Annex B2.3: Fish Assessment Report

Standard Gate two submission for London Water Recycling SRO

Notice – Position Statement

This document has been produced as the part of the process set out by RAPID for the development of the Strategic Resource Options (SROs). This is a regulatory gated process allowing there to be control and appropriate scrutiny on the activities that are undertaken by the water companies to investigate and develop efficient solutions on behalf of customers to meet future drought resilience challenges.

This report forms part of suite of documents that make up the 'Gate 2 submission.' That submission details all the work undertaken by Thames Water in the ongoing development of the proposed SRO. The intention at this stage is to provide RAPID with an update on the concept design, feasibility, cost estimates and programme for the schemes, allowing decisions to be made on their progress.

Should a scheme be selected and confirmed in the Thames Water final Water Resources Management Plan (WRMP), in most cases it would need to enter a separate process to gain permission to build and run the final solution. That could be through either the Town and Country Planning Act 1990 or the Planning Act 2008 development consent order process. Both options require the designs to be fully appraised and, in most cases, an environmental statement to be produced. Where required that statement sets out the likely environmental impacts and what mitigation is required.

Community and stakeholder engagement is crucial to the development of the SROs. Some high-level activity has been undertaken to date. Much more detailed community engagement and formal consultation is required on all the schemes at the appropriate point. Before applying for permission Thames Water will need to demonstrate that they have presented information about the proposals to the community, gathered feedback and considered the views of stakeholders. We will have regard to that feedback and, where possible, make changes to the designs as a result.

The SROs are at a very early stage of development, despite some options having been considered for several years. The details set out in the Gate 2 documents are still at a formative stage.

Disclaimer

This document has been written in line with the requirements of the RAPID Gate 2 Guidance and to comply with the regulatory process pursuant to Thames Water's statutory duties. The information presented relates to material or data which is still in the course of completion. Should the solutions presented in this document be taken forward, Thames Water will be subject to the statutory duties pursuant to the necessary consenting process, including environmental assessment and consultation as required. This document should be read with those duties in mind.

LONDON EFFLUENT REUSE SRO

Annex B.2.3. Fish Assessment Report

Report for: Thames Water Utilities Ltd

Ref. **4700399659**

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Version 1.0 – 29/07/2022		First Draft
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Customer:
Thames Water Utilities Ltd

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CONTENTS

1. INTRODUCTION

This report is part of series of Environmental Assessment Reports which catalogue the set of environmental assessments of the London Effluent Reuse Strategic Resource Option (SRO) through RAPID Gate 2: *Detailed feasibility, concept design and multi-solution decision making* and onward to RAPID Gate 3: *Developed design, finalised feasibility, pre-planning investigations and planning applications*. The reports set out the environmental assessments, which will in turn support regulatory assessment requirements proportionate to RAPID Gate 2 and onward to RAPID Gate 3. The scope and approach to the environmental evidence provided in these reports was set out in the Gate 2 Scoping Report and consulted on with the National Appraisal Unit (NAU) in November 2021.

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1.1 LONDON EFFLUENT REUSE STRATEGIC RESOURCE OPTIONS

For Gate 2, the London Effluent Reuse SRO is set out as four source options and a range of sizes. One option is in east London, utilising final effluent from Beckton sewage treatment works (STW). The other three options are in west London, utilising crude sewage or final effluent from Mogden STW to a maximum total reduction of 200 Ml/d, with differing London Effluent Reuse scheme discharge locations in the freshwater River Thames.

Full details of the conceptual design of the four schemes are provided in the Conceptual Design Reports[1] (CDR). For assessment purposes no specific mitigation is allowed for unless included as part of option design as set out in CDR (other than the Habitats Regulations Assessment (HRA) Stage 2 and Initial Environmental Appraisal (IEA)) which has regard for additional mitigation as per the ACWG methodology). A direct river abstraction (DRA) intake would include appropriate fish screening and all new outfalls would include appropriate European eel management measures.

High level summaries of each option are provided below. A full summary for the indicative operating pattern of a London Effluent Reuse SRO is presented in Section 1.2 of the Physical Environment Assessment Report[2]. The fish assessment presented in this report is based upon impact pathways identified in the Physical

[1] Jacobs (2022) London Reuse Strategic Resource Option, Gate 2 Conceptual Design Reports.

[2] Ricardo (2022) London Effluent Strategic Resource Option, Gate 2 Physical Environment Assessment Report.

Environment Assessment Report and the Water Quality Assessment Report[3], both of which reports should be read prior to reading this report.

1.1.1 Beckton Water Recycling Scheme

Final effluent from Beckton STW would be treated at a new AWRP within Beckton STW for advanced treatment. Recycled water would be conveyed via a new tunnel from the Beckton AWRP to Lockwood Pumping Station and then a TLT extension from Lockwood Pumping Station to a proposed new outfall located on a side channel of the freshwater Lee Diversion Channel, known as the Enfield Island Loop, upstream of the existing Thames Water Enfield intake to the King George V Reservoir. Additional abstraction for public water supply on a put/take basis would be through existing intakes in the Lower Lee, to supplement the raw water supply to the Lee Valley reservoirs. The option reduces the final effluent at the extant Beckton STW outfall to the estuarine Thames Tideway.

The Beckton water recycling scheme has been assessed for Gate 2 independently at 100 Ml/d, 200 Ml/d, and 300 Ml/d.

1.1.2 Mogden Water Recycling Scheme

Final effluent from Mogden STW would be pumped in a new pipeline to a new advanced water recycling plant (AWRP) located at a site near Kempton water treatment works (WTW)) for advanced treatment. Recycled water would be transferred in a new pipeline for discharge into the freshwater River Thames at a new outfall upstream of the existing Thames Water Walton intake. Additional abstraction for public water supply on a put-take basis would be through existing downstream intakes on the River Thames. AWRP wastewater and reverse osmosis (RO) concentrate would be conveyed back to Mogden STW inlet works via a return pipeline(s). There is an option that the AWRP wastewater could be discharged to the South Sewer for return to Mogden STW, but it is not possible to return the RO concentrate by this means. The scheme reduces the final effluent at the extant Mogden STW outfall to the estuarine Thames Tideway.

The Mogden water recycling scheme has been assessed for Gate 2 independently at 50 Ml/d, 100 Ml/d, 150 Ml/d and 200 Ml/d.

1.1.3 Mogden South Sewer Scheme

Crude sewage would be diverted from the South Sewer of the sewerage catchment of Mogden STW. The South Sewer runs close to Kempton Park WTW and the diverted sewage would be pumped to a new AWRP located at a site near Kempton WTW for advanced treatment. Recycled water would be transferred in a new pipeline for discharge into the freshwater River Thames at an outfall upstream of the existing Thames Water Walton intake, potentially upstream of the Affinity Water Walton intake. Additional abstraction for public water supply on a put-take basis would be through existing downstream intakes on the River Thames. Waste streams from the AWRP would be conveyed by a new pipeline and treated at Mogden STW. The scheme reduces the final effluent at the extant Mogden STW outfall to the estuarine Thames Tideway.

The Mogden South Sewer scheme has been assessed for Gate 2 at 50 Ml/d.

During Gate 2, Thames Water took the decision to pause development of the Mogden South Sewer scheme due to limitations on available flow within the sewer, cost of the scheme and regional modelling not selecting the scheme under any water resources planning horizon scenario. The Gate 1 concept design is therefore used in Gate 2, with the exception where scheme elements are shared with the Mogden water recycling scheme (certain conveyance routes, AWRP and discharge location) which have been further developed through Gate 2.

The Mogden South Sewer scheme has not been progressed through Gate 2 environmental assessments, and so a dedicated assessment section is not included within this report. However, due to the similarities with the 50 Ml/d Mogden water recycling scheme (AWRP, discharge location and volume), the outcomes of that assessment can be considered representative of a fish assessment of a 50 Ml/d Mogden South Sewer scheme.

[3] Ricardo (2022) London Effluent Strategic Resource Option, Gate 2 Water Quality Assessment Report.

1.1.4 Teddington DRA Scheme

Final effluent from Mogden STW would be subject to further treatment at a new tertiary treatment plant (TTP) at Mogden STW. The treated water would be transferred in a new pipe-jacked tunnel for discharge into the freshwater River Thames at a new outfall upstream of the tidal limit at Teddington Weir. Additional abstraction for public water supply on a take-put basis would be through a new intake from the freshwater River Thames, upstream of the new outfall. Abstracted water would be pumped into the nearby Thames-Lee Tunnel for transfer to Lockwood pumping station, part of Thames Water's Lee Valley reservoirs in North London. The scheme reduces the final effluent at the extant Mogden STW outfall to the estuarine Thames Tideway.

The Teddington DRA scheme has been assessed for Gate 2 independently at 50 Ml/d, 75 Ml/d, 100 Ml/d and 150 Ml/d.

1.2 THE PURPOSE OF THIS REPORT

The purpose of this series of Assessment Reports is to set out the environmental baseline for each reach of the full study area to identify the source of greatest potential magnitude of change that a London Effluent Reuse SRO might cause within that reach, and then assess the potential for change to environmental receptors (aquatic ecology). The report identifies where additional data and/or more detailed analysis is required in Gate 3 as the London Effluent Reuse SRO designs are developed and operating regimes refined. The findings of these reports provide the evidence base to inform the HRA, Water Framework Directive (WFD) and IEA assessments.

This report provides the assessment for the Gate 2 Fish topic. As per the Gate 2 Fish Evidence Report[4], Table 1-1 outlines the task and approach to assessment for the aquatic ecology assessment for Gate 2 of the London Effluent Reuse SRO. It also outlines the evidence base that has been used to undertake the assessment for each of the tasks.

