however, where partnership groups are available to monitor traps and access to the site is safe.

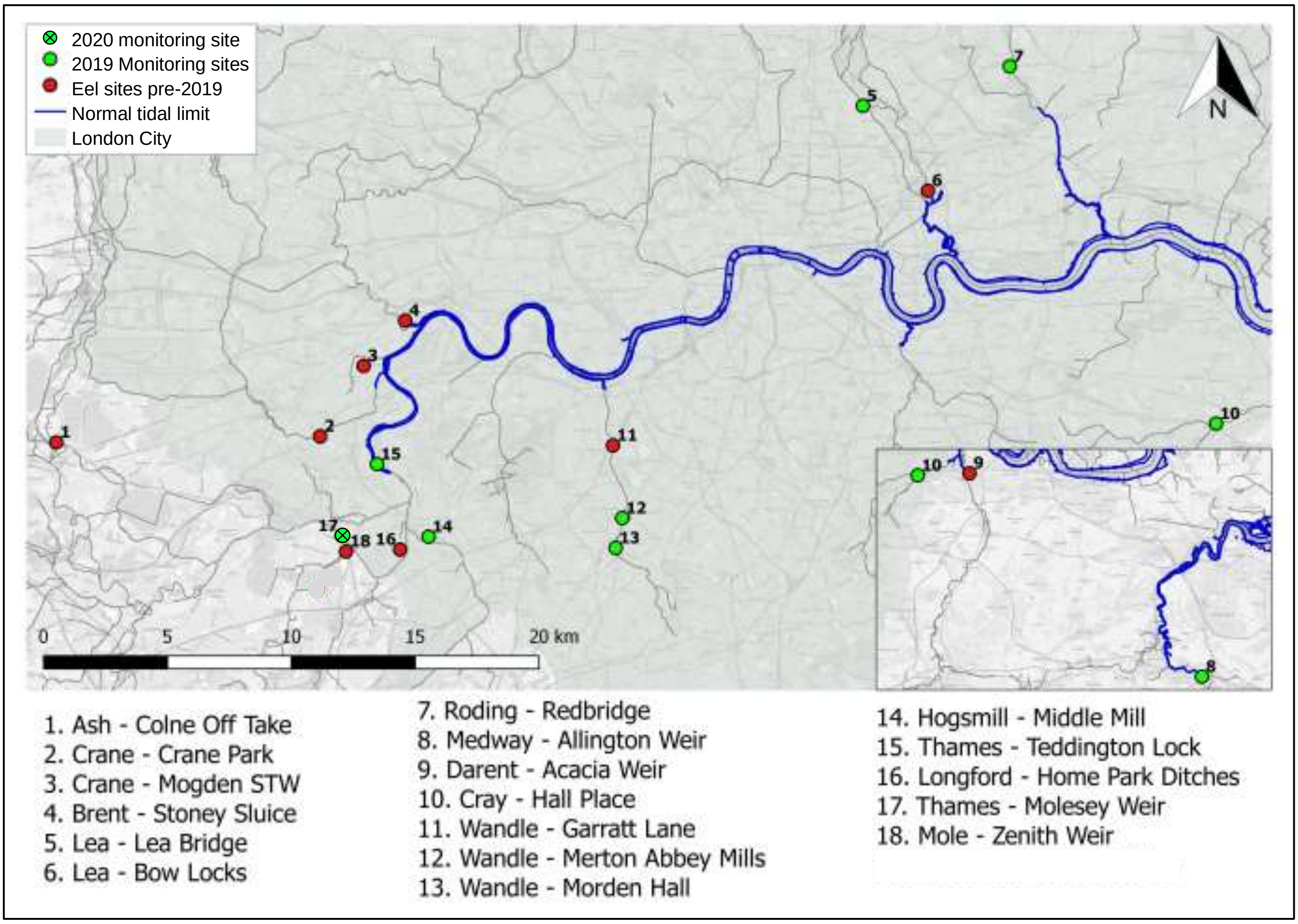


Figure 3: Locations of the monitoring sites, that have been monitored for ≥ 3 years, within the Thames RBD, 2005 to 2020. Map created using QGIS©

2.2. Site Selection

Selecting sites within the Thames RBD for eel monitoring has been governed by several factors. These include:

- A need to understand the spatial and temporal pattern and distribution of eel migration throughout the Thames RBD.
- Choosing sites lower down in a river system closer to the tidal confluence since these provide a better and more immediate indication of eel recruitment within any year.
- Practical considerations, such as where both partnership organisations and volunteers are available to monitor, and sites where there is safe access to an eel pass.

The aim is to have a minimum of three years data collected from each site. Exceptions to this are our 'index sites', Roding- Redbridge, Medway- Allington Lock and Thames- Molesey Weir, where the development of a data time series in being produced to inform on long-term recruitment trends. Where the volunteers are willing, monitoring beyond three years at citizen scientist sites is encouraged as longer-term data sets have more value in showing trends in upstream freshwater eel migration

2.3. Trap Design

Traps are installed at barriers within rivers which impede upstream eel migration. This is a straightforward approach to monitoring glass eel and elver migration as they congregate while attempting to find an upstream passage (Harrison *et al.,* 2014). The basic trap design, as developed by Naismith and Knights (1988), and used for 15 years at the River Roding is shown in Figure 4. The water flowing down a media filled trough from the water pipe attracts eels, encouraging them to climb up the trough and into the holding tank that provides a safe refuge for them away from direct sunlight (EA, 2011a; Piper *et al.,* 2012). While based on the same design principles, the traps at each site now differ, examples of more recently used traps are shown in Figure 5. Pumped traps (as shown in Figure 5) have been used as part of this project but they are costly to maintain, with pumps regularly clogging with river debris and breaking, so we do not advocate their use. In the future we will be making every effort to seek alternatives to the use of pumps where possible.

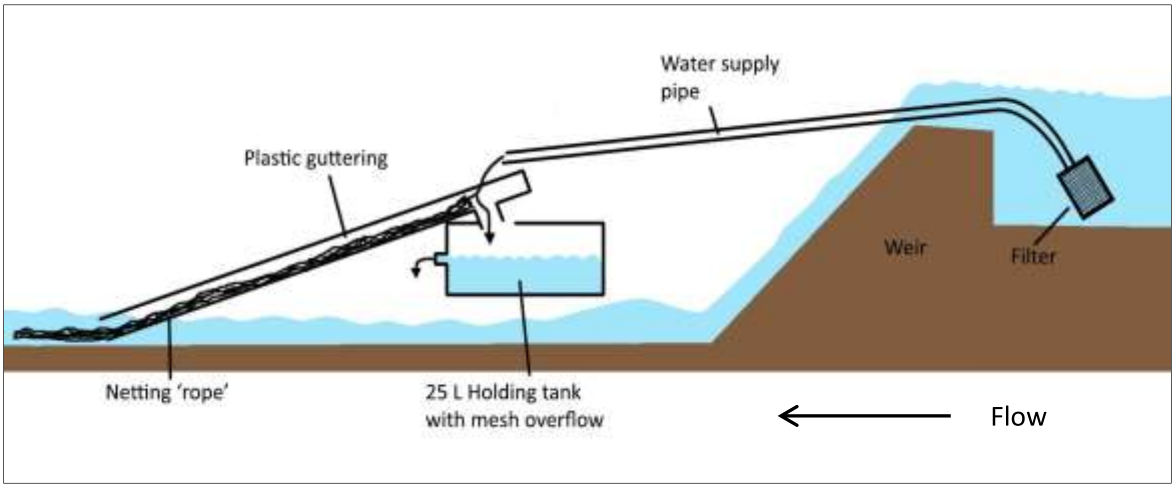


Figure 4: Schematic of the basic trap design used on the River Roding.

