Thames Tideway Aquatic Ecology Research

Smelt surveys on the Thames

Rationale of research approach

The European smelt *Osmerus eperlanus* L. inhabits cold-water estuaries in Europe, from North Russia to North West Spain. Smelt are currently categorised as Least Concern on the global International Union for Conservation of Nature (IUCN) Red List of Threatened Species, however, in the UK, the species has suffered significant declines since the early 19th century due to water pollution, over exploitation, and destructive river engineering affecting up-river migration and spawning habitats. Improvements to water quality in the latter half of the 20th century has seen smelt recorded from 36 of the original 52 water courses in England including the Tidal Thames (Colclough 2013). Smelt populations are still considered threatened in the UK by the Environment Agency due to their rarity and the number of anthropogenic pressures they still face and consequently, in 2006, smelt was listed as a 'species of principal importance' in the Natural Environment and Rural Communities (NERC) Act (2006). In 2007, smelt was listed as a UK Biodiversity Action Plan (BAP) Priority Species and has remained in subsequent legislation which focuses biodiversity conservation in the UK, namely the UK Post-2010 Biodiversity Framework (Defra 2012). In addition, smelt was identified as a Focus for Conservation Importance (FOCI) species on the Marine and Coastal Access Act in 2009 and as such, the Thames Estuary was considered as a candidate Marine Conservation Zone, with smelt as one of its FOCI. The presence of smelt in an estuary can be used as an indicator of good water quality due to their sensitivity to pollution.

Most European smelt populations are anadromous, which means they migrate through estuaries from the sea to spawn. Smelt reach sexual maturity at two to three years and tend to school together in lower estuarine environments to overwinter prior to mass spawning further upstream. A number of environmental factors have been attributed to initiating smelt spawning events, including water temperature, tidal state, freshwater flow, salinity and lunar phase. During broadcast spawning, females distribute approximately 25,000 eggs on the riverbed in fast flowing water, normally above the saline influence. Following spawning, adults migrate back into the marine environment where some continue to grow and spawn for another one to two years, although considerable mortality occurs during the spawning event itself. Smelt eggs have an outer envelope that bursts after spawning and attaches to stones, aquatic plants and river structures so that the egg is suspended in the water column to facilitate oxygen exchange. The average incubation period lasts up to 35 days, although low flows and/or high temperatures can lead to high egg mortality. Young larvae initially feed on diatoms but incorporate successively larger zooplankton into their diet as they increase in size. Juveniles remain in fresh or brackish water from spring to early autumn, before moving to the marine environment.

It is believed adult smelt aggregate in the lower Tidal Thames, around Gravesend, in February and March, before commencing their upstream migration to spawn in March and April; spawning is thought to occur in the area between Battersea and Wandsworth before the larvae and juveniles passively move with the tide and become distributed throughout the Tidal Thames.

In 2015 and 2016 the Zoological Society of London (ZSL), Bournemouth University Global Environmental Solutions (BUG), HR Wallingford and SC[2] conducted a study to map the likely spawning grounds of smelt in the tidal Thames. Although the tidal Thames holds one of the largest-known breeding populations of smelt in the UK, the specific spawning location(s) had not, until 2016, been identified. Using the results from a series of ichthyoplankton nettings in combination with hind- and fore- cast models, the study was able to conclude that smelt spawn in the area between Wandsworth Bridge and 600m upstream of this (between the 19.5 km and 20 km mark from Teddington Lock) (Figure 1). This location has an additional freshwater influence due to the nearby confluence of the River Wandle; previous research suggests smelt prefer to spawn in freshwater-dominated estuarine waters as a higher salinity reduces smelt egg hatching success. However, it could not be ruled out that the spawning could extend further West to Barnes Bridge (Figure 1).