The study area for the London Effluent Reuse SRO has been divided into the following water courses (Figure 1-1):

- The freshwater River Thames from Shepperton Weir to the tidal limit at Teddington
  - Reach A – Shepperton Weir to Affinity Water Walton Intake
  - Reach B – Affinity Water Walton Intake to Thames Water Walton Intake
  - Reach C – Thames Water Walton Intake to Teddington Weir
- Channels of the freshwater Lee from Newman's Weir on the Enfield Island Loop to the tidal limit at Three Mills Lock
  - Reach G – Newmans Weir on the Enfield Island Loop to Chingford Abstractions
  - Reach H – Chingford Abstractions to Three Mills Lock
- The estuarine Thames Tideway from the tidal limit at Teddington to 3km seawards of Beckton STW outfall, noting the estuarine model boundary is at Southend-on-Sea.
  - Reach D – Teddington Weir to Battersea Park
  - Reach E – Battersea Park to Tower Bridge
  - Reach F - Tower Bridge to 3km seawards of Beckton STW
- The estuarine Bow Creek (tidal Lee) from Three Mills Lock to the Thames Tideway.
  - Reach I - Three Mills Lock to Thames Tideway

Section 2 of this report sets out reference conditions for the zone of influence of the London Effluent Reuse SRO sub-options. Sections 3-5 outlines the environmental assessment for each SRO sub-option included in the Gate 2 submission. Section 6 provides summary of current knowledge gaps and future investigations.

[4] Ricardo (2021) London Effluent Strategic Resource Option, Gate 2 Fisheries Evidence Report

Figure 1-1 Map showing locations of schemes and reaches for London Effluent Reuse SRO

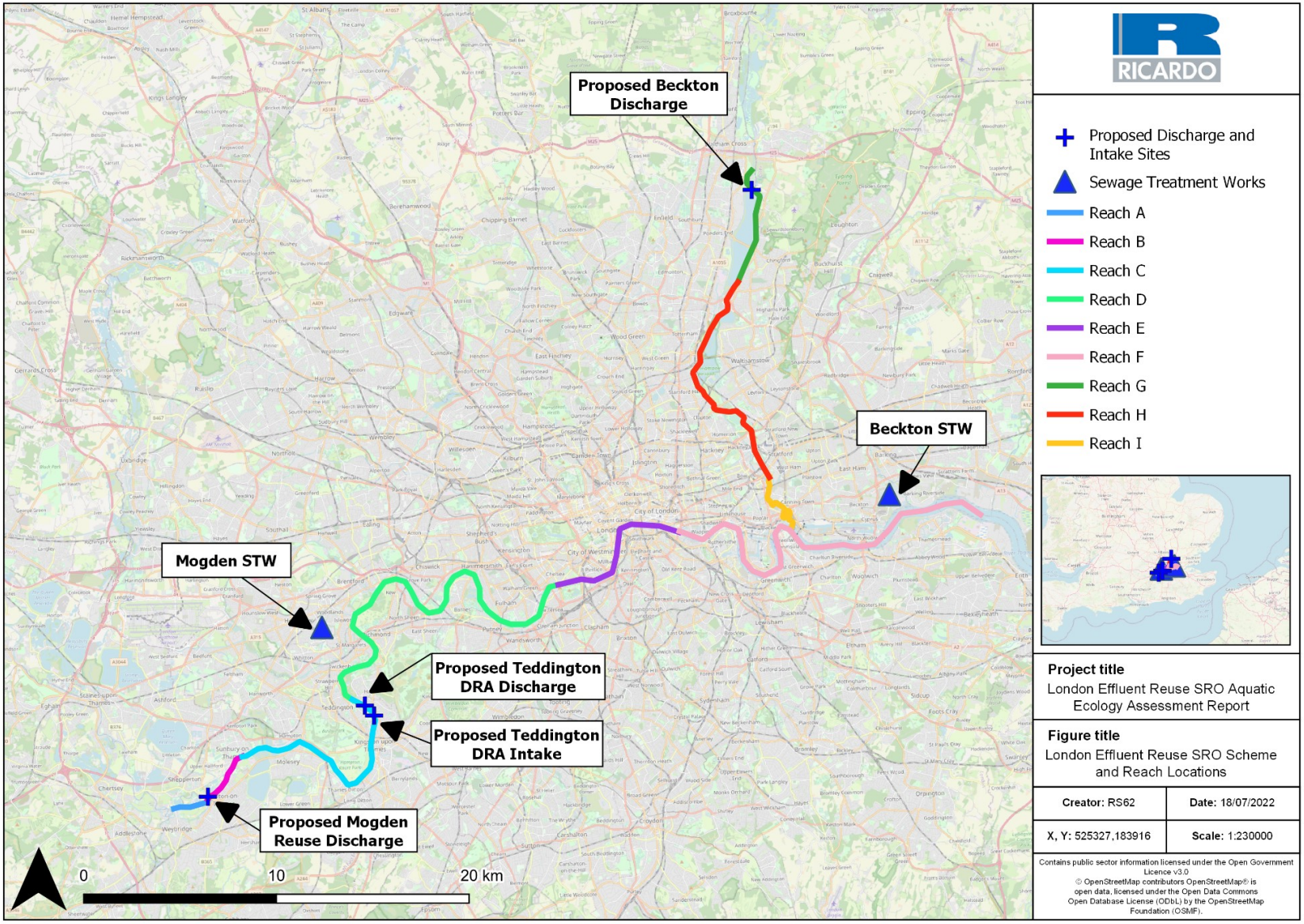


Table 1-1 Tasks and assessment approach to the fisheries assessment for London Effluent Reuse SRO

Task item	Scope of assessment	Approach to assessment	Evidence Base for Task
a. Fish (WFD/NERC) Freshwater and Estuarine (including European eel)	• Update the Gate 1 assessment using additional baseline data collected during Gate 1 and Gate 2 and updated physical environment and water quality assessments (including modelling)	• Update Gate 1 baseline data to include survey information (e.g. survey time, survey extent) to determine CPUE for comparison with Gate 1 and Gate 2 monitoring data collected by SRO project team. • Review data and update baseline sections for juvenile fish using Gate 1 and Gate 2 monitoring data. • Review and refine species temperature thresholds / thermal preferenda for spawning, juvenile and adult life stages . • Update assessment in consideration of the interpretation of the fluvial conditions within the Lower Thames and Thames Tideway. Studies will include an assessment of reuse discharge, water levels and velocity patterns throughout the study area (both river and estuary) for the range of reference conditions and scenarios with reuse option. • Update assessment to consider modelled information on marginal exposure in the estuary. • Update assessment in consideration of the interpretation of the water quality assessment . • Update assessment to consider outfall designs in relation to intake (DRA only) and outfall screening. • Suggest further mitigation measures (where required) for design/engineering interface.	• EA Ecology & Fish Data Explorer data throughout the study area (both river and estuary). • Assessment of EA fisheries survey data including boom boat, hydroacoustic and Atlantic salmon and sea trout records post 2013. • Juvenile fish seine surveys at 11 sites (Lower Thames 10 sites and one site downstream of intake on the R. Lea. • Electrofishing at three sites (Lower Thames: Sunbury Weir Pool & Molesey main weir pool and downstream of intake on the R. Lea. • Reservoir seine and fyke net surveys at seven reservoir sites. • Thames Tideway Tunnel data. • FAO/IFM Fish pass manuals. • EA eel manual. • SNIFFER guidance for temperature standards for marine and freshwater environments.
b. Weir pool/marginal habitat assessment (including Sunbury creek)	• Update the Gate 1 assessment using additional baseline data collected during Gate 1 and Gate 2 and updated physical environment and water quality assessments (including modelling)	• Review data and update baseline sections for juvenile fish using Gate 1 and Gate 2 monitoring data. • Update assessment in consideration of the interpretation of the 3D fluvial modelling of outfalls and weir pools for different scenarios. • Suggest further mitigation measures (where required) for design/engineering interface.	• EA Ecology & Fish Data Explorer data. • Physical Environment and Water quality assessments will provide scenario outputs for each of the SRO schemes. • UKHab and MoRPH surveys within eight reaches within lower Thames in 2021. • River Thames 1D river modelling and 3D river modelling at outfalls and weir pools.
c. Migratory fish (including European eel)	• Update the Gate 1 assessment using additional baseline data collected during Gate 1 and Gate 2 and updated physical environment and water quality assessments (including modelling)	• Review monitoring data of Sunbury, Molesey and Teddington fish passes and update relevant baseline sections. • Review of wider monitoring datasets for migratory species (including shad and lamprey) • Update the assessment using the interpretation of the TELEMAC model data to understand how flow and levels change against critical levels identified for target fish species under different scenarios. • Review of potential for impact pathway to the weirs in the Enfield Island Loop of the River Lee Diversion.	• EA Ecology & Fish Data Explorer data. • Fish eDNA surveys at eight sites • Thames Tideway Tunnel data. • Review of olfactory cues of diadromous fish and salmonid migratory cues. • Bathymetry, flow, velocity, water quality data (spot samples and continuous sondes).

Task item	Scope of assessment	Approach to assessment	Evidence Base for Task
		• Suggest further mitigation measures (where required) for design/engineering interface.	
d. Olfactory cues investigations	• Update the Gate 1 assessment using the desktop review of available information on olfactory cues • In order to assess masking of migratory salmonid olfaction, data is required on the ratio of treated effluent to river water under baseline conditions and modelled under various scenarios.	• Update assessment in consideration of the interpretation of the fluvial (flow and water quality) model, including the fluvial flow series at key locations and extent of mixing zones . • Update assessment in consideration of the interpretation of the water quality assessment, including risk to olfactory cues.	• Review of olfactory cues of diadromous fish and salmonid migratory cues. • Bathymetry, flow, velocity, water quality data (spot samples and continuous sondes). • Assessment of WFD and EQSD chemical quality throughout the study area (both river and estuary) for the range of reference conditions and scenarios with reuse option.
e. European Smelt	• Update the Gate 1 assessment using additional baseline data collected during Gate 1 and Gate 2 and updated physical environment and water quality assessments (including modelling)	• Update assessment in consideration of the interpretation of the fluvial (flow and water quality) model, including the fluvial flow series at key locations and extent of mixing zones. • Update assessment in consideration of the interpretation of the water quality assessment, including risk to olfactory cues.	• Smelt Ichthyoplankton surveys at five sites. • Smelt Egg/Sediment surveys at six sites. • Smelt eDNA surveys at eight sites. • EA Ecology & Fish Data Explorer data. • Thames Tideway Tunnel data. • Bathymetry, flow, velocity, water quality data (spot samples and continuous sondes).