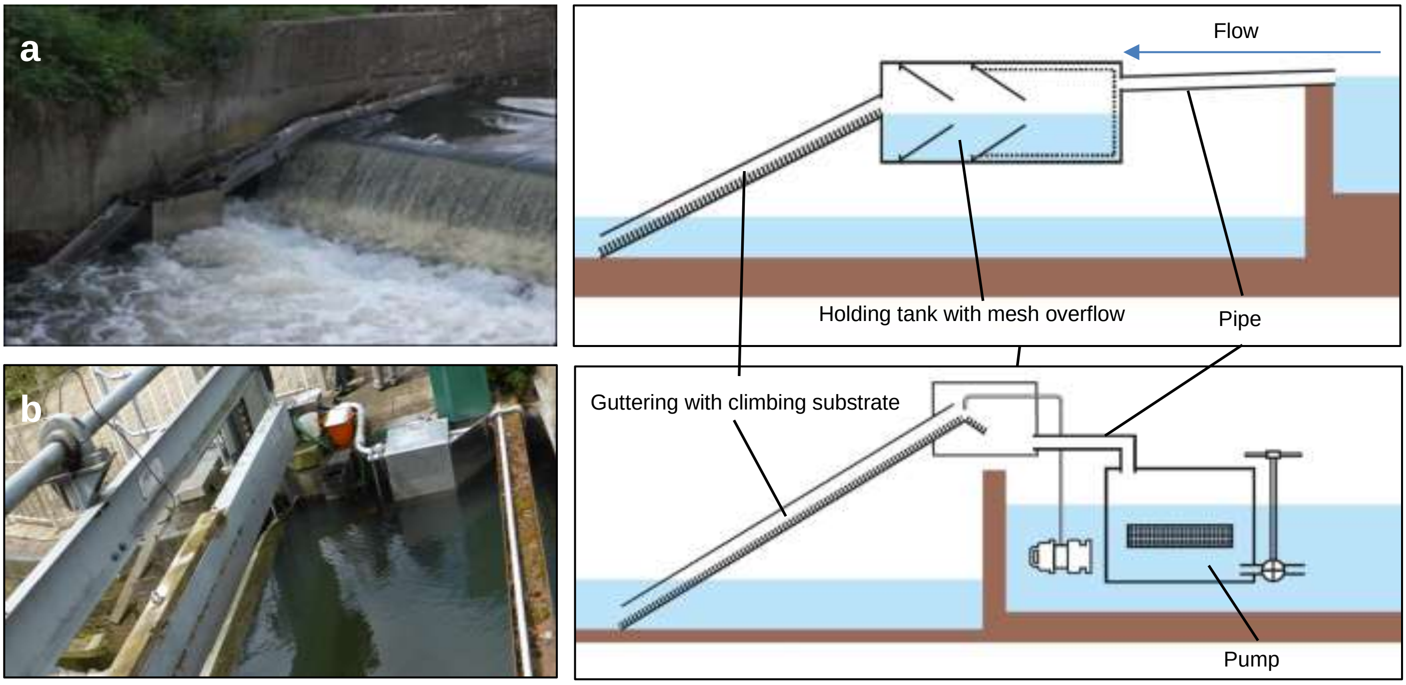


Figure 5: Photos and schematics of two different types of traps used for monitoring by citizen scientists. (a) a gravity supplied trap at Hogsmill-Middle Mill, and (b) a pumped trap at Brent- Stoney Sluice.

As a result of the differences in trap design, the trapping performance will also differ, and therefore direct comparisons of catches between sites should only be made with an understanding of the performance of the traps used. Table 1 gives a broad assessment of the performance of the traps used in the monitoring project. Trap performance provides an indication of the proportion of the total number of eels moving upstream at the trapping site that might be caught by each trap. Those traps with a high-performance rating are assumed to be trapping a higher proportion of passing eels compared to medium or low performing traps. It is used as a guide only to inform analysis of the catch data.

Trap performance varies according to:

- The presence or absence of a bypass channel around the trap. Performance decreases with the presence of a bypass route that avoids the trap.
- The wider the river channel that the trap is positioned on, the lower the performance rating.
- The more impassable the barrier that the trap is positioned downstream of, the greater the performance of trapping.

Table 1: The Performance rating of the eel traps used in the project for ≥ 3 years.

Site	Efficiency rating
Ash- Colne Off Take	Medium
Brent- Stoney Sluice	High
Crane- Crane Park Island	Low
Crane- Mogden STW	Medium
Cray- Hall Place	Medium
Darent- Acacia Weir	Medium
Hogsmill- Middle Mill	Medium
Lea- Bow Locks	Low
Lea- Lea Bridge	High
Longford- Home Park	High
Medway- Allington Lock	Medium
Mole- Zenith	Low
Roding- Redbridge	Low
Thames- Molesey Weir	Low
Thames- Teddington Lock	Low
Wandle- Merton Abbey Mills	High
Wandle- Morden Hall	High
Wandle- Garratt Lane	Low

2.4. Citizen Scientist Training and Monitoring

Due to COVID-19 citizen science training and monitoring was unable to take place in 2020. The process usually takes place in the following format: All citizen scientists are inducted onto the project via a two-hour training session. Training includes: an introduction into eel biology with an overview of possible causes of eel population decline, the purpose and outputs of survey work, methods of checking the trap and measuring eels, and a demonstration of how to use the online portal for data submission. Volunteers are shown how to capture, process and release eels at a trap. All volunteers on the project undertake a classroom-based health and safety briefing and must also read and sign risk assessments prepared for each site. In 2019, these training sessions were attended by 114 volunteers, taking the cumulative total of volunteers trained to 981 since the project launch in 2011. Each trap site has a lead coordinator or coordinating partnership organisation.