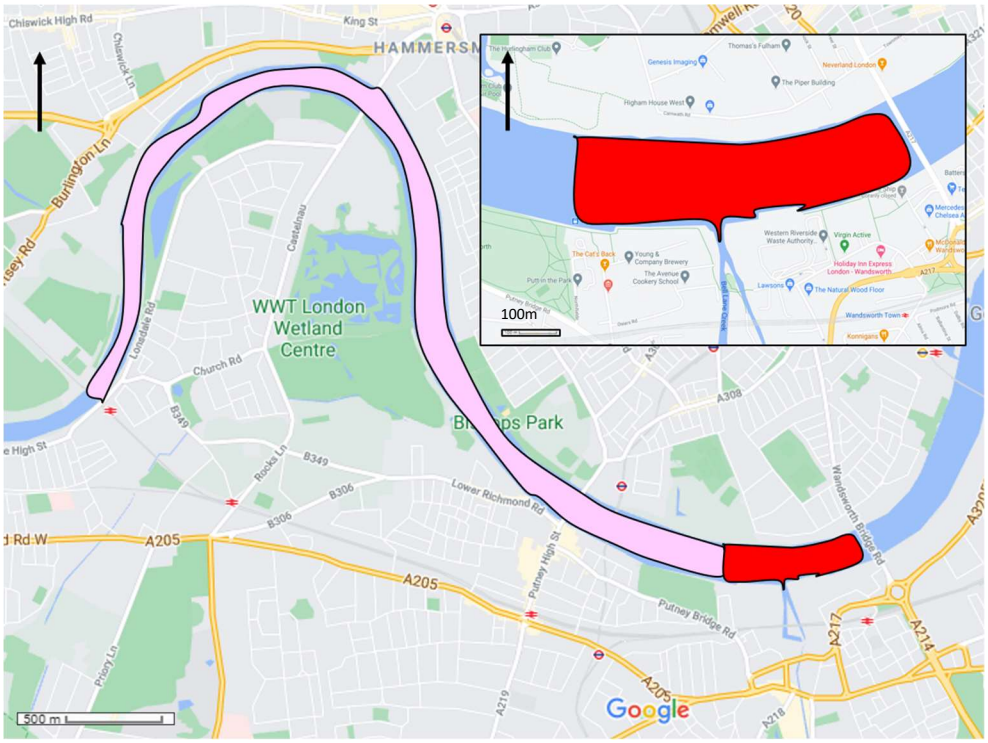

Figure 1: Location of predicted smelt spawning ground. Red shows the most likely spawning ground and pink shows the potential extension of this spawning ground upstream

Furthermore, the data from the 2016 study indicated that smelt spawn over an elongated period of five weeks during March and the beginning of April. Previous research in the suggested that smelt spawn simultaneously in one event, but these data support research from other water bodies where elongated spawning periods have been described. A recent tagging study in Suffolk suggested that smelt spent on average 15 days and 4.7 days during the spawning period in the River Yare and River Waveney respectively. This study provided valuable insight, however much more work is needed to understand how spawning / hatching sites vary between years under different environmental conditions (for example different freshwater flows) and how juvenile smelt utilise the estuary spatially prior to their departure to the marine environment.

In 2017 and 2018 Tideway funded ZSL, BUG and SC[2] to conduct juvenile fish surveys across the tidal Thames between March and October. The purpose of this study was to provide a pre Thames Tideway Tunnel baseline of early life history stage fish (ELHS) against which future improvements in water quality could be quantified. As part of this study in 2017 smelt larvae were caught at the Putney survey site on the 21st March indicating successful smelt spawning. However, in 2018 no

smelt were caught in the Putney survey site across March or April indicating that in the upper tidal Thames there was no evidence of recruitment for that year. Smelt were however caught further downstream in 2018 near Greenwich suggesting there may be a second spawning site on the river. During March and April 2018 percussive piling was conducted at four sites along the tidal Thames, Chelsea Embankment, Albert Embankment, Victoria Embankment, and Blackfriars Bridge, linked to the construction of the Thames Tideway Tunnel. This piling was sporadic, up to 5 hours a day and only during daylight hours.

The ZSL, BUG, SC^2 consortium were contracted by Tideway to conduct further research in 2019 and 2020 to build on these previous studies into the presence of smelt spawning in the upper Thames. This report presents these findings.

Methodology

Ichthyoplankton Sampling

Four sites in the upper Tidal Thames: Battersea, Wandsworth, Putney, and Chiswick (Figure 2), were surveyed each week between March to April in 2019 and mid-February to the end of March in 2020. It was intended in 2020 to continue surveying until mid-April however COVID-19 government enforced lock down measures made any further fieldwork impossible.