2. BASELINE CONDITIONS

2.1 INTRODUCTION

To inform the assessment for each of the tasks set out in Table 1-1, this section establishes the reference conditions for each task as per the relevant study area. The study area for each task has been set out per task as it is not consistent across tasks. The reference conditions for each of the following tasks has been set out in the following sections:

- Freshwater Fish (including European eel) – Section 2.3
- Weir pool/marginal habitat (including Sunbury creek) - Section 2.4
- Estuarine Fish (including European eel) – Section 2.5
- Migratory Fish (including European eel) – Section 2.6
- European Smelt – Section 2.7
- Olfactory cues – Section 2.8

This reference conditions assessment has been undertaken for the following for each task:

- Fish data across Reaches A, B and C in the freshwater River Thames, Reaches D, E and F in the estuarine Thames Tideway, Reaches G and H in the freshwater Lee Diversion Channel and Reach I in the estuarine River Lee
- Marginal habitats across Reaches A, B and C in the freshwater River Thames and Reach G in the freshwater Lee Diversion Channel

Where this report may make reference to A82 and M96 flow series, respectively these refer to 1 in 5 year and 1 in 20-year flow events. Full details of the scenarios selected is provided in Section 1.2 of the Physical Environment Assessment Report[2].

A full list of survey sites and data ranges, along with figures presenting survey locations are provided in the Fish Evidence Report[4].

2.2 ASSESSMENT METHOD OVERVIEW

2.2.1 Freshwater fish

Freshwater fish can be divided into three main groups, and these are salmonid fish such as brown trout (*Salmo trutta*), coarse fish such as dace (*Leuciscus leuciscus*) and lamprey species such as brook lamprey (*Lampetra planeri*). However, there are migratory species such as Atlantic salmon (*Salmo salar*) and European eel (*Anguilla anguilla*) along with estuarine species such as flounder (*Platchthys flesus*) that have life-stages that are present within freshwater. As such, migratory and estuarine fish are considered separately within the separate sections of this report but have been included (where appropriate) within the reach assessments as follows e.g. European eel.

Primary data searches were conducted using the Environment Agency (EA) Ecology and Fish Data Explorer[5] for all monitoring sites located within individual study reaches. All records over the preceding 11 years (i.e. between 1 January 2010 and 31 December 2021) were collated and analysed to determine the overarching fish community[6]. These data were supplemented by data obtained from other monitoring programmes (London Effluent Reuse SRO fish monitoring 2021 to 2022) and via specific data requests to the EA in order to obtain their Lower Thames hydroacoustic fish survey data (2003 to 2016) and EA fish pass data (2001 to 2016).

As part of the recommendations made within the London Effluent Reuse Gate 1 Fish Assessment[7] reach specific fisheries monitoring have been undertaken during 2022[8,9] to support the primary data searches. These

[5] https://environment.data.gov.uk/ecology/explorer/

[6] The 11 year dataset was set out in the Evidence Report and agreed with the NAU, it also aligns with the Physical Environment and Water Quality assessment's datasets.

[7] Ricardo (2021). London Effluent Reuse Strategic Resource Option, Gate 1 Environmental Studies – Annex B.2.3. Fish Assessment.

[8] Atkins (2022). London Reuse SRO 2022 ichthyoplankton surveys. Atkins | 5200973 2022 Ichthyoplankton survey report_v2.0.

[9] Atkins (2022). London Reuse SRO 2022 ichthyoplankton surveys. Atkins | 5200973 2022 Smelt Spawning Surveys_v2.0

data along with the evidence to support this Gate 2 Fish Assessment are found within a separate London Effluent Reuse SRO Gate 2 Fish Evidence Report.

2.2.2 Estuarine Fish

Primary data searches were conducted using the Environment Agency (EA) Ecology and Fish Data Explorer[5] for all monitoring sites located within individual study reaches. All records over the preceding 11 years (i.e. between 1 January 2010 and 31 December 2021) were collated and analysed to determine the overarching fish community. These data were supplemented by data obtained from other monitoring programmes such as the Thames Tideway Tunnel (TTT) survey data (2011 to 2014).

Environmental DNA (eDNA) surveys were conducted over a nine week repeat sampling period in spring 2022 (from w/c 11th February to w/c 25th April[10]), at eight different locations (Putney; Hammersmith; Barnes Bridge; Kew Bridge; Kew Gardens; Richmond; Ham; and Teddington) within Reach D of the estuarine Thames Tideway. A standardised protocol using commercial eDNA kits, was completed in the field. Water samples were filtered (5 µm glass fibre prefilter and 0.8 µm membrane) and preserved on site. Following filtration, samples were buffered within the filter, allowing for storage at room temperature, and reducing the need for immediate extraction of DNA. After on site processing, filters were individually sealed into labelled bags and sent for third-party professionally accredited eDNA analysis[11] involving metabarcoding of the 12S rRNA gene[12]. Amplification success was determined by gel electrophoresis. Outputs collated suggest confirmatory presence and distribution of migratory fish species.

2.3 FRESHWATER FISH

2.3.1 Freshwater River Thames

Reach A – Shepperton Weir to Affinity Water Walton Intake

Reach A is characterised by slow flowing deep glide characteristic of a lowland river. The main river channel has been heavily modified within this reach having been split into two channels; the original River Thames flows north of Desborough Island and the second channel Desborough Cut, flows to the south of Desborough Island. The two channels present within this reach are hydrologically distinct, Desborough cut is a straightened modified channel design to aid navigation, whereas the original River Thames channel maintains a relative sinuosity. Although the original River Thames channel is also relatively heavily modified there remains a substantial portion of natural margin which is known to support juvenile fish populations, as well as areas of flow dependent river habitat in weir pools, weir streams and in distributaries such as the Sunbury Creek.

A total of 37 fisheries surveys across 10 sites constitute the baseline dataset for the reach as can be seen in Figure 2-1. EA monitoring data constitutes a large portion of the baseline dataset, and in addition, several project-specific fish monitoring surveys were completed in 2021 following recommendations in the Gate 1 assessment e.g. juvenile fish and fish weir pool surveys.

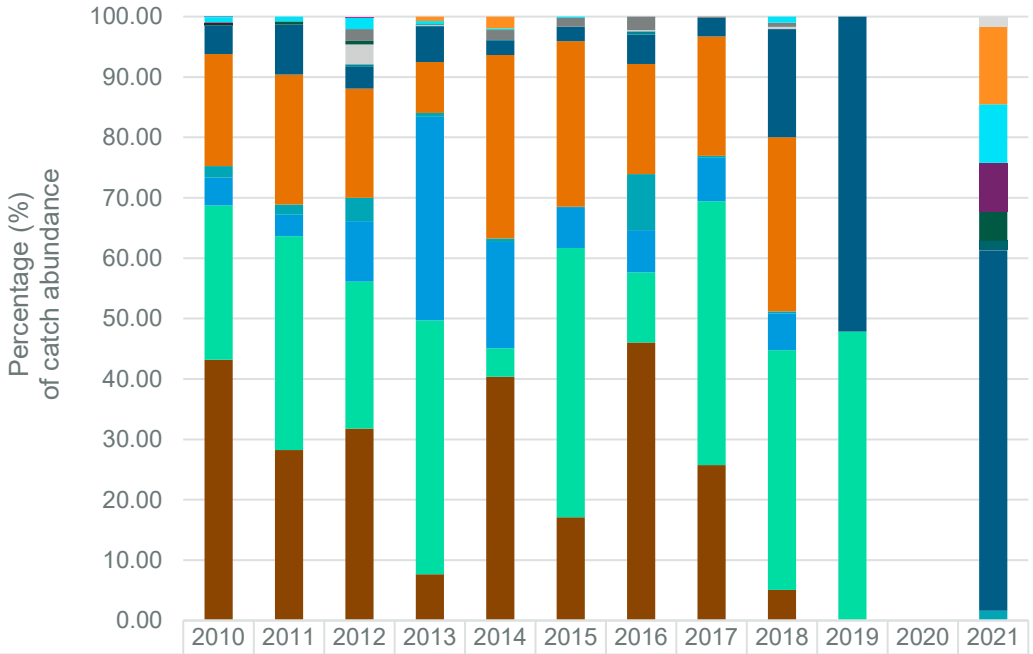
The EA and project-specific fisheries monitoring data within Figure 2-1 indicate that the fish community within this reach is diverse and representative of the dominant river habitat i.e. a slow-flowing glide typical of a lowland river. Several species dominate the fish community in the majority of years and these species include roach (*Rutilus rutilus*), gudgeon (*Gobio gobio*), bleak (*Alburnus alburnus*), dace, chub (*Squalius cephalus*) and perch (*Perca fluviatilis*), which contribute to ~95% of the reported total abundance. Less frequent within Figure 2-1 is the occurrence of fish species such as tench (*Tinca tinca*), barbel (*Barbus barbus*), bream (*Abramis brama*), bullhead (*Cottus gobio*) and pike (*Esox lucius*). European eel and one record of brown trout have also been recorded within this reach.