Trapping starts in early April and stops by the last day of September. This period covers the peak time of upstream eel movement in the Thames RBD. Increasing water temperatures stimulates upstream eel migration. A threshold for enhanced migratory behaviour peaks at 14-16°C, no or little migration occurs beneath 10-11°C (White and Knights, 1997). Traps are inspected at least twice per week during the monitoring period. The frequency of trap inspections ensures elvers are never held in the traps for longer than four days. At some sites, where catches become greater than 100 eels per day, the frequency of inspections is increased and can be completed as often as daily. The length of trapped eels is measured and recorded at all sites (Figure 6). Where more than 50 eels are recorded, a sub-sample of 50 eels are randomly selected and measured to provide a representative sample of all the eels trapped on that occasion. Following measurement, eels are released back into the river, near the bank edge, upstream of the barrier. To avoid volunteers handling large eels, those estimated to be longer than 300mm are released without measuring and recorded on the database as >300mm. Eel trapping is permitted under the Salmon and Freshwater Fisheries Act, 1975, by the Environment Agency.

Figure 6: Trained citizen scientists and ZSL staff collecting and measuring eels.

2.5. Data Processing

Eel counts, eel length measurements, the date of the survey and the citizen scientist's name are uploaded to a database on the ZSL website with restricted access. Here ZSL staff quality check the data and, if necessary, contact citizen scientists to validate any unusual records. Training is provided and a thorough data checking and validation process is embedded in the methodology to ensure the quality of the data, in line with recommendations in Tweddle *et al*., 2012.

Trapping duration at each site varies between years due to occasional trap failure. Trap failure is documented to enable a record of the total number of days the trap is active over the monitoring period, termed the "effort". The total number of eels caught is divided by the total number of successful trapping days in order to calculate the catch per unit effort (CPUE). This accounts for annual variability in trapping effort as a result of trap failure. It is vital that any comparison of catch between years recognises the effort made and therefore a more useful comparison of elver recruitment over time is made using CPUE.

Catch totals and CPUEs for all sites are supplied to the Thames RBD, Eel Management Plan (EMP) annually; eels ≤120mm are recorded and reported separately in line with the EU Eel Regulation (EC no. 1100/2007; EC 2007). The production of graphics and data analysis has been carried out using MS Excel.

3. Results

3.1. 2020 Catch Totals

A total of 62 eels have been recorded in 2020 at Thames-Molesey Weir. The proportion of elver (eels of ≤120mm) to yellow eels showed a reduction from 82.6% in 2019 to 77.4% in 2020.

3.2. CPUE – Catch Per Unit Effort

The annual mean CPUE, 2011 to 2020, for each site is shown in Table 2. CPUE fluctuates between years across most sites and shows high variance from the mean within a single season. The annual CPUE recorded for Thames- Molesey Weir increased in comparison to the previous year from 0.57 in 2019 to 0.61 in 2020 but this is the second lowest CPUE recorded for the site in nine years of monitoring it.

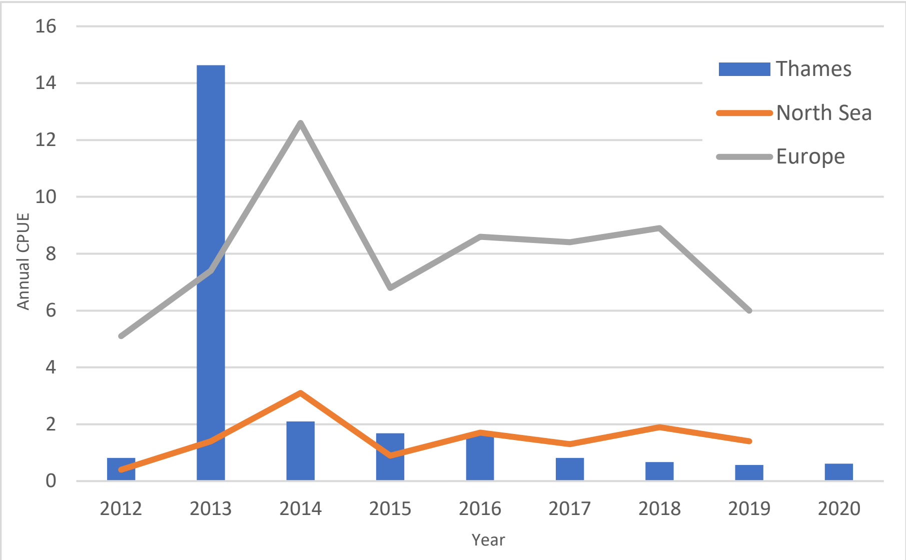
3.2.1 Index sites

The annual mean CPUE from the index sites; sites that have been monitored for five years or more with no alterations to downstream structures, are illustrated in Figure 7. Two sites; Medway- Allington lock and Thames- Molesey weir, saw peaks in CPUE in 2013. After which, CPUE at both sites declined significantly and has since varied year by year.

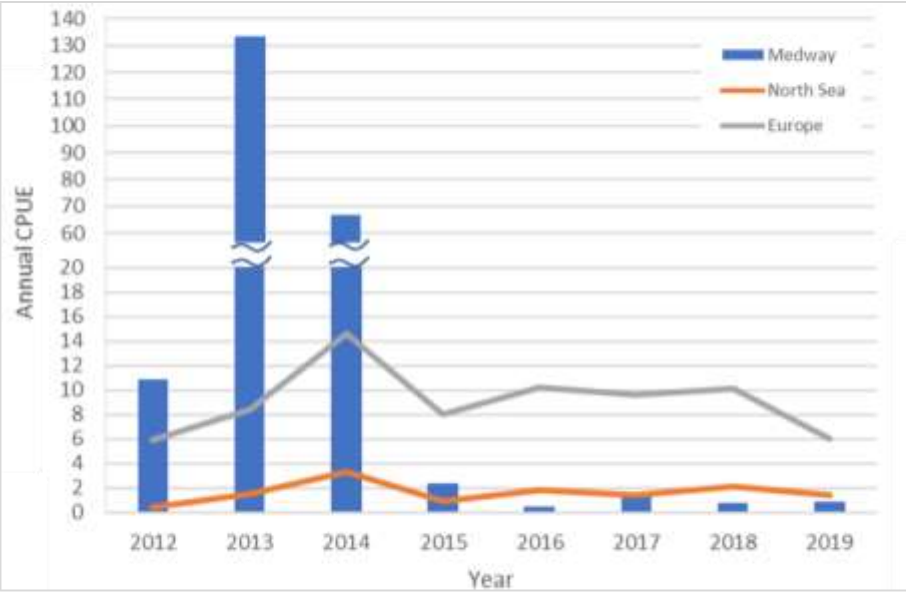
The CPUE data for Roding- Redbridge is displayed from 2005; when monitoring at the site started, to 2019 (Figure 7). In 2019 the CPUE displays a decrease compared to the previous year, in contrast to an increase seen from 2016-2018. 2005 remains the year of highest CPUE at Roding- Redbridge.

Table 2: Annual CPUE (eel day^{-1}) per site.