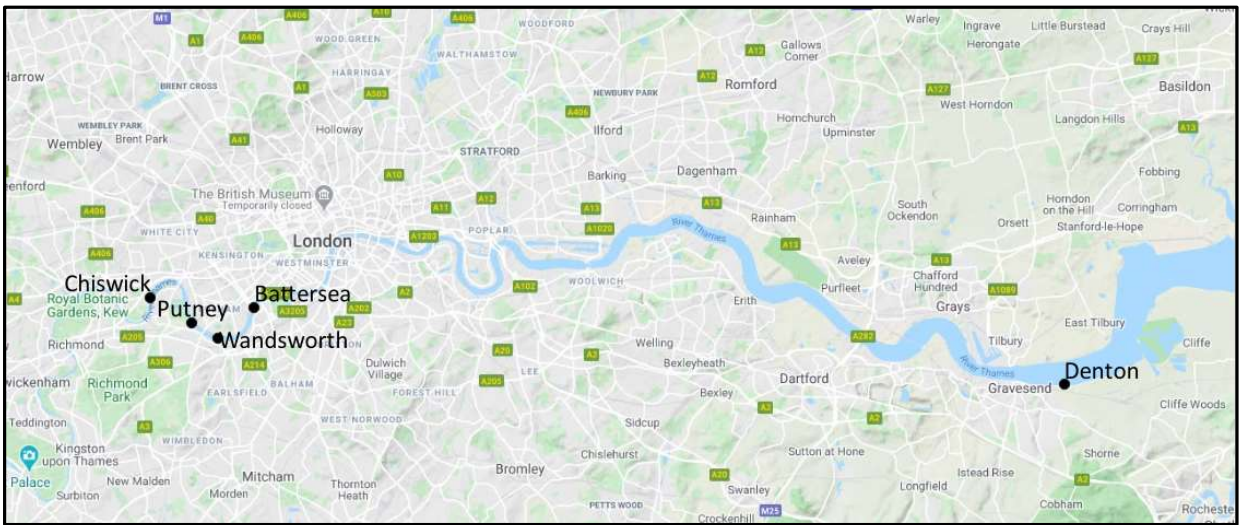

Figure 2: The smelt survey sites in the upper and lower tidal Thames

Consistent with previous annual surveys, two ichthyoplankton nets (surface and 2 m depth) were deployed from a boat tied to a buoy or Passive Debris Collector (PDC) at three of the survey sites, Battersea, Wandsworth and Putney (Figure 3). At the Chiswick site the ichthyoplankton net was deployed from a pier, and only on the surface. The ichthyoplankton nets had a 250 µm mesh narrowing into a cod end, with a 1.5m total length. The opening of the net was maintained by a 30 cm square steel collar and rope cradle, with a Hydro-bios 438 110 mechanical flow meter for horizontal operations attached to calculate the volume of water sampled. Each net (surface and 2m) was deployed for a total of 5 minutes with water velocity recorded at the start and end of the sample. Upon recovery the contents of the cod end were washed into a marked bucket of water for further processing. At least two netting events (a netting event included one surface and one 2 m ichthyoplankton net deployed) occurred at each site during each survey date.

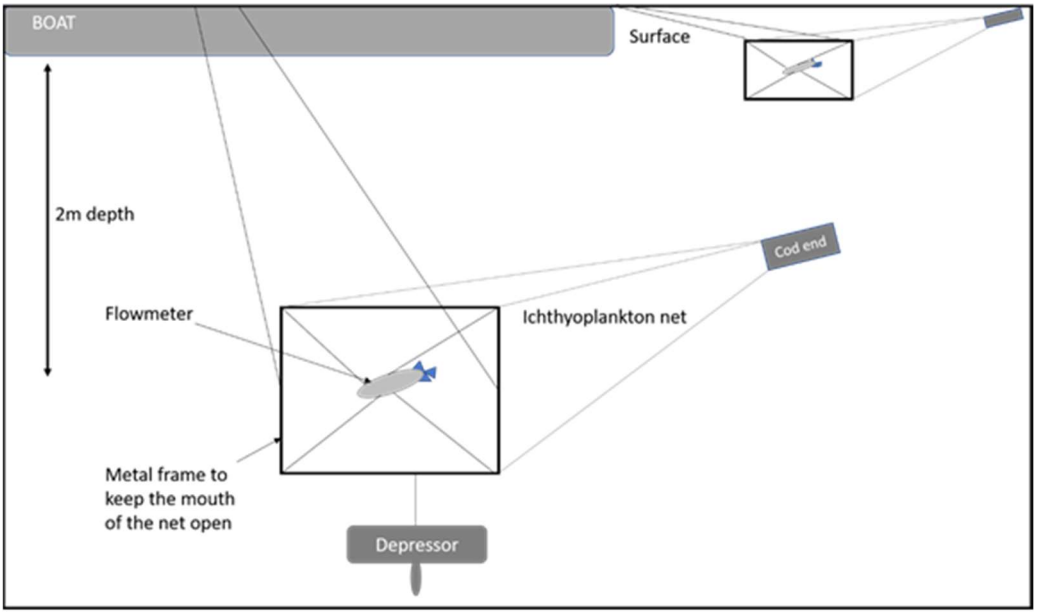

Figure 3: a schematic showing the surface and 2m depth ichthyoplankton nets deployed from a RIB for mid-channel sampling.

Data were collected on all fish species caught during the sampling. The catch from each netting event was processed separately. Adult fish or fish of conservation concern were identified, measured, and released alive. Larval and juvenile life stages were humanely euthanised in a solution of clove oil and fixed in 4% formaldehyde. Fixed samples were sent to BUG for species identification, enumeration, length measurement and assessment of developmental (ontogenetic) stage.

At the laboratory, all larval fish were washed in freshwater and viewed using a zoom binocular microscope to define species identity using the keys of Pinder (2001) and Munk & Nielsen (2005) for freshwater and marine species respectively. Individual fish were measured to the nearest 0.5 mm using either an eye-piece mounted graticule or a pair of Mahr digital callipers. In addition to fish length (recorded as total length or fork length for species with a concave caudal fin), the ontogenetic stage of development of each individual was also noted in accordance with staging models proposed by Pinder (2001; 2004).