[10] 8 Note: An additional filter was used at each of the 8 sites during week 8 in an attempt to increase sensitivity for reporting shad (following an EA request to add shad to the April eDNA sampling), and therefore two sample results are available (two different filters) for week 8.

[11] 9 https://www.naturemetrics.co.uk

[12] 10 Riaz, R., Shehzad, W., Viari, A., Pompanon, F., Taberlet, P., and Coissac, E. EcoPrimers: inference of new DNA barcode markers from whole genome sequence analysis. Nucl. Acids. Res. 39, e145. 2011.

Figure 2-1: Reach A - Shepperton Weir to Affinity Water Walton Intake, fisheries monitoring data represented as the proportion of species recorded within the total annual reported catch abundance.



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Tench	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stone loach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.61
Ruffe	0.06	0.00	0.00	0.76	1.94	0.00	0.00	0.00	0.00	0.00	0.00	12.90
Roach x common bream hybrid	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pike	0.79	0.79	1.94	0.49	0.29	0.18	0.00	0.00	1.02	0.00	0.00	9.68
Bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.06
Minnow	0.12	0.00	1.94	0.00	1.65	1.47	2.20	0.21	0.68	0.00	0.00	0.00
European eels > elvers	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
European eel	0.00	0.53	0.56	0.11	0.00	0.04	0.00	0.00	0.00	0.00	0.00	4.84
Eel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.61
Common bream	0.03	0.00	3.33	0.11	0.00	0.00	0.24	0.00	0.34	0.00	0.00	0.00
Brown / sea trout	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barbel	0.03	0.00	0.42	0.11	0.06	0.00	0.49	0.00	0.00	0.00	0.00	0.00
Perch	4.75	8.26	3.61	5.94	2.41	2.36	4.90	3.06	17.97	52.17	0.00	59.68
Chub	18.57	21.51	18.06	8.44	30.39	27.44	18.24	19.81	28.81	0.00	0.00	0.00
Bleak	1.88	1.74	3.89	0.62	0.59	0.04	9.30	0.32	0.34	0.00	0.00	1.61
Dace	4.63	3.52	10.00	33.71	17.58	6.78	6.98	7.17	6.10	0.00	0.00	0.00
Roach	25.56	35.40	24.31	42.05	4.70	44.60	11.63	43.73	39.66	47.83	0.00	0.00
Gudgeon	43.16	28.25	31.81	7.65	40.39	17.09	46.02	25.71	5.08	0.00	0.00	0.00

Reach B – Affinity Water Walton Intake to Thames Water Walton Intake

Within Reach B the Thames channel is relatively straight and consists predominantly of heavily modified banking from the Walton Bridge discharge location downstream, boat moorings and at the lower extent of this reach is Sunbury Weir and the associated Sunbury Creek side channel.

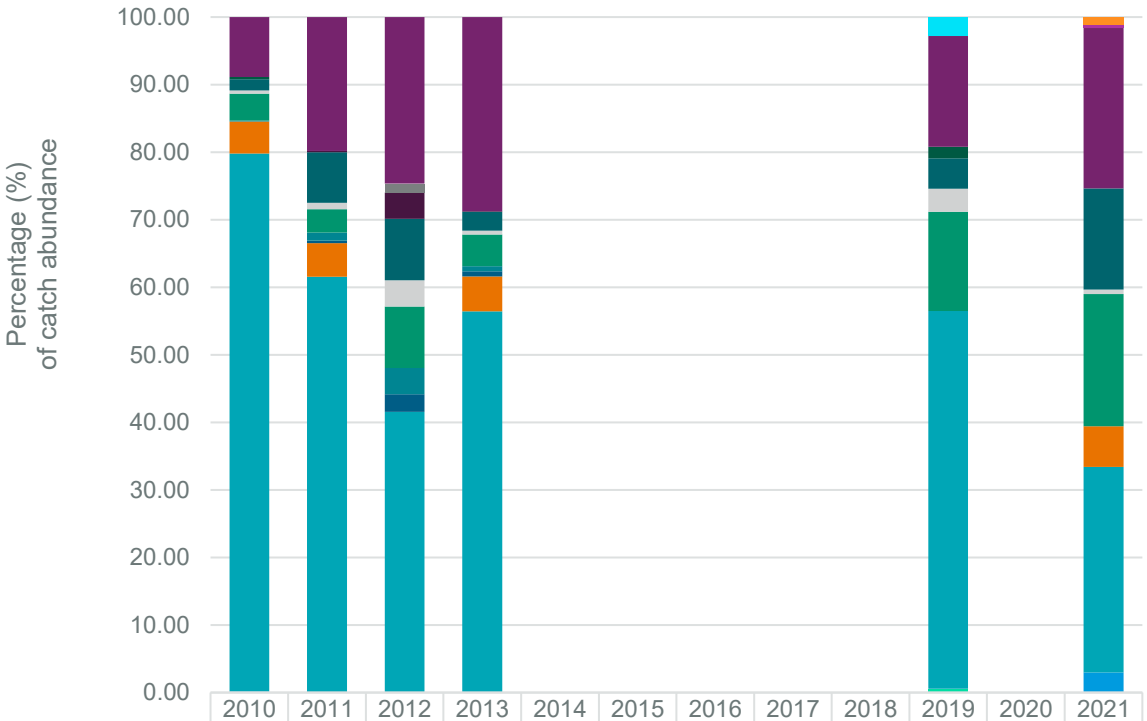
A total of 12 fisheries surveys across 5 sites constitute the baseline dataset for the reach as can be seen in Figure 2-2. EA monitoring data again constitutes a large portion of the baseline dataset, and in addition, several project-specific monitoring surveys were completed in 2021 following recommendations in the Gate 1 assessment.

The EA and project-specific fisheries monitoring data within Figure 2-2 indicates that the fish community within this reach is diverse and representative of the dominant habitats associated with a slow-flowing glide and are typical of a lowland river such as the Thames. Several species dominate the fish community within most years

including roach, gudgeon, bleak, dace, chub, pike and perch contributing to ~95% of the reported total abundance.

Less frequent is the occurrence of species such as tench, barbel, bream, common carp and minnow. European eels have also been recorded within this reach.

Figure 2-2: Reach B Affinity Water Walton Intake to Thames Water Walton Intake, fisheries monitoring data represented as the proportion of species recorded within the total annual reported catch abundance.



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Minnow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.15
Eel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46
Tench	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.82	0.00	0.00
Dace	8.88	19.81	24.68	28.73	0.00	0.00	0.00	0.00	0.00	16.38	0.00	23.73
Common [wild] carp	0.00	0.00	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chub	0.00	0.19	3.90	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
European eels > elvers	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.69	0.00	0.00
Perch	1.68	7.50	9.09	2.78	0.00	0.00	0.00	0.00	0.00	4.52	0.00	14.98
Pike	0.46	0.96	3.90	0.56	0.00	0.00	0.00	0.00	0.00	3.39	0.00	0.69
Bleak	3.98	3.46	9.09	4.68	0.00	0.00	0.00	0.00	0.00	14.69	0.00	19.59
Barbel	0.15	1.15	3.90	0.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
European eel	0.00	0.38	2.60	0.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gudgeon	4.75	5.00	0.00	5.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.99
Roach	79.63	61.54	41.56	56.46	0.00	0.00	0.00	0.00	0.00	55.93	0.00	30.41
Common bream	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00
Common carp varieties	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00
Bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Reach C – Thames Water Walton Intake to Teddington Weir

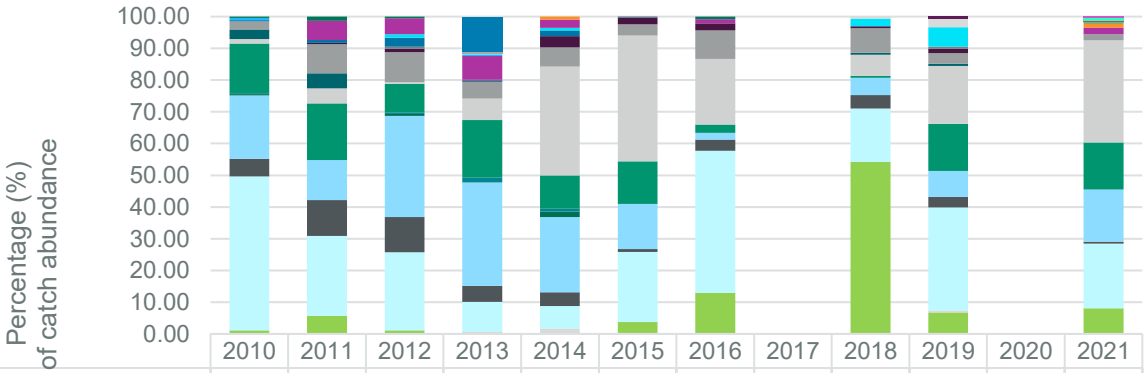
Within Reach C the Thames channel is relatively wide consisting predominantly of heavily modified banking, boat moorings and at the lower extent exists Teddington Weir.

A total of 33 fisheries surveys across 12 sites constitute the baseline dataset for the reach as can be seen in Figure 2-3. EA monitoring data constitutes a large portion of the baseline dataset, in addition, several project-specific monitoring surveys were completed during 2021 to 2022 following recommendations in the Gate 1 assessment.

The EA and project-specific fisheries monitoring data indicate that the fish community within this reach as a whole is diverse and representative of the dominant habitats being slow-flowing glide typical of a lowland river. As can be seen within Figure 2-3 below, several species dominate the fish community in most years including roach, gudgeon, bleak, dace, chub, pike, and perch contributing to ~90% of the reported total abundance.

Less frequent is the occurrence of species (including *INNS species of interest[13]) such as tench, barbel, bream, common carp, mirror carp, *grass carp (*Ctenopharyngodon idella*), *zander (*Sander lucioperca*), ruffe (*Gymnocephalus cernuus*), flounder, 3 spined stickleback (*Gasterosteus aculeatus*), rudd (*Scardinius erythrophthalmus*), bullhead, stone loach (*Barbatula barbatula*) and minnow (*Phoxinus phoxinus*). European eel, brown trout and Atlantic salmon have also been recorded within this reach.