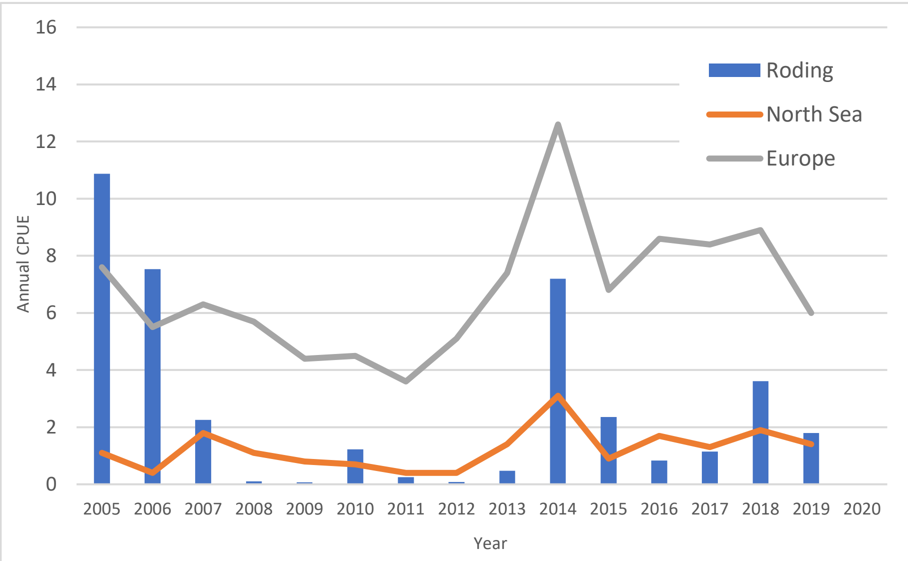
Site	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Ash- Colne Off Take	-	-	-	0.27	0.1	0.1	-	-	-	-
Brent- Stoney Sluice	-	-	15.3	244.31	114.63	88.94	210.29	507.46	-	-
Crane- Crane Park Island	0	0	0	-	-	-	-	-	-	-
Crane- Mogden STW	-	-	-	-	5.96	6.35	3.87	0.93	-	-
Cray- Hall Place	0	0.01	0.04	-	-	-	-	0.11	0.21	-
Darent- Acacia Weir	-	0.16	0.02	1.21	0.08	0.09	-	-	-	-
Ember- Island Barn Sluice	-	-	-	-	-	-	6.81	-	-	-
Hogsmill- Middle Mill	-	0.01	0.04	0.08	0.08	0.18	0.21	0.12	0.21	-
Lea- Bow Locks	-	0.09	1.48	2.98	0.61	0.88	-	-	-	-
Lea- Lea Bridge	-	-	-	-	-	56.57	132.95	98.925	117.46	-
Longford- Home Park	-	-	0.62	2.82	2.53	2.31	-	-	-	-
Medway- Allington Lock	-	10.9	133.3	66.68	2.34	0.48	1.49	0.76	0.87	-
Mole- Zenith Weir	-	1.25	0.09	0.1	0.52	-	-	-	-	-
Roding- Redbridge	-	0.08	0.47	7.2	2.36	0.83	1.15	3.61	1.79	-
Thames- Molesey Weir	-	0.82	14.63	2.1	1.68	1.63	0.82	0.67	0.57	0.61
Thames- Teddington Lock	-	-	-	0.36	0.02	0.25	0.31	0.50	0.06	-
Wandle- Merton Abbey Mills	0	0.97	0.64	2.46	0.5	1.41	11.34	0.79	0.92	-
Wandle- Morden Hall	-	-	-	-	-	-	2.43	1.64	1.29	-



a) Thames- Molesey Weir



b) Medway- Allington Lock



c) Roding- Redbridge

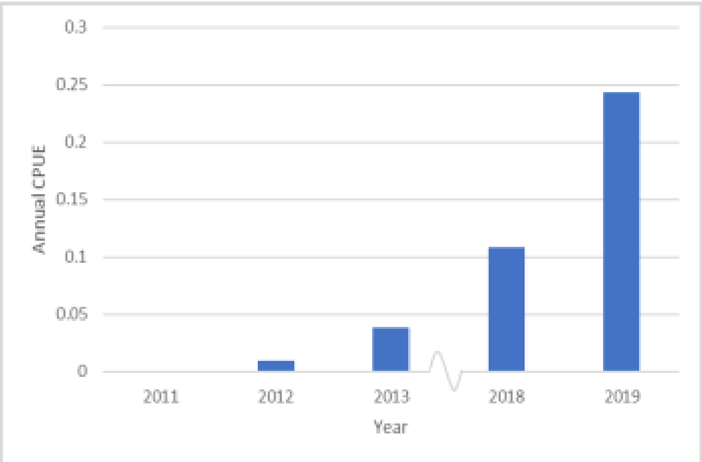
Figure 7: Annual CPUE for Index sites a) Thames- Molesey Weir, b) Medway- Allington Lock, c) Roding- Redbridge since monitoring began in 2005 with ICES recruitment index for North Sea and Europe (ICES, 2019).

3.2.2 Impact of barriers to migration and eel pass installation

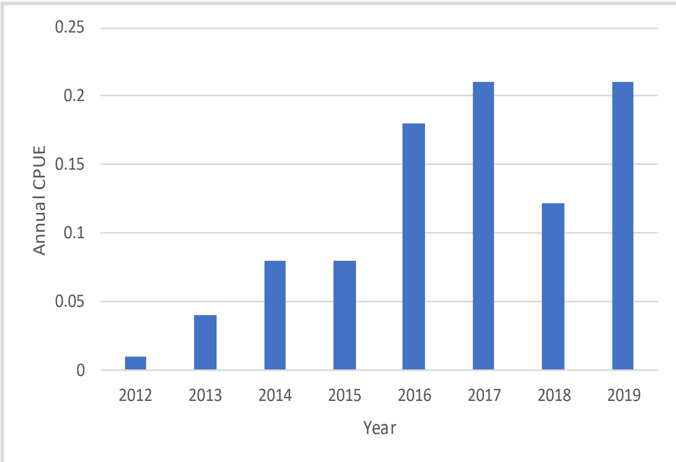
The annual CPUE of sites that have had eel passes installed downstream of the monitoring are shown in Figure 8. Monitoring at Cray- Hall Place started in 2011 but stopped in 2013 having collected three years of data. Monitoring recommenced at Hall Place in 2018 following the installation of an eel pass downstream. The annual CPUE displays a peak in 2019 compared to the previous four years of monitoring.

The River Hogsmill has been monitored since 2012, during this time, two eel passes have been installed downstream of the monitoring site (2013 & 2015). Annual CPUE has continued to rise since 2012, with the exception of 2018, which saw a decline in CPUE.