Sediment Sampling

Sediment sampling was completed between Battersea Bridge and Putney each week in 2019, in the shallowest subtidal areas of the river. A river-bed sediment sampler suspended by rope was lowered and retrieved by hand (Figure 4) from a RIB. The sampler had a sample volume of 0.5 litres, measured 30 x 16 x 13cm and weighed 2.2kg.

Figure 4: The sediment sampling grab

Collected sediment samples were examined for the presence of fish eggs. Any items thought to be potential eggs were fixed in 4% formaldehyde and sent to BUG for taxonomic analysis. This technique was only used in 2019 as an experimental method to pinpoint spawning sites.

Results

Ichthyoplankton

In 2019, eight surveys across eight days were undertaken between the 6th March to 24th April, and one training day before the season commenced, across the four sites. This culminated in 184 ichthyoplankton netting events, comprising 117 from the boat across the three sites Putney, Wandsworth, and Battersea and 67 from the pier at Chiswick.

No smelt eggs or fry were recorded throughout the 2019 survey at any of the sites. One juvenile European eel was caught and released at Putney from the mid-channel on the 26th March and over 1,900 flounder were caught in ichthyoplankton nets across the four sites. The majority of the flounder were caught at a depth of 2m between the 26th March and 23rd April, with a noticeable peak in catch on the 18th April (Figure 5).

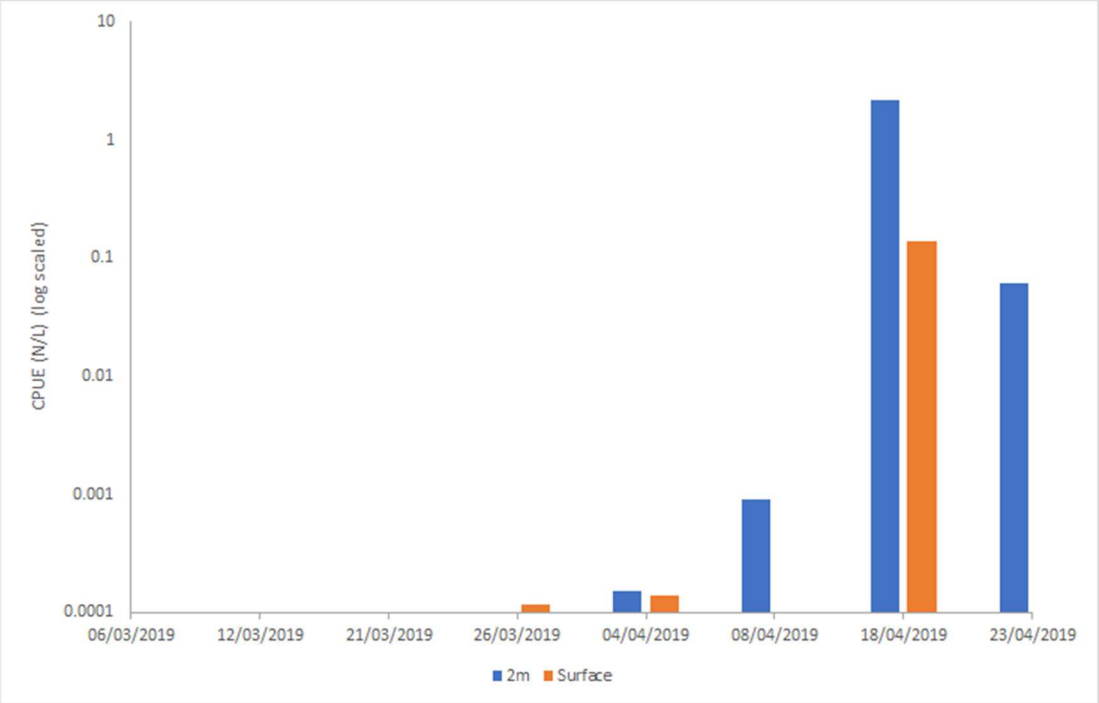

Figure 5: The Catch per Unit Effort (CPUE) of flounder caught in ichthyoplankton nets across the survey season at 2m depth and on the surface

Flounder were caught in all the survey sites in 2019, however most of the flounder were caught at the Putney survey site, followed by Wandsworth (Figure 6).