Figure 2-3: Reach C Thames Water Walton Intake to Teddington Weir, fisheries monitoring data represented as the proportion of species recorded within the total annual reported catch abundance.



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Stone loach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31
Bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.62
Brown trout	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31
Rudd	0.00	0.00	0.00	10.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3-spined stickleback	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Minnow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.62
Grass carp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.00	0.00
Flounder	0.37	1.30	0.56	0.00	0.00	0.22	0.86	0.00	0.00	0.00	0.00	0.31
Tench	0.74	0.00	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common carp varieties	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	2.70	0.00	0.00
Ruffe	0.00	0.00	0.00	0.00	0.88	0.00	0.00	0.00	0.00	0.00	0.00	1.24
European eel	0.00	6.09	5.03	7.42	2.63	0.22	1.29	0.00	0.00	0.00	0.00	2.17
Common bream	0.00	0.00	1.12	0.00	0.88	0.00	0.00	0.00	2.41	6.08	0.00	0.00
Common [wild] carp	0.37	0.87	2.79	0.30	1.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atlantic salmon	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.00	0.00
Barbel	0.00	0.43	1.12	0.30	3.51	1.97	2.16	0.00	0.60	1.35	0.00	0.00
Chub	2.59	9.13	9.50	5.34	6.14	3.51	9.05	0.00	7.83	3.38	0.00	1.86
European eels > elvers	2.96	4.78	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.68	0.00	0.00
Bleak	1.48	4.78	0.56	6.82	34.21	39.69	20.69	0.00	6.63	18.24	0.00	32.20
Perch	15.56	17.83	8.94	18.10	10.53	13.38	2.59	0.00	0.60	14.86	0.00	14.86
Zander	0.37	0.00	0.56	1.48	0.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mirror carp	0.37	0.00	0.56	0.00	1.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dace	20.00	12.61	31.84	32.64	23.68	14.25	2.16	0.00	5.42	8.11	0.00	16.41
Pike	5.56	11.30	11.17	5.04	4.39	0.88	3.45	0.00	4.22	3.38	0.00	0.62
Roach	48.52	25.22	24.58	9.50	7.02	22.15	44.83	0.00	16.87	32.43	0.00	20.43
Brown / sea trout	0.00	0.00	0.00	0.59	1.75	0.00	0.00	0.00	0.00	0.68	0.00	0.00
Gudgeon	1.11	5.65	1.12	0.00	0.00	3.73	12.93	0.00	54.22	6.76	0.00	8.05

[13] Ricardo (2022). London Effluent Reuse Strategic Resource Option, Gate 2 INNS Assessment Report 1.0. Ref. 4700399659. Ricardo ref. ED13591.

2.3.2 Freshwater Lee Diversion Channel

Reach G – Newmans Weir on the Enfield Island Loop to Chingford Abstractions

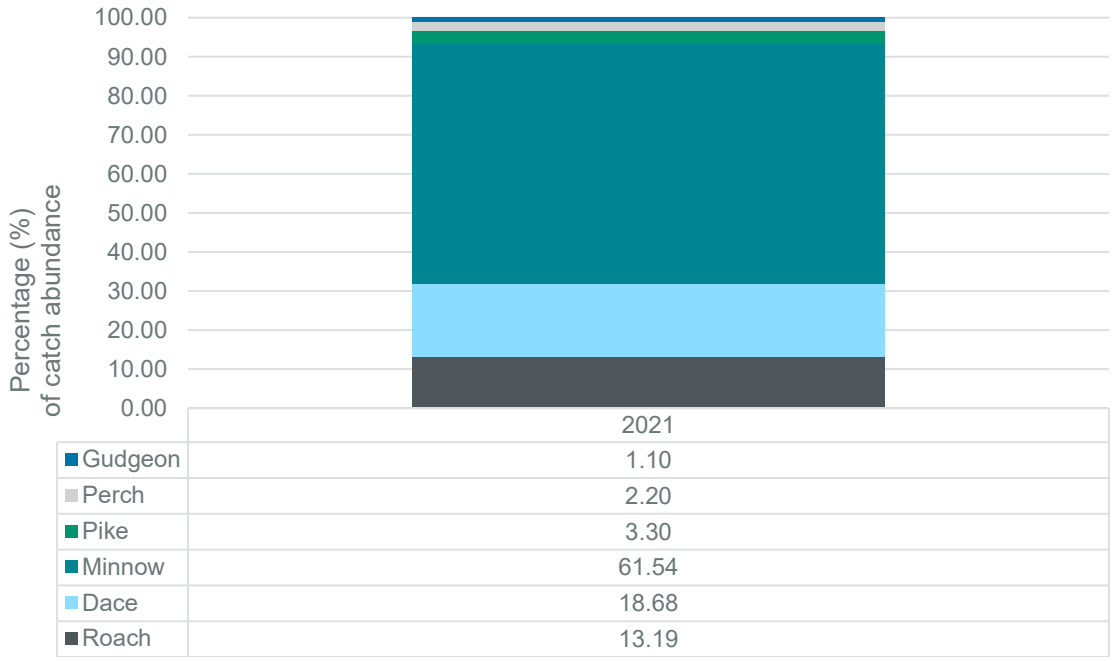
Reach G is characterised by a moderately flowing shallow river. The majority of the River Lee through this reach is heavily modified for flood relief.

A total of one fisheries survey across one site constitute the baseline data for this reach as can be seen in Figure 2-4. The data in this reach is from the project-specific monitoring surveys completed in 2021 following recommendations in the Gate 1 assessment.

The project-specific fisheries monitoring data indicate that the fish community within this reach as a whole is moderately diverse and representative of the dominant habitats found within a tributary of a lowland river i.e. moderately flowing run. As can be seen within Figure 2-4, several species dominate the fish community in most years including roach, dace and minnow contributing to ~93% of the reported total abundance.

Less frequent is the occurrence of species such as pike, perch and gudgeon.

Figure 2-4: Reach G – Newmans Weir on the Enfield Island Loop to Chingford Abstractions, fisheries monitoring data represented as the proportion of species recorded within the total annual reported catch abundance.



Reach H – Chingford Abstractions to Three Mills Lock

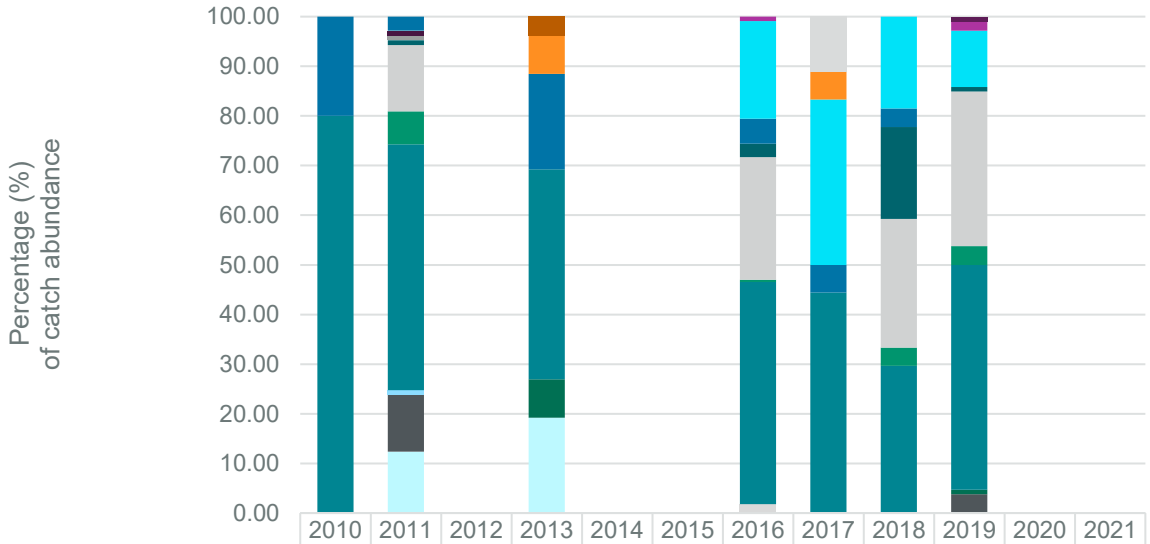
Reach H is characterised as being a moderately flowing shallow river. The majority of the River Lee through this reach is heavily modified for flood defence and the river joins multiple other heavily modified watercourses. There are some sections of naturalised river within this reach, though these sections are still moderately flowing shallow in nature.

A total of nine fisheries surveys across four sites constitute the baseline dataset for the reach as can be seen in Figure 2-5. EA monitoring data constitutes a large portion of the baseline dataset, and project-specific monitoring surveys were completed in 2021 following recommendations in the Gate 1 assessment.

The EA and project-specific fisheries data in Figure 2-5 indicate that the fish community within this reach as a whole is diverse and representative of the dominant habitats being moderately flowing run typical of a tributary of a lowland river. Several species dominate the fish community in most years including roach, gudgeon, bleak, dace, chub and perch contributing to ~77% of the reported total abundance.

Less frequent is the occurrence of species such as tench, bream, common carp, mirror carp, roach/chub hybrid and bullhead. European eels have also been recorded within this reach.

Figure 2-5: Reach H Chingford Abstractions to Three Mills Lock, fisheries monitoring data represented as the proportion of species recorded within the total annual reported catch abundance.