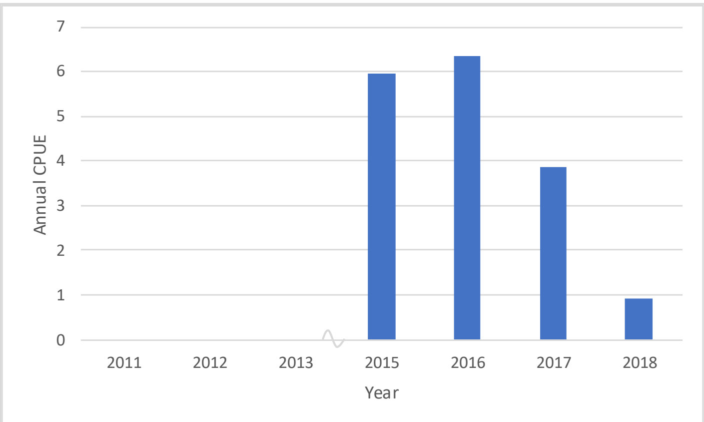
Two sites have been monitored on the River Crane; Crane Park Island (2011-2013) and Mogden STW (2015-2018) (figure 8.c). Zero eels were caught at Crane Park and monitoring ceased in 2013 having collected three years of data. In 2015 monitoring recommenced on the Crane at Mogden STW. Eel catches increased compared to Crane Park 2011-2013 with a peak in 2016, before a decline.



(a) Cray- Hall Place



(b) Hogsmill- Middle Mill

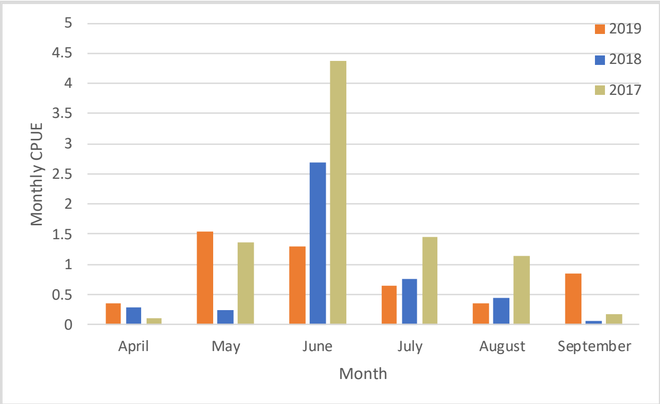


(c) Crane- Crane Park Island (2011-2013)/ Mogden STW (2015-2018)

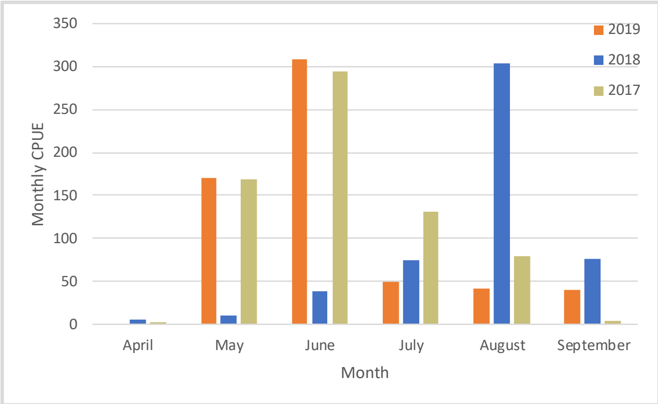
Figure 8. Annual CPUE for (a) Cray- Hall Place, (b) Hogsmill- Middle Mill and (c) Crane- Crane Park Island (2011-2013)/ Mogden STW (2015-2018)

3.2.4 Monthly CPUE .

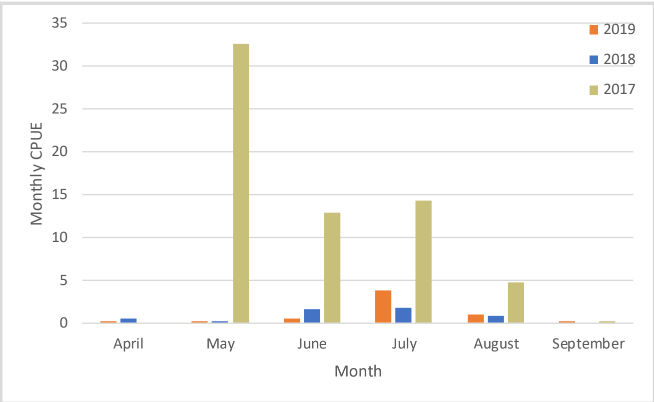
The monthly CPUE for five citizen science monitoring sites, across three years, is shown in Figure 9. All sites shown have been monitored for five or more consecutive years. Brent-Stoney Sluice, which was surveyed up until 2018, displays clear peaks in monthly CPUE during August and September between 2016 to 2018, the highest peak in CPUE presented in August 2018. In comparison, three other sites, Lea- Lea Bridge, Medway- Allington Lock, Thames-Molesey Weir, show a rise in monthly CPUE during mid-season before a decline; with the exception of Medway-Allington lock in 2019 which had a peak in CPUE in May, prior to a decline. Additionally, in 2020, Thames- Molesey Weir showed a peak in CPUE in May at the beginning of the season, after which monthly CPUE declined. Following this CPUE can be seen to rise slightly in August before dropping off at the end of the season. The monthly CPUE at Wandle- Merton Abbey Mills remains low across the years, although a spike in CPUE was shown in 2017.



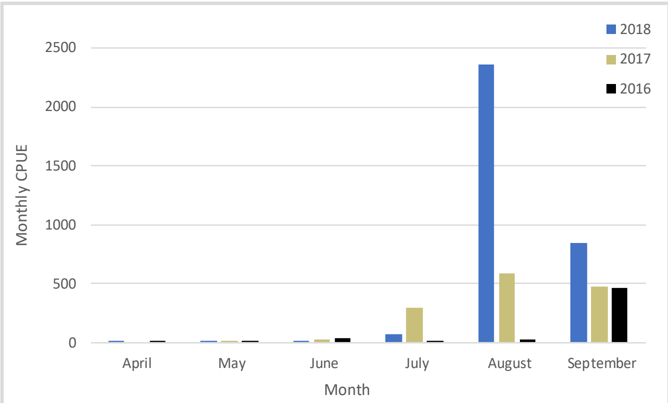
a) Medway- Allington Lock



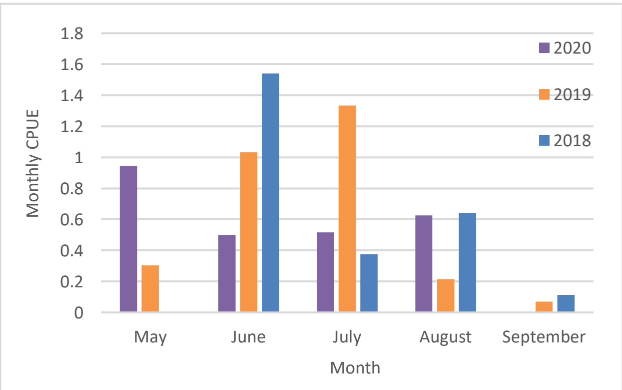
b) Lea- Lea Bridge



c) Wandle- Merton Abbey Mills



d) Brent- Stoney Sluice



e) Thames- Molesey Weir

Figure 9: Monthly CPUE across three years at five citizen science monitoring sites in order of distance from estuary mouth. Brent- Stoney Sluice includes data from 2016-2018 only, as monitoring at this site ceased after 2018.