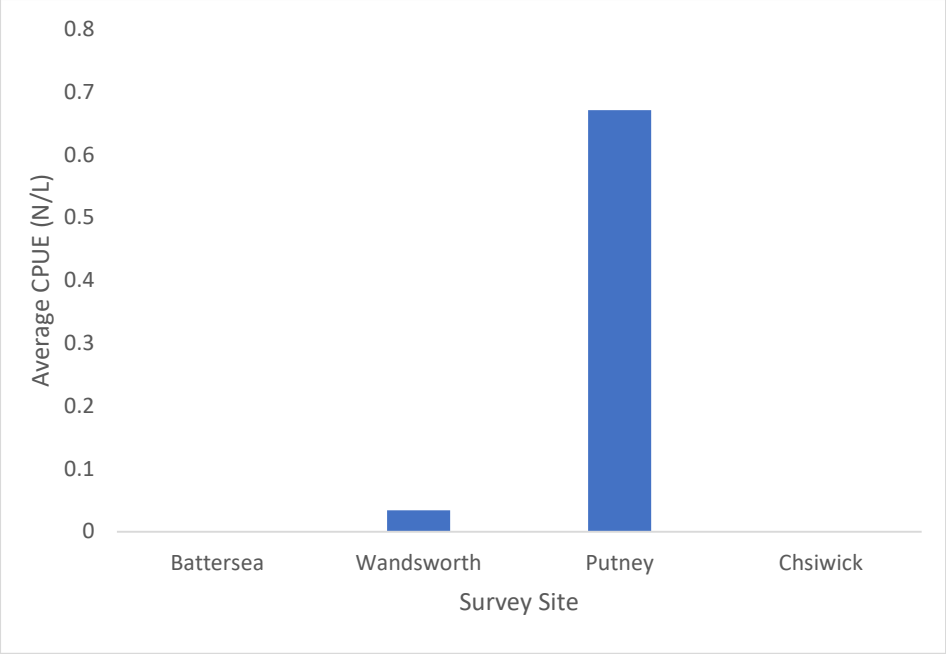

Figure 6: The average catch per unit effort (CPUE) for flounder caught in ichthyoplankton nets across each survey site in the number per fish per litre.

In 2020, surveys were planned to take place every week between 19th February through until 9th April, however due to the COVID-19 government lock down, all fieldwork was called off after the 16th March, and as such not all survey work for this project was able to be completed. Fifty-eight ichthyoplankton tows were conducted across the four sites, 34 from the surface and 24 from a depth of 2m. No boat-based surveys were able to be conducted on the 5th March due to equipment problems and therefore the Putney, Wandsworth and Battersea sites were not surveyed that week, however the Chiswick site was surveyed.

27 smelt eggs, one hatching larvae and 17 free-swimming larvae (or free-embryos) were recorded across three of the survey sites, Battersea, Wandsworth and Putney during four weeks of the 2020 season (Figure 7 and Table 1) in both the surface and 2m depth samples. Eggs and larvae were recorded from the end of February (26th) through until the last survey on the 16th March indicating an extended spawning season. Furthermore, with eggs being caught at all three survey sites simultaneously this may indicate multiple spawning locations across this area. Larvae varied in size between 5 mm and 7 mm (Table 1) and were recorded primarily at the Putney site (n=16) but also in Battersea (n=1).

No smelt were recorded from the Chiswick survey site, indicating that the area between Putney and Chiswick may have represented the upper tidal limit for spawning in 2020.

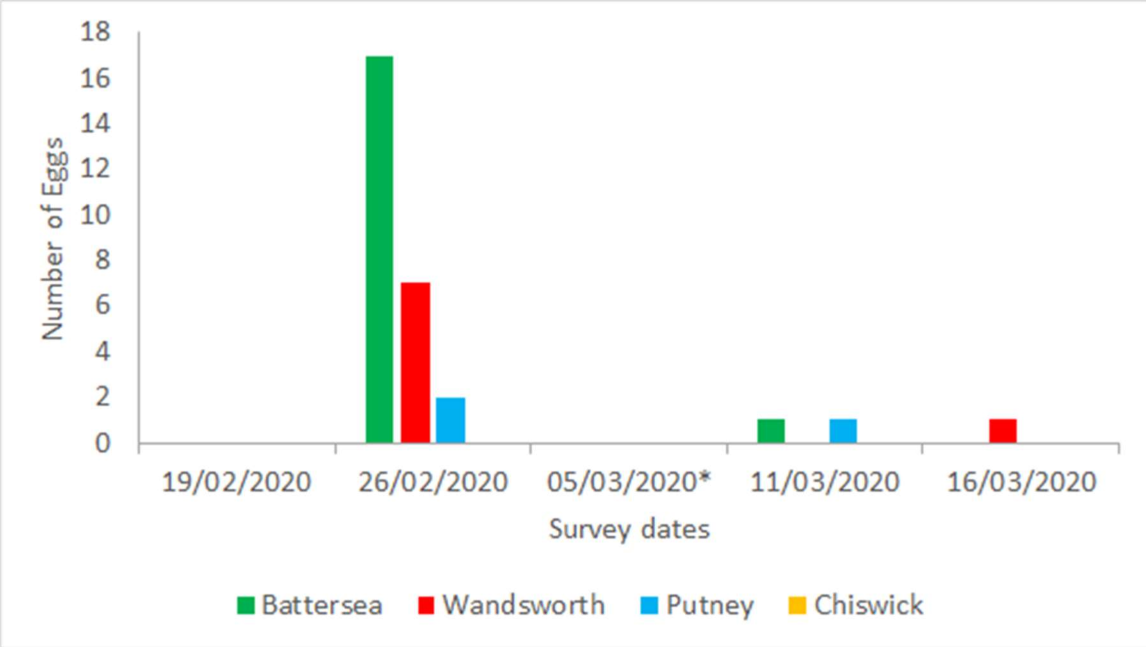

Figure 7: Number of eggs caught at each survey site. *There was no sampling effort at Battersea, Wandsworth and Putney on the 5th March due to technical issues.