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Mirror carp	0.00	0.00	0.00	3.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common [wild] carp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.94	0.00	0.00
Minnow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pike	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.11	0.00	0.00	0.00	0.00
Tench	0.00	0.00	0.00	7.69	0.00	0.00	0.00	5.56	0.00	0.00	0.00	0.00
European elvers	0.00	0.00	0.00	0.00	0.00	0.00	0.91	0.00	0.00	1.89	0.00	0.00
European eels > elvers	0.00	0.00	0.00	0.00	0.00	0.00	19.63	33.33	18.52	11.32	0.00	0.00
Perch	20.00	2.86	0.00	19.23	0.00	0.00	5.02	5.56	3.70	0.00	0.00	0.00
3-spined stickleback	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common carp varieties	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Roach x chub hybrid	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chub	0.00	0.95	0.00	0.00	0.00	0.00	2.74	0.00	18.52	0.94	0.00	0.00
Gudgeon	0.00	13.33	0.00	0.00	0.00	0.00	24.66	0.00	25.93	31.13	0.00	0.00
Dace	0.00	6.67	0.00	0.00	0.00	0.00	0.46	0.00	3.70	3.77	0.00	0.00
Roach	80.00	49.52	0.00	42.31	0.00	0.00	44.75	44.44	29.63	45.28	0.00	0.00
Common bream	0.00	0.00	0.00	7.69	0.00	0.00	0.00	0.00	0.00	0.94	0.00	0.00
Tench varieties	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bleak	0.00	11.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.77	0.00	0.00
European eel	0.00	12.38	0.00	19.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Roach x common bream hybrid	0.00	0.00	0.00	0.00	0.00	0.00	1.83	0.00	0.00	0.00	0.00	0.00
Stone loach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

2.4 WEIR POOL AND MARGINAL HABITAT

2.4.1 Overview

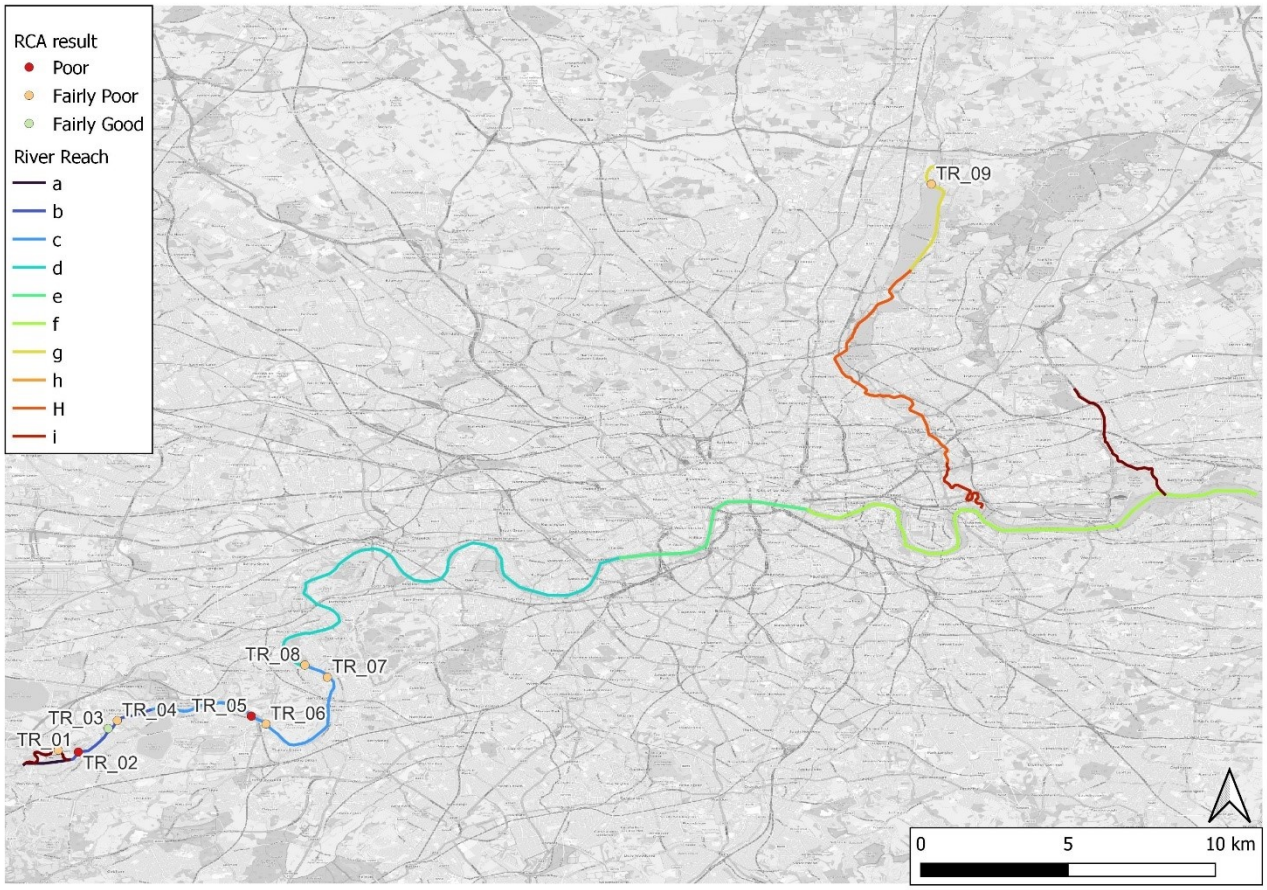
This section sets out the reference conditions for the weir pool and marginal habitat assessment:

- Freshwater River Thames - Section 2.4.2
- Freshwater Lee Diversion Channel – Section 2.4.3

The evidence available, the general patterns observed in the data and any notable pressures are outlined for each of these reaches in the following sections.

Details of the survey results are shown in the River Condition Assessment (RCA), Baseline Survey Results report (Jacobs, 2022)[14]. A total of eight RCAs were associated with the River Thames (TR_01 to TR_08) and one RCA was associated with the River Lee (TR_09), these are shown on Figure 2-6. RCAs were undertaken within areas with potentially sensitive marginal habitat and potentially impacted riverine reaches which could be subject to changes in level and flow (see Evidence Report[15] for further details). Surveys followed the Modular River Physical (MoRPh) field methodology[16] Each MoRPh survey provides a preliminary condition score, which is combined with an assessment of the river type to give a final condition score. A river type is a defined group of river channels displaying similar planform, bed material and morphological features and dynamics reflecting the flow and sediment transfer processes to which it is subject to. For a breakdown of each river's assessed field characteristics, see Table 4-3 in the River Condition Assessment Baseline Survey Results report[17].

Figure 2-6: River Condition Assessment results



2.4.2 Freshwater River Thames

There are three defined reaches of the freshwater River Thames; reaches A to C. RCAs were undertaken on each of reaches A, B and C and the headline results are detailed below.

Reach A – Shepperton Weir to Affinity Water Walton Intake

One RCA is associated with Reach A; TR_01 and this reach includes the weir pool near Shepperton associated with Lock Island and Hamhaugh Island. The result of the MoRPH assessment found this section of the River Thames to be 'Large' type and in Fairly Poor condition. Large rivers are those that are too wide or deep for reliable bed material information to be collected during a MoRPh field survey.

[14] Jacobs. (2022). London Effluent Reuse SRO. River Condition Assessment Baseline Survey Results. B22849BM 2.

[15] Ricardo (2021) London Effluent Strategic Resource Option, Gate 2 Aquatic Ecology Evidence Report

[16] Gurnell, A. M., & Shuker, L. J. (2022). The MoRPh Survey. Technical Reference Manual 2022 version. Available at https://modularriversurvey.org/professional-help/ . (Accessed 04 May 2022).

[17] Jacobs. (2022). London Effluent Reuse SRO. River Condition Assessment Baseline Survey Results. B22849BM 2.

Reach B – Affinity Water Walton Intake to Thames Water Walton Intake

Three RCAs are associated with Reach B; TR_02, TR_03 and TR_04. Site TR_03 is within Sunbury Creek and not the main channel. The weir pool found within this reach is located at Molesey weir. The results of the MoRPH assessment are:

- TR_02: 'Large' type and Poor condition
- TR_03 (Sunbury Creek): 'H' type and Fairly Good condition
- TR_04: 'Large' type and Fairly Poor condition

'H' type rivers are those which typically have a straight/sinuous planform, sand dominated substrate with gravel/cobble and are unconfined or partially confined in their valley.

Reach C – Thames Water Walton Intake to Teddington Weir

Four RCAs are associated with Reach C; TR_05, TR_06, TR_07 and TR_08. The weir pool found within this reach is located at Sunbury weir. The results of the MoRPH assessment are:

- TR_05: 'Large' type and Poor condition
- TR_06: 'Large' type and Fairly Poor condition
- TR_07: 'K' type and Fairly Poor condition
- TR_08: 'Large' type and Fairly Poor condition

'K' type rivers are those which typically have a straight/sinuous planform, silt/clay dominated substrate with sand/gravel and are unconfined or partially confined in their valley.

2.4.3 Freshwater Lee Diversion Channel

There are three defined reaches of the Lee Diversion Channel, Reach G, Reach H and the tidal Reach I. RCAs were only undertaken within Reach G as part of the London Effluent Reuse scheme Gate 2 RCA survey.

Reach G - Newmans Weir on the Enfield Island Loop to Chingford Abstractions

One RCA is associated with reach G; TR_09, which is downstream of Nemans weir pool. The result of the MoRPH assessment found this section of the River Lee to be 'H' type and in Fairly Poor condition.

2.5 ESTUARINE FISH

2.5.1 Overview

Primary data searches were conducted using the Environment Agency (EA) Ecology Transitional and Coastal (TraC) monitoring dataset for all monitoring sites located within individual study reaches. All records over the preceding 11 years (i.e. between 1 January 2010 and 31 December 2021) were collated and analysed to determine the species recorded within the Thames Tideway and their relative abundance. The aim of the data review is to define the overarching community structure and identify patterns were present. These data are supplemented by data obtained from other monitoring programmes[18].