4. Discussion

4.1. Catch Data

As a consistent methodology for monitoring eel recruitment throughout the Thames RBD has now been in place at the Roding- Redbridge for 15 years, Medway- Allington for eight years and Thames- Molesey for nine years, the data provides a useful source of information on changes in recruitment over time. By having multiple sites, we can also infer recruitment trends into the wider Thames RBD.

Recruitment continues to be low when compared to levels of recruitment recorded prior to the 1980s (ICES, 2017), and most sites show a pattern of recruitment similar to those observed in other catchments in the North Sea (ICES, 2017), and across Europe (Figure 2), where a small peak in recruitment was observed in 2014 (ICES, 2014). Traps on the River Brent- Stoney Sluice, Roding- Redbridge and Wandle- Merton Abbey Mills all experienced an increased CPUE in 2014 compared to the years either side. Medway- Allington Lock and Thames- Molesey Weir had a more prominent peak in 2013, within the three-year time period during which the increase was observed across Europe (Figure 7 & Table 2) (ICES, 2014).

The variability in results between rivers is fascinating, with some tributaries seemingly receiving the bulk of the eel recruitment, whilst others have very few. Knowing whether these are real differences in relative eel numbers travelling up rivers or whether variability is down to differences in trapping performance, is a limitation of the methodology. Trap performance is impacted by a number of factors including: the position of the entrance of the trap ladder in the river and the hydrodynamic conditions at the entrance of the ladder (Piper et al. 2012), the passability of the barrier or presence of bypass channels that eels can use to avoid the trap. For this reason, provided the trapping method is consistent, the data has most value in assessing variations over time at a particular site and only enables conservation mangers to draw broad conclusions about the variation in catch numbers between sites. For a more complete understanding of eel stock ecology in the Thames RBD, citizen science upstream migration monitoring should be accompanied by a suite of other research projects including: monitoring of yellow eel stock and silver eel escapement (the migration of silver eel to the Sargasso Sea to spawn) and acoustic telemetry studies aimed at improving our understanding of eel behaviour in the Thames RBD.

4.2. Timing of the upstream migration

Although the monitoring shows a defined 'monitoring season' there is surprising variation between sites in the timing of peak catches within this (Figure 9). From 2016-2018, Brent- Stoney Sluice displayed a peak in monthly CPUE towards the end of the monitoring season. Comparatively, peaks in catch appear to occur across mid-summer at Medway- Allington Lock, Thames- Molesey Weir and Wandle- Merton Abbey Mills. Examining monthly CPUE helps us to determine patterns in yearly recruitment of elvers between the rivers and associated monitoring sites across London. Knowing when eels are moving upstream is important for conservation managers as the information is used to restrict in-river activities that might otherwise interfere with normal migration, for example percussive piling or dredging, both of which could harm or delay successful fish migration (Kjelland et al. 2015). In addition to knowing when eels are moving, conservation managers need to know the size distribution of eels in rivers.

4.3. Distribution of elvers in the Thames RBD

The large spatial distribution of sites also allows us to see patterns of recruitment within the Thames RBD. The data show a weak negative correlation between percentage of catch recorded as elvers and the distance of the site from the tidal limit (appendix A). The proportion of yellow eel in the catch increases with distance from the tidal limit. There are exceptions to this however, such as Thames- Molesey Weir.

Information on which lifecycle stage makes up the highest percentage of catch within the various river sections of the RBD, is needed to advise regulators on appropriate screen size selection to prevent elvers being killed by abstraction pumps. Entrainment and impingement of eel at abstraction points, cooling water intakes and tidal power plants can be a major cause of eel mortality in some rivers (DEFRA 2010). Under the Eels (England and Wales) Regulations 2009, the Environment Agency has the powers to require that abstractors screens are placed on intakes to prevent harm to eel stocks. Screen designs, approach velocity of the abstracted water, and slot width of the screen are all dependent on the presence and size of the eels in the vicinity, which is determined by either direct monitoring, or inferred presence from other studies.

4.4. Migration Barriers and Passes

Being mindful of differing trapping performance ratings, monitoring data allows for a comparison of catches across sites or, perhaps more importantly, a comparison between actual and expected catch for a site. Low or zero catches at sites may indicate barriers to migration located downstream of monitoring sites. The ideal for eel migration and the wider river ecology is barrier removal, but where this is not feasible the installation of eel passes can help mitigate impacts. Several examples of the positive, localised impact of eel passes have been highlighted by the monitoring data. For instance, Figure 8 shows CPUE from Cray- Hall Place increasing over time following the installation of two eel passes downstream on the Cray: in 2016 the Environment Agency improved eel passage at Crayford Gauging Weir and in 2019 ZSL added a pass to Vitbe Sluice. The River Crane is also an example of this. From 2011 to 2013 the trap monitored at Crane- Crane Park Island (CPI) caught no eels, prompting the installation of two eel passes that allow eels to migrate up into the Crane catchment, via the Duke of Northumberland's River, from the Thames (appendix A). One of these passes, at Crane- Mogden STW, contains a trap and monitoring of this trap (2015 to 2018) recorded the recruitment of eels to the catchment (appendix A). There are no barriers on the River between Crane- Mogden

STW and Crane- CPI. A similar pattern has also been seen at Hogsmill- Middle Mill, where CPUE has shown an increasing trend from 2012, two passes were installed downstream of the Hogsmill monitoring site, one in 2013 and another in 2015.

4.5 Restoring Migration Routes

Restoring habitat connectivity using eel passes is a focus for the TEEP. Since 2005, the project has been using passes with traps to restore migratory pathways. In addition, eel passes have been built without traps, as listed in table 3.

Table 3: Eel passes (without traps) built by the ZSL Thames European Eel Project since 2013.

Year	Site	Location	Funder
2013	River Darent	A24 Road bridge	Esmee Fairbairn Foundation
2014	River Hogsmill	Clattern Bridge	Esmee Fairbairn Foundation & SERT
2015	Duke of Northumberland's River (Crane Catchment)	Kidds Mill	SITA Trust
2015	River Brent	Osterley Weir	SITA Trust & Environment Agency
2016	River Mole	Zenith Weir	SITA Trust
2017	River Roding	Passingford Mill	BT
2018	River Roding	Loughton Gauging Weir	BT
2018	River Mole	Dorking Gauging Weir	European Maritime Fisheries Fund and Disney Conservation Fund
2018	River Mole	Wilderness Weir	European Maritime Fisheries Fund and Uniper
2019	River Cray	Vitbe Sluice	European Maritime Fisheries Fund
2019	River Roding	River Roding	BT
2020	River Lea	Lea Bridge Sluice	Disney Conservation Fund

In 2020, with the help of the Disney Conservation fund, a new pass was built at Lea-Lea Bridge. Table 2 shows that this site recorded high CPUEs in the four years it was monitored. During the monitoring the pump that supplied the pass regularly broke and it became clear that the system was not sustainable. As a result, in 2020 ZSL worked with Canal and Rivers Trust to remove the old pass and install a bigger, more resilient pass that relies on gravity rather than a pump to allow eels to pass this important site in the Lea catchment.