Table 1: Smelt catch during the 2020 surveys. (The fungus on the eggs described below is a common external fungus often observed on fish eggs).

Location	Date	Method	Species	Length	Life stage	Notes
Battersea	26.02.2020	2m	Smelt		egg	no ontogenetic notes due to fungus
Battersea	26.02.2020	2m	Smelt		egg	no ontogenetic notes due to fungus
Battersea	26.02.2020	2m	Smelt		egg	no ontogenetic notes due to fungus
Battersea	26.02.2020	2m	Smelt		egg	no ontogenetic notes due to fungus
Battersea	26.02.2020	2m	Smelt		egg	no ontogenetic notes due to fungus
Battersea	26.02.2020	2m	Smelt		egg	no ontogenetic notes due to fungus
Battersea	26.02.2020	2m	Smelt		egg	no ontogenetic notes due to fungus
Battersea	26.02.2020	2m	Smelt		egg	just hatching
Putney	26.02.2020	2m	Smelt		egg	epiboly (developmental stage)
Putney	26.02.2020	2m	Smelt		egg	epiboly
Wandsworth	26.02.2020	Surface	Smelt		egg	Epiboly
Wandsworth	26.02.2020	Surface	Smelt		egg	Epiboly
Wandsworth	26.02.2020	2m	Smelt		egg	Epiboly
Wandsworth	26.02.2020	2m	Smelt		egg	Epiboly
Wandsworth	26.02.2020	2m	Smelt		egg	Epiboly
Wandsworth	26.02.2020	2m	Smelt		egg	Epiboly
Wandsworth	26.02.2020	2m	Smelt		egg	Epiboly
Battersea	26.02.2020	Surface	Smelt		egg	organogenesis (head forming)
Battersea	26.02.2020	Surface	Smelt		egg	Epiboly
Battersea	26.02.2020	Surface	Smelt		egg	Epiboly
Battersea	26.02.2020	Surface	Smelt		egg	Epiboly
Battersea	26.02.2020	Surface	Smelt		egg	Epiboly
Battersea	26.02.2020	Surface	Smelt		egg	Epiboly
Battersea	26.02.2020	Surface	Smelt		egg	Epiboly

Battersea	26.02.2020	Surface	Smelt		egg	Epiboly
Battersea	26.02.2020	Surface	Smelt		egg	Epiboly
Putney	11.03.2020	Surface	Smelt	6.5	Free embryo (larvae)	
Putney	11.03.2020	Surface	Smelt	6.5	Free embryo	
Putney	11.03.2020	Surface	Smelt	6.5	Free embryo	
Putney	11.03.2020	Surface	Smelt	5	Free embryo	
Putney	11.03.2020	Surface	Smelt	7	Free embryo	
Putney	11.03.2020	Surface	Smelt	6.5	Free embryo	
Putney	11.03.2020	Surface	Smelt	5.5	Free embryo	
Putney	11.03.2020	Surface	Smelt	6	Free embryo	
Battersea	11.03.2020	Surface	Smelt	6.5	Free embryo	
Putney	11.03.2020	2m	Smelt	6	Free embryo	
Putney	11.03.2020	2m	Smelt	6	Free embryo	
Putney	11.03.2020	2m	Smelt	6.5	Free embryo	
Putney	11.03.2020	2m	Smelt	5	Free embryo	
Putney	11.03.2020	2m	Smelt	6.5	Free embryo	
Putney	11.03.2020	2m	Smelt	5	Free embryo	
Putney	11.03.2020	2m	Smelt	5.5	Free embryo	
Putney	11.03.2020	2m	Smelt	6	Free embryo	
Putney	11.03.2020	Surface	Smelt		egg	eyed (close to hatching)
Wandsworth	16.03.2020	Surface	Smelt		egg	no ontogenetic notes due to fungus

Grab Samples

In 2019, eight survey days were undertaken across the four survey sites. This culminated in 64 grab events, comprising 45 grabs between Battersea Bridge and Putney and 19 from the Chiswick Pier (Figure 8). No smelt or other fish eggs were recorded in any of the grab samples taken.

Figure 8: Locations of grab samples taken throughout the 2019 survey season, marked by grey dots.

Environmental Variables

Freshwater discharge

The freshwater discharge (m^3/s) from the River Thames varies considerably year to year (Figure 9). Freshwater discharge governs the salinity regime within the tidal reaches. In 2016 and 2018 discharge was generally higher between January and April than 2015, 2017 or 2019. Freshwater flow data are not yet available from 2020.