2.5.2 Estuarine Thames Tideway

Reach D – Teddington Weir to Battersea Park

Reach D is characterised by the presence of Teddington weir at the upstream extent which represents the tidal limit of the Thames Tideway. The main river channel has been heavily modified within this reach and includes the half-tide sluice at Richmond which impounds water between Teddington and Richmond for navigation purposes, and referred to as the Richmond Pound. Reach D is subject to numerous further bank and channel modifications further down river as it enters West London until the reach ends at Albert Bridge next to Battersea Park.

A total of 70 fisheries surveys across four sites constitute the baseline dataset for Reach D as can be seen in Figure 2-7. The EA TraC fish data constitutes the only source of data for this reach and this data indicates that the fish community is predominantly freshwater in nature but it also indicates the transitional nature of the

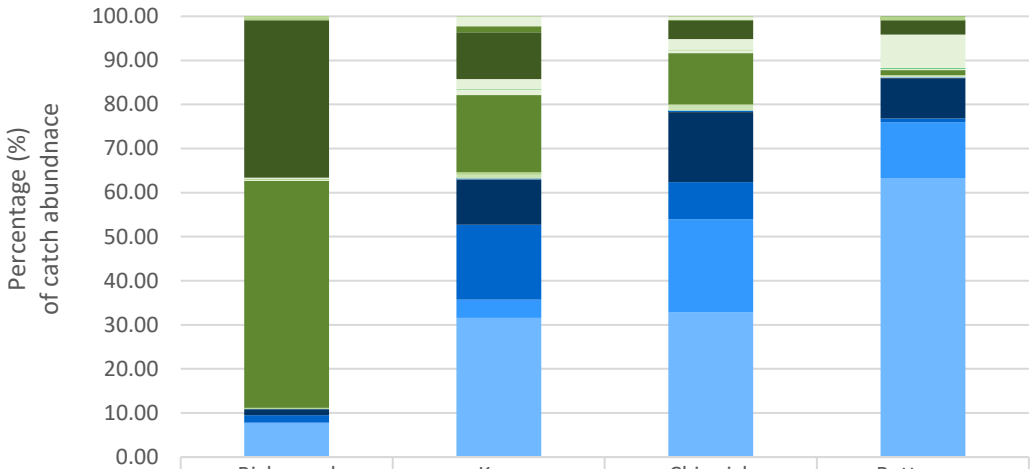
[18] ZSL (2021). The State of the Thames 2021: Environmental trends of the Tidal Thames. McCormick, H., Cox, T., Pecorelli, J., and Debney, A.J. (Eds). ZSL, Regent's Park, London, UK.

Upper Tideway with the inclusion of estuarine and marine juvenile species. Figure 2-7 shows that the species assemblage moves from a freshwater species dominant community towards a marine dominant community down river from Teddington Weir. At the furthest upstream site at Richmond (located 5 km downstream of Teddington weir) the catch abundance data is dominated by roach and dace which account for on average 33% and 43% of the total yearly catch abundance respectively. Less frequent is the occurrence of other species typical of freshwater rivers such as chub, bream, bullhead and gudgeon amongst others. Although on average the data at this site shows a greater abundance of species typical of a freshwater river, there is also representation of numerous marine species including flounder, smelt, sea bass (*Dicentrarchus labrax*), common goby (*Pomatoschistus microps*) and sand smelt (*Atherina presbyter*). On average marine species account for <25% of annual catch abundance. Though, several years record notably higher abundances of estuarine/marine species, such as in 2012 were flounder account for ~82% of catch abundance and 2016 were sea bass account for ~28% of catch abundance.

At the second most up river site at Kew, located 10 km downstream of Teddington weir the catch abundance data in Figure 2-7 shows a transition toward a dominance of marine species with flounder being the most frequently captured species making up 32% of catch abundance. Sea bass, common goby and smelt also account for a large portion of catch abundance at this site accounting for 17 %, 10 % and 4 % respectively. Roach and dace catch abundance remains relatively high at the site accounting for 11% and 18% respectively. Less frequent is the occurrence of other species typical of freshwater rivers such as chub, bream, bullhead and gudgeon amongst others. Although on average the data at this site shows a greater abundance of species typical of a freshwater watercourse, there is also representation of numerous marine species including flounder, smelt, sea bass, common goby and sand smelt. On average marine species account for <25% of annual catch abundance. Though, several years record notably higher abundance of marine species, such as in 2012 were flounder account for ~82% of catch abundance and 2016 were sea bass account for ~28% of catch abundance. European eel and one record of brown trout have also been recorded within this reach.

At the Chiswick and at Battersea sites, located 12 km and 22 km downstream of Teddington weir respectively, the fish community shows a continued progression towards a species assemblage indicative of estuaries. Species such as flounder, smelt, sea bass and common goby account for >75% of catch abundance at Chiswick and >85% of catch abundance at Battersea. Freshwater species remain present at both sites, though accounting for a smaller proportion of overall catch abundance roach, common bream, dace, perch and 3-spined stickleback are still recorded in most years.

Figure 2-7: Reach D Teddington Weir to Battersea Park, fisheries monitoring data represented as the proportion of species (freshwater: green/ marine: blue) recorded within the total reported catch abundance per monitoring site.



	Richmond	Kew	Chiswick	Battersea
Mirror carp	0.01	0.00	0.00	0.00
Stickleback sp.	0.04	0.00	0.00	0.00
Minnow	0.16	0.00	0.00	0.00
Gudgeon	0.42	0.06	0.00	0.00
Pike	0.00	0.03	0.05	0.00
Brown / sea trout	0.01	0.00	0.05	0.03
Rudd	0.01	0.00	0.00	0.03
Zander	0.00	0.03	0.00	0.03
Roach x common bream hybrid	0.00	0.00	0.00	0.61
Bleak	0.13	2.13	0.71	0.06
Perch	0.13	1.35	0.24	0.20
Roach	35.71	10.66	4.12	3.21
Common bream	0.21	2.22	2.42	7.50
Chub	0.27	0.06	0.19	0.06
European elvers	0.00	0.09	0.00	0.18
3-spined stickleback	0.21	1.26	0.62	0.29
Dace	51.53	17.51	11.61	1.14
Bullhead	0.21	0.54	0.24	0.09
European eels > elvers	0.01	0.48	0.76	0.18
European eel	0.02	0.39	0.47	0.23
Thick lipped grey mullet	0.00	0.06	0.00	0.00
Thin lipped grey mullet	0.00	0.00	0.05	0.00
Sprat	0.00	0.00	0.14	0.00
Sand smelt	0.01	0.12	0.00	0.15
Sand goby	0.00	0.03	0.19	0.09
Common goby	1.39	10.27	15.82	9.08
Sea bass	1.66	17.00	8.38	0.88
Smelt	0.01	4.14	21.03	12.64
Flounder	7.84	31.56	32.92	63.34

Reach E – Battersea Park to Tower Bridge

There are no fish data within this reach and therefore no baseline assessment. Reach E does not fall within any WFD surveillance fish monitoring programmes but did fall within previous statutory monitoring programmes

in support of the European Freshwater Fish Directive[19]. As part of the National Rivers Authority (NRA) Thames Tideway monitoring programme, a site at Vauxhall (TQ 30275 78234) was surveyed during 1992 and 1993 as part of the then regional fish monitoring programme[20]. A total of six fish species were recorded at Vauxhall consisting of two freshwater, two migratory and two estuarine fish species (Table 2-1).

Table 2-1: Reach E NRA fisheries presence/absence data representing the species recorded

Fish Species	Species Guild: Freshwater (FW), Migratory (M) or Estuarine (ES)
Atlantic salmon	M
Bass	ES
Dace	FW
European eel	M
Flounder	ES
Perch	FW

Reach F Tower Bridge to 3km seawards of Beckton STW

Reach F is characterised by the presence of Tower Bridge at the upstream extent and the main river channel has been heavily modified within this reach for navigation and is subject to numerous influences as the river flows from the City of London central business district. Reach F ends at Thamesmead which is ~3km downstream of Beckton STW.

A total of 71 fisheries surveys across two sites constitute the baseline dataset for the reach as can be seen in Figure 2-8. EA transitional and coastal monitoring data constitutes the only source of data for this reach and the EA data indicates that the fish community within this reach as a whole is diverse demonstrates the transitional nature of this reach being within the middle of the Thames Tideway.

As can be seen within Figure 2-8, the species assemblage continues to transition into a marine dominant community as the Thames Tideway flows seaward. At the furthest upstream site, Greenwich, located 7 km downstream of Tower Bridge, the catch abundance data indicates that the community is dominated by species indicative of estuaries. However, species typical of freshwater are still present accounting for ~23% of catch abundance with species including perch, dace, roach, common bream, 3-spined stickleback, chub, pike, zander and rudd.

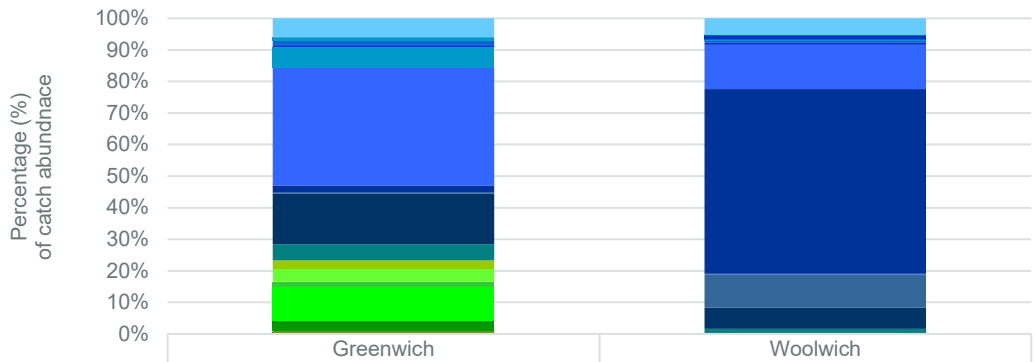
Species typical of estuarine/marine environments represent ~73% of catch abundance, the majority of which is made up of flounder, smelt, common goby, sea bass, sand smelt. Less frequent are: hooknose / pogge (*Agonus cataphractus*), Dover sole (*Solea solea*), pouting / bib (*Trisopterus luscus*), sand goby (*Pomatoschistus minutus*), thin lipped grey mullet (*Liza ramada*), herring (*Clupea harengus*), sprat (*Sprattus sprattus*), big scaled sand smelt (*Atherina boyeri*), short-snouted seahorse (*Hippocampus hippocampus*), thick lipped grey mullet (*Chelon labrosus*).