Figure 10. The gravity eel pass at Lea-Lea Bridge under construction in July 2020

To date, the cumulative total of eel habitat made accessible by both the project's monitoring sites, and the eel passes is calculated to be 138.95 ha. DEFRA's eel population model estimates that 5.88 kg silver eel biomass, escapes from each hectare of habitat in the Thames RBD (DEFRA, 2015). This means that as a result of this project a further 817.03kg of silver eels are expected to escape to the Sargasso Sea per year.

4.6. Partnership Support

A key objective of the project is to support our partnership organisations in taking measures that contribute to the conservation of the European eel. ZSL do this by offering technical advice on improving eel passage, highlighting funding opportunities, supporting funding bids and assisting with eel pass and easement installations.

In 2018, ZSL produced a field guide for assessing the passability of man-made river structures by European eels entitled the Eel Barrier Assessment Tool (EBAT). This step-by-step guide has been designed for use by NGOs, consultants and regulators to aid in determining structure passability. The user can record the basic parameters of a structure and its bankside environment to produce a course assessment to help influence and prioritize future pass installations to notable barriers. Assessing the passability of structures is important so that barriers to migration can be eliminated and conservation benefits maximised.

Access to EBAT is available through the ZSL website:

http://www.zsl.org/eels

4.7. Thames Yellow Eel Study

In 2019, with the assistance of the Environment Agency and funding from the European Maritime Fisheries Fund (EMFF), ZSL carried out a fyke-netting study of yellow eels in the River Thames. The study aimed to generate a better understanding of yellow eel populations in the Thames and develop a robust methodology that could be replicated in future studies.

Over the course of the study, a total of 61 eels were recorded – 43 in June, 15 in August, and 3 in November. The average CPUE across all sites for 2019 was 0.29 eels/cod end/night. CPUE was found to decline with increasing distance from the estuary, with no eels being recorded at a study site located ~54km from the tidal limit at Teddington. In regard to eel length vs distance from tidal limit, the study found a general trend of increasing average length with increasing distance from the tidal limit for both 2011 and 2019, at sites where eels were recorded.

These data have been compared to previous Thames fyke-netting data through measuring relative eel abundance, based on CPUE. The repetition of this study and the subsequent data gathered will be a useful tool in monitoring the impact of the various management measures that have been implemented to improve eel population in the Thames since 2009.

4.8. Project Plans for 2021

Due to high annual CPUEs on the Rivers Lea and Brent, (Table 2) these rivers remain a priority for the TEEP. In 2021 our aim is to work with The Canal and River Trust to upgrade the currently broken eel pass at Stoney Sluice.

We also plan to link the TEEP with the ambitious work the Environment Agency is planning to carry out as part of its Fish Pass Project on the River Wey. The aim remains to integrate citizen science eel monitoring at a site on the River Wey, close to the confluence with the Thames, but the timescale for installation of the new passes is unclear.

We will also continue to work with partners, such as Thames Estuary Partnership's Fish Migration Roadmap project and the Environment Agency led, River Obstacles team to fill the gaps in our knowledge of where barriers to eel migration are in the Thames RBD (and across the UK).

In 2019 ZSL convened a meeting with Environment Agency Fisheries staff, Kent Wildlife Trust, Medway Swale Estuary Partnership and the Medway Valley Countryside Partnership to discuss a possible collaborative project for eel in Kent. A priority project has emerged to use 'mop head' monitoring to gather evidence on the impact of tidal control devices on eel migration in the Thames Estuary. ZSL will continue to support the development of this project.

4.9. Project Impact and Citizen Science Engagement

The project has been a success thanks to the significant commitment of partnership organisations and volunteer citizen scientists. Some volunteers and organisations have remained engaged with the project over eight years, allowing consistent monitoring data to be collected across a large area. To date, 22 partner organisations and 981 volunteers have been involved within the programme, representing the significant capacity of the project to raise awareness and deeper public understanding of the issues facing the European eel in the Thames RBD.

One factor that has contributed to continued participation of citizen scientists has been a sustained two-way communication between conservation practitioners and volunteers. The project officer has remained readily available and responsive to project partners and citizen scientists. At the end of each migration season, all citizen science volunteers involved in the eel project and our other citizen science projects are invited to the 'Citizen Science Forum'. The forum gives ZSL an opportunity to thank volunteers, provide feedback on the outputs of the projects and also encourages a free-flow exchange of information and ideas between citizen scientists and the invited expert speakers.

The sustained high level of engagement of project participants has enabled the programme to develop into the largest single catchment study of elver migration within the UK. The project demonstrates that citizen scientists provide a cost-effective contribution to freshwater conservation at a catchment scale and produce a reliable source of data to advise regional, national and international conservation management.

It is important to recognise that the European eel status still remains 'critical' (ICES, 2017). Eels have a long generation period so the impacts of recent conservation efforts across Europe are unlikely to be observed for at least several years and up to a decade (ICES, 2014). The continuation of elver recruitment monitoring to assess longer term recruitment trends is considered to be of high importance.

For full details of barrier assessment reports and future projects please contact ZSL.

References

Baltazar-Soares, M., Biastoch, A., Harrod, C., Hanel, R., Marohn, L., Prigge, E., Evans, D., Bodles, K., Behrens, E., Bohning, C. W. & Eizaguirre, C. (2014). Recruitment collapse and population structure of the European eel shaped by local ocean current dynamics. *Current Biology*, 24, 104-108.

Bonhommeau, S., Chassot, E., Planque, B., Rivot, E., Knap, A. H. & Le Pape, O. (2008). Impact of climate on eel populations of the Northern Hemisphere. *Marine Ecology Progress Series*, 373, 71-80.

Chadwick, S., Knights, B., Thorley, J. L. & Bark, A. (2007). A long-term study of population characteristics and downstream migrations of the European eel *Anguilla anguilla* (L.) and the effects of a migration barrier in the Girnock Burn, north-east Scotland. *Journal of Fish Biology*, 70, 1535-1553.

Cresci, A. (2020). A comprehensive hypothesis on the migration of European glass eels (Anguilla anguilla). Biological Reviews.

DEFRA (2010). Eel Management Plans for the United Kingdom: Thames River Basin District. [Online] Available: http://archive.defra.gov.uk/foodfarm/fisheries/documents/fisheries/emp/thames.pdf

DEFRA (2015). Report to the European Commission in line with Article 9 of the Eel Regulation 1100/2007 Implementation of UK Eel Management Plans, London, UK.

Dekker, W. (2003). Did lack of spawners cause the collapse of the European eel, *Anguilla anguilla*? *Fisheries Management and Ecology*, 10, 365-376.

Environment Agency (EA) (2010). Eel Management Plans for the United Kingdom: Thames River Basin District. Environment agency, Bristol, UK.

Environment Agency (EA) (2011a). Monitoring elver and eel populations. The Eel Manual-GEHO0211BTMY-E-E. Environment Agency, Bristol, UK.