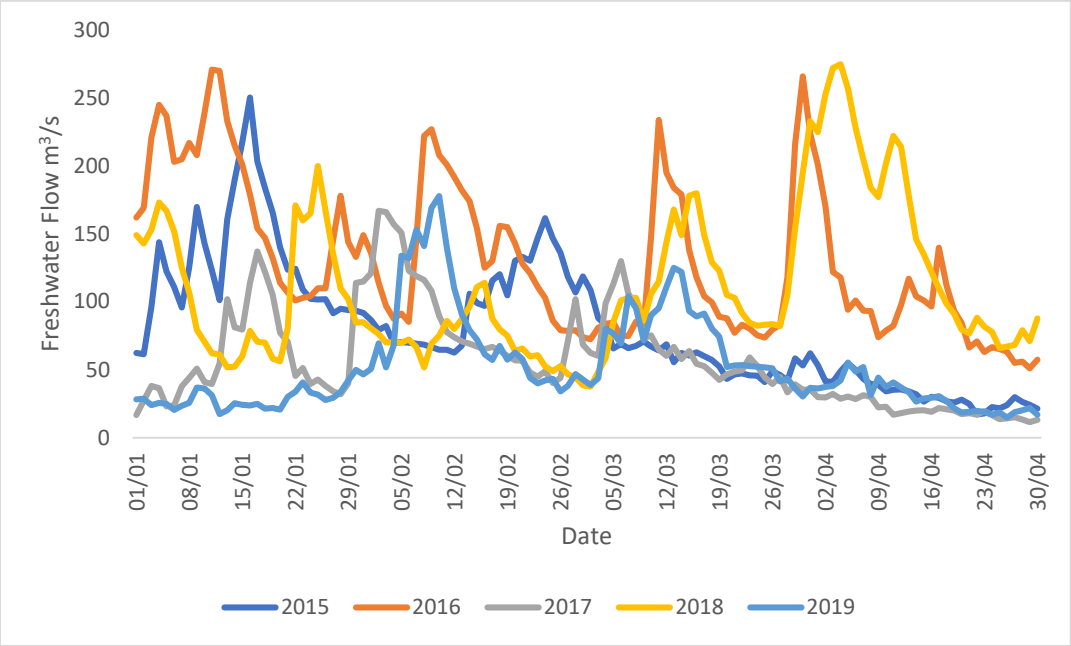

Figure 9: Freshwater discharge on the Thames from the Environment Agency's Kingston Gauging Weir January to April 2015 - 2019

Environmental Variables

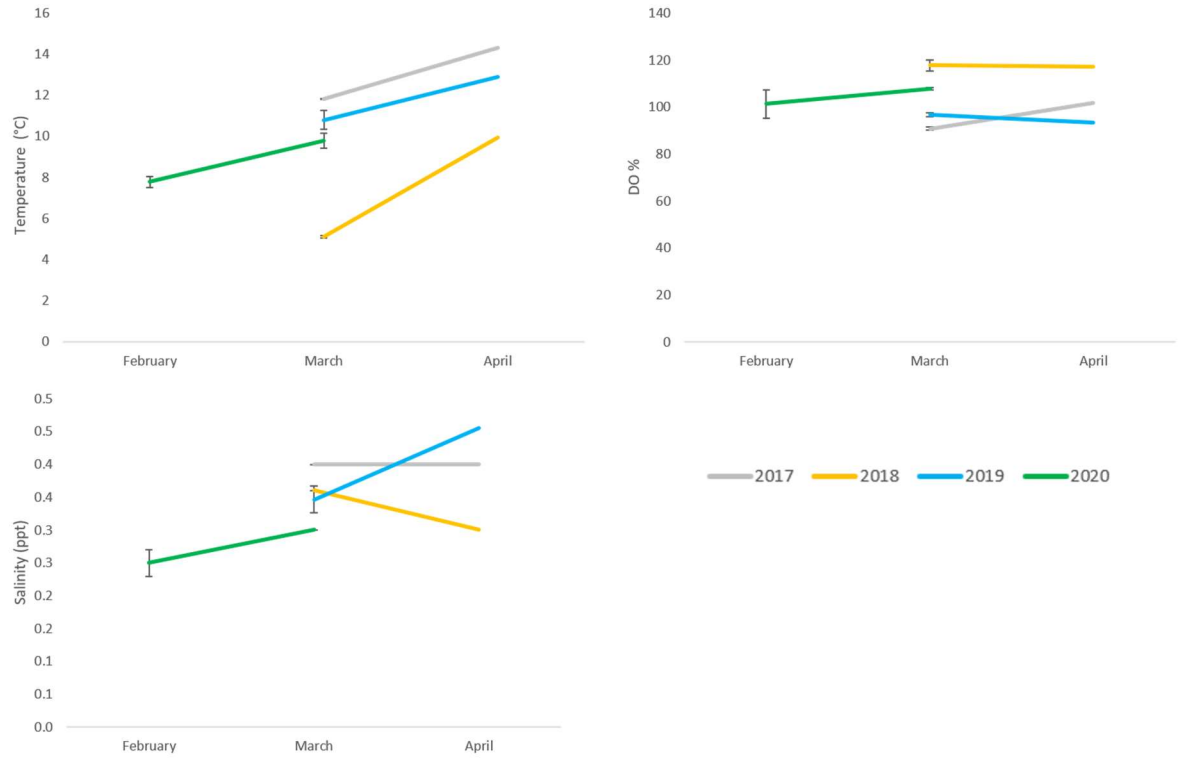

Figure 10: Mean Temperature, Dissolved Oxygen and Salinity (with SE) measured in Putney between 2017 and 2020 taken during fish surveys. These variables were not measured in February 2017-2019 or April 2020 due to no survey effort at these times.

Mean temperature, dissolved oxygen, and salinity between February to April 2017 to 2020 showed variation within these months across each of the years (Figure 10). Notably, spring 2018 was particularly cold and the salinity in spring 2020 was lower than other years. There was however no specific trends or relationships between parameters noted between any of the years.

Percussive Piling

In 2018, percussive piling activities took place at eight stations throughout March and April between Albert Bridge and Blackfriars Bridge at four locations. This piling was strictly controlled, time limited (never longer than five hours) and only took place during daylight hours.

In 2019, vibro and impact piling was conducted on 18 occasions between 3 January and 13 March at the Albert Embankment site. Between 22 February and 13 March piling occurred most days for a maximum time of 1hr 44 mins. Details of the piling activity can be found in Appendix 1.

In 2020, no piling was reported to take place between January and March end.

Discussion

Survey data from previous ZSL led surveys between 2015 and 2018 evidenced the upper tidal Thames between Putney and Battersea, but especially around Wandsworth, was a key smelt spawning site with spawning recorded every year except for 2018 (ZSL Guidance Document, 2016;

ZSL, 2019). The 2019 and 2020 surveys presented in this report demonstrate spawning in this area did not occur in 2019 but was present 2020.

Over 40 smelt eggs and larvae were caught in ichthyoplankton tows between Battersea, Wandsworth and Putney in 2020, between the end of February and middle of March, indicating an extended spawning season. This finding is consistent with the 2015-2016 survey data which also evidenced an extended spawning season at this site (ZSL Guidance Document, 2016). Without accurate modelling it is not possible to isolate the specific spawning ground(s) between Battersea and Putney but as eggs were recorded across all three sites on the same survey date it is possible that spawning activity extends across this reach. In 2020 no smelt were caught at the Chiswick site indicating that the upper limit to smelt spawning was between Putney and Chiswick.

In the six years ZSL have been surveying this reach over the smelt spawning season, just 2018 and 2019 have no evidence of recruitment which implies no spawning events. Although there was variation in all environmental variables from year to year (Figure 8 and 9) there were no obvious differences in trends in the environmental variables in 2018 and 2019 to the other years.

For the Thames Tideway Tunnel construction, percussive piling has been necessary at some of the sites along the river. In 2018 piling took place at Albert Embankment, Chelsea Embankment, Victoria Embankment and Blackfriars, whereas in 2019 activities were limited to the Albert Embankment site. Percussive piling has been linked to avoidance behaviour in certain fish species of up to 250m upstream and downstream of the piling site (THA Aquatic, 2017). As smelt migrate up the tidal Thames from the outer estuary to spawn between Battersea and Putney, it is possible that the percussive piling impacted on their migratory performance and/or spawning activity in 2018 and 2019. In 2020, no percussive piling was undertaken during the smelt reproductive season and spawning was evidenced again by the presence of eggs and larvae. This observation suggests that further research into potential for percussive piling to impact on smelt populations is urgently needed.

References

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ZSL. (2016) Guidance Document: Conservation of Tidal Thames Fish through the Planning Process. Report by the Zoological Society of London, October 2016.

Appendix 1

Table showing the piling regime at Albert Embankment (ALBEF) Tideway site January – March 2019.

Date	Vibro duration (Hr:mn)	Impact duration (Hr:mn)
03/01/2019	None	00:56
16/01/2019	00:18	None
17/01/2019	None	00:35
18/01/2019	00:22	00:52
01/02/2019	00:18	00:30
02/02/2019	00:58	None
05/02/2019	None	00:04
11/02/2019	00:16	None
12/02/2019	None	00:50
22/02/2019	00:59	None
23/02/2019	None	01:35
24/02/2019	None	00:28
25/02/2019	None	00:25
26/02/2019	None	01:19
04/03/2019	00:11	01:11
05/03/2019	None	00:46
06/03/2019	None	00:31
08/03/2019	00:22	00:26
09/03/2019	00:25	01:44
13/03/2019	01:19	None