Feunteun, E. (2002). Management and restoration of European eel population (*Anguilla anguilla*): An impossible bargain. *Ecological Engineering*, 18, 575-591.

Feunteun, E., Laffaille, P., Robinet, T., Briand, C., Baisez, A., Olivier, J. M., & Acou, A. (2003). A review of upstream migration and movements in inland waters by anguillid eels: toward a general theory. In Eel biology (pp. 191-213). Springer, Tokyo.

Gollock, M., Curnick, D. & Debney, A. (2011). Recent recruitment trends of juvenile eels in tributaries of the River Thames. *Hydrobiologia*, 672, 33-37.

Harrison, A. J., Walker, A. M., Pinder, A. C., Briand, C. & Aprahamian, M. W. (2014). A review of glass eel migratory behaviour, sampling techniques and abundance estimates in estuaries: implications for assessing recruitment, local production and exploitation. *Reviews in Fish Biology and Fisheries*, 24, 967-983.

Henderson, P. A., Plenty, S. J., Newton, L. C. & Bird, D. J. (2012). Evidence for a population collapse of European eel (*Anguilla anguilla*) in the Bristol Channel. *Journal of the Marine Biological Association of the UK*, 92, 843-85.

ICES advice for 2015 (2014). Widely distributed and migratory stocks: European eel.

ICES stock advice (2016). European eel (Anguilla anguilla) throughout its natural range.

ICES stock advice (2017). European eel (Anguilla anguilla) throughout its natural range.

ICES stock advice (2019). European eel (Anguilla anguilla) throughout its natural range.

IUCN (2014). IUCN Red List of Threatened Species. Version 2014.3. <www.iucn.org>. Downloaded on 14th January 2015.

Jacoby, D. M. P., Casselman, J. M., Crook, V., DeLucia, M., Ahn, H., Kaifu, K., Kurwie, T., Sasal, P., Silfvergrip, A. M. C., Smith, K. G., Uchida, K., Walker, A. M. & Gollock, M. J. (2015). Synergistic patterns of threat and the challenges facing global anguillid eel conservation. *Global Ecology and Conservation*, 4, 321-333.

Kjelland, M.E., Woodley, C.M., Swannack, T.M. et al..2015. A review of the potential effects of suspended sediment on fishes: potential dredging-related physiological, behavioral, and transgenerational implications, Environment Systems and Decisions 35: 334-350.

Maes, G. & Volckaert, F. (2007). Challenges for genetic research in European eel management. *Ices Journal of Marine Science*, 64, 1463-1471.

Naismith, I. A. & Knights, B. (1988). Migrations of elver and juvenile European eels, *Anguilla anguilla* L., in the River Thames. *Journal of Fish Biology*, 33 (Supplement A), 166-175.

Piper, A. T., Wright, R. M. & Kemp, P. S. (2012). The influence of attraction flow on upstream passage of European eel (*Anguilla anguilla*) at intertidal barriers. *Ecological Engineering*, 44, 329-336.

Tweddle, J.C., L. D. Robinson, M. J. O. Pocock and H. E. Roy. 2012. Guide to Citizen Science: Developing, Implementing and Evaluating Citizen Science to Study Biodiversity and the Environment in the UK. Natural History Museum and NERC Centre for Ecology & Hydrology for UK-EOF, NHM.

Wheeler, A. C. (1979). The Tidal Thames: The History of a River and Its Fishes. London: Routledge and Kegan Paul.

White, E. M. and B. Knights. 1997. Environmental factors affecting migration of the European eel in the Rivers Severn and Avon, England. Journal of Fish Biology 50:1104-1116

Winter, H. V., Jansen, H. M. & Bruijs, M. C. M. (2006). Assessing the impact of hydropower and fisheries on downstream migrating silver eel, *Anguilla anguilla*, by telemetry in the River Meuse. *Ecology of Freshwater Fish*, 15, 221-228.

Appendix

Site Name	Distance from tidal limit (km)	2012	2013	2014	2015	2016	2017	2018	2019	2020
Ash-Colne Off Take	28.6	-	-	27 (0%)	16 (0%)	16 (6%)	-	-	-	-
Brent-Stoney Sluice	0	-	1,239 (75%)	36,646 (91%)	20,410 (86%)	12,985 (75%)	30,071 (83%)	63,940	-	-
Crane-Crane Park Island	4.2	0	0	-	-	-	-	-	-	-
Crane-Mogden STW	2.2	-	-	-	565 (51%)	946 (58%)	588 (40%)	150 (17.3%)	-	-
Cray-Hall Place	2.9	1	3	-	-	-	-	9 (12.5%)	18 (61.1%)	-
Darent-Acacia Weir	0.5	45 (36%)	9 (89%)	466 (97%)	26 (73%)	26 (88%)	-	-	-	-
Ember-Island Barn Sluice	7.7	-	-	-	-	-	75 (26%)	-	-	-
Hogsmill-Middle Mill	3.8	1 (0%)	7 (58%)	11 (83%)	13 (30%)	27 (19%)	34 (47%)	20 (15%)	35 (30.8%)	-
Lea-Bow Locks	0	13 (100%)	208 (71%)	399 (88%)	121 (83%)	133 (85%)	-	-	-	-
Lea-Lea Bridge	6	-	-	-	-	8,089 (39%)	20,474 (37%)	15,828 (4.7%)	16,914 (37.1%)	-
Longford- Home Park	4.5	-	49 (98%)	240 (75%)	316 (87%)	173 (73%)	-	-	-	-
Medway-Allington Lock	0	1,079 (91%)	12,802 (99%)	4,934 (99%)	421 (99%)	75 (97%)	115 (96%)	130 (99.2%)	146 (95.1%)	-
Mole-Zenith Weir	7.8	138 (23%)	18 (82%)	19 (89%)	90 (58%)	-	-	-	-	-
Roding-Redbridge	6	11 (60%)	113 (75%)	2,318 (96%)	404 (71%)	156 (92%)	140 (79%)	347 (72%)	305 (97.04%)	-
Thames-Teddington Lock	0	-	-	10 (100%)	5 (100%)	33 (100%)	47 (97%)	76 (100%)	9 (100%)	-
Thames-Molesey Weir	8.1	133 (23%)	2,473 (99%)	327 (98%)	261 (96%)	250 (87%)	117 (85%)	64 (70.3%)	86 (82.6%)	62 (77.7%)
Wandle-Merton Abbey Mills	5.5	139 (14%)	69 (32%)	332 (25%)	68 (3%)	213 (7%)	1,497 (7%)	129 (34.9%)	143 (4.9%)	-
Wandle- Morden Hall	6.2	-	-	-	-	-	241 (2%)	305 (12.8%)	200 (7.9%)	-
Total number of eels		**1,559**	**16,987**	**45,729**	**22,716**	**23,122**	**54,189**	**80,998**	**18,016**	**62**

Appendix A Table 2: Distance from the tidal limit and total number of eels caught at each site. Values in brackets represent the percentage of the catch that are elvers (body length ≤120mm).