At the second and furthest down river site at Woolwich, located 17 km downstream of Tower Bridge, the catch abundance data shows a transition toward a dominance of estuarine/marine species with freshwater species largely absent except for low recorded abundances of perch, 3-spined stickleback and European eel accounting for <0.1% of total catch abundance. Sand goby, flounder, seabass, Dover sole and smelt account for a large portion of catch abundance at this site accounting for ~95% of catch abundance. Less frequent are species such as red mullet (*Mullus barbatus*), whiting (*Merlangius merlangus*), common goby, dab (*Limanda limanda*), dragonet (*Callionymus lyra*), cod (*Gadus morhua*) and herring amongst others.

[19] Council Directive 78/659/EEC. Council Directive of 18 July 1978 on the quality of fresh waters needing protection or improvement in order to support fish life.

[20] Colclough, S., Dutton, C. & Coates (1993). Tidal Thames quarterly fisheries surveys. National Rivers Authority, Thames Region – South East Area Internal Report.

Figure 2-8 Reach F Tower Bridge to 3km seawards of Beckton STW, fisheries monitoring data represented as the proportion of species (freshwater: green/ marine: blue) recorded within the total reported catch abundance per monitoring site.



	Greenwich	Woolwich
Smelt	6.11	5.29
Plaice	0.00	0.03
Lesser (Nillsons) pipefish	0.00	0.00
Thornback ray / Roker	0.00	0.01
Dab	0.00	0.03
Painted goby	0.00	0.04
Red gurnard	0.00	0.00
Dragonet	0.00	0.01
Cod	0.00	0.00
Reticulated dragonet	0.00	0.00
Greater pipefish	0.00	0.00
Whiting	0.00	1.14
Tub gurnard	0.00	0.29
Red mullet	0.00	0.12
Thick lipped grey mullet	0.09	0.02
Short-snouted seahorse	0.02	0.00
Big scaled sand smelt	0.97	0.00
Sprat	1.28	0.64
Herring	0.23	0.68
Thin lipped grey mullet	0.31	0.00
Hooknose / Pogge	0.02	0.03
Sand smelt	6.64	0.00
Flounder	37.25	14.10
Sand goby	2.26	58.52
Pouting / Bib	0.02	0.30
Dover sole	0.26	10.37
Sea bass	16.17	6.68
Common goby	5.08	1.59
European eel	2.65	0.05
Perch	4.05	0.01
Dace	1.42	0.00
Common bream	10.97	0.00
European eels > elvers	0.36	0.00
European elvers	0.36	0.00
Roach	2.40	0.00
3-spined stickleback	0.76	0.00
European glass eels	0.02	0.00
Brown / sea trout	0.03	0.00
Roach x common bream hybrid	0.17	0.00
Rudd	0.03	0.00
Chub	0.03	0.00
Pike	0.02	0.00
Zander	0.02	0.00

Reach I - Estuarine Bow Creek (tidal Lee) Reach I: Three Mills Lock to Thames Tideway

There are no fish samples within this reach and therefore no baseline assessment. The tidal section of the River Lee does not fall within any WFD surveillance fish monitoring programmes or any previous statutory monitoring programmes in support of the European Freshwater Fish Directives[21].

However, an investigative survey was undertaken by the NRA of the tidal section of the River Lee in 1991 from Hackney to Bow Creek[22]. Due to the tidal nature of the river then a qualitive assessment of the fishery was obtained as opposed to a quantitative evaluation. A total of 13 fish species were recorded consisting of nine freshwater fish and four estuarine species.

Table 2-2 Reach I NRA fisheries monitoring presence/absence data representing the species recorded.

Fish Species	Species Guild Freshwater (FW), Migratory (M) or Estuarine (ES)
Bleak	FW
Bream	FW
Dace	FW
European eel	M
European smelt	M
Flounder	ES
Mullet sp. (Liza sp.)	ES
Perch	FW
Pike	FW
Roach	FW
Sand Smelt (Atherina p)	ES
Threespined stickleback	FW
Tench	FW

2.6 MIGRATORY FISH

2.6.1 Overview

The River Thames is utilised by a number of migratory species including

- European Eel (*Anguilla anguilla)*
- Atlantic Salmon (*Salmon salar*)
- Sea Trout (*Salmo trutta*)
- River Lamprey (*Lampetra fluviatilis*)
- Sea Lamprey (*Petromyzon marinus*)
- European Smelt (*Osmerus eperlanus*)
- Twaite Shad (*Alosa fallax*)

The extent to which these species utilise the Thames catchment is dependent upon fish passability and presence of spawning habitat. A systematic review of the available open-source data collated by the EA during freshwater (FW) and transitional and coastal (TRaC) surveys was completed for the entirety of the Thames River Basin District (RBD).

[21] Council Directive 78/659/EEC COUNCIL DIRECTIVE of 18 July 1978 on the quality of fresh waters needing protection or improvement in order to support fish life.

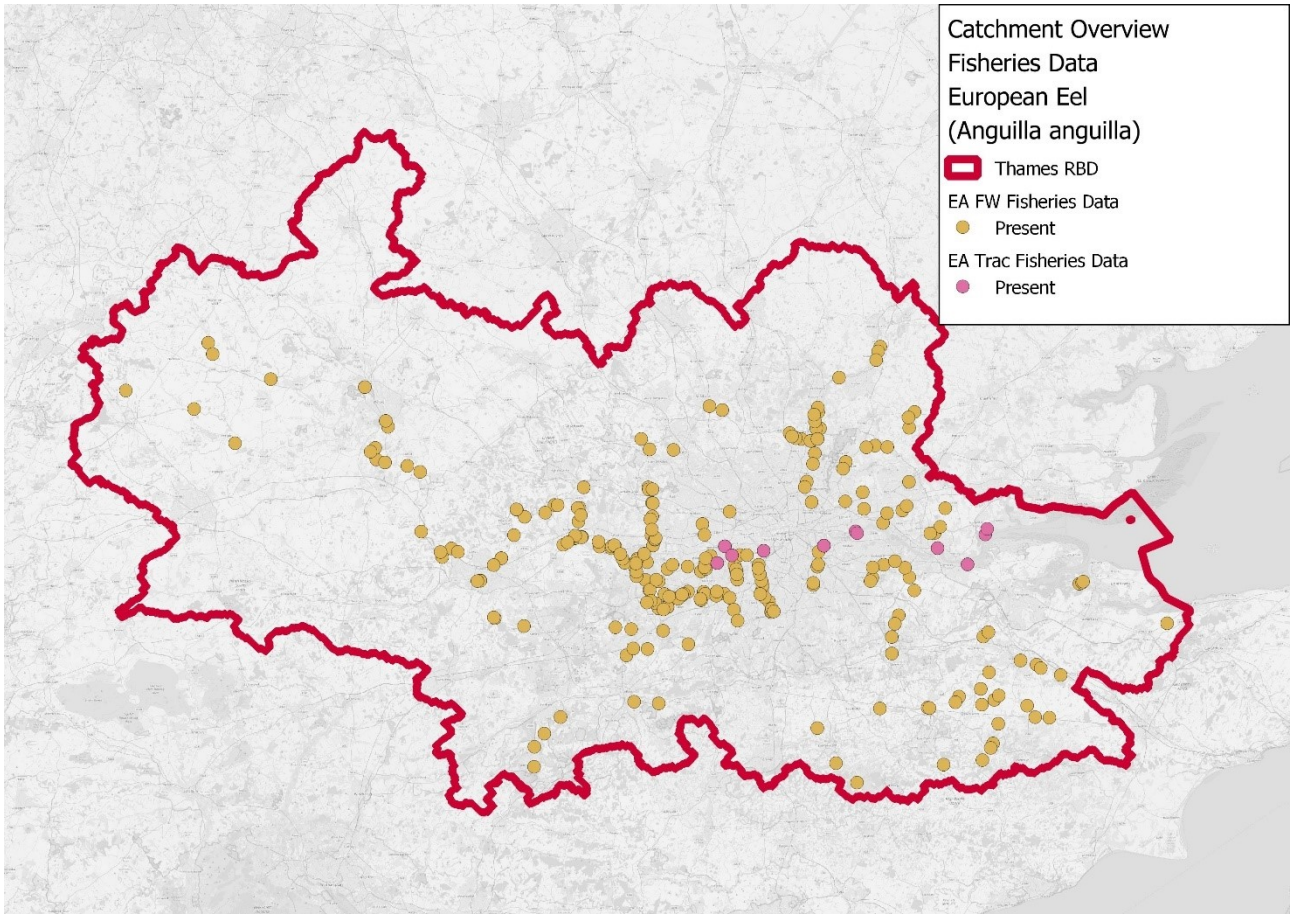
[22] Tyner, R. (1992). Thames East Lower Lee Survey 1991. National Rivers Authority Internal Report.

The purpose of this review was to provide an overview of the penetration and distribution of migratory species into the estuary. These data are supplemented by data obtained from the 2022 eDNA monitoring programme.

European Eel (*Anguilla anguilla*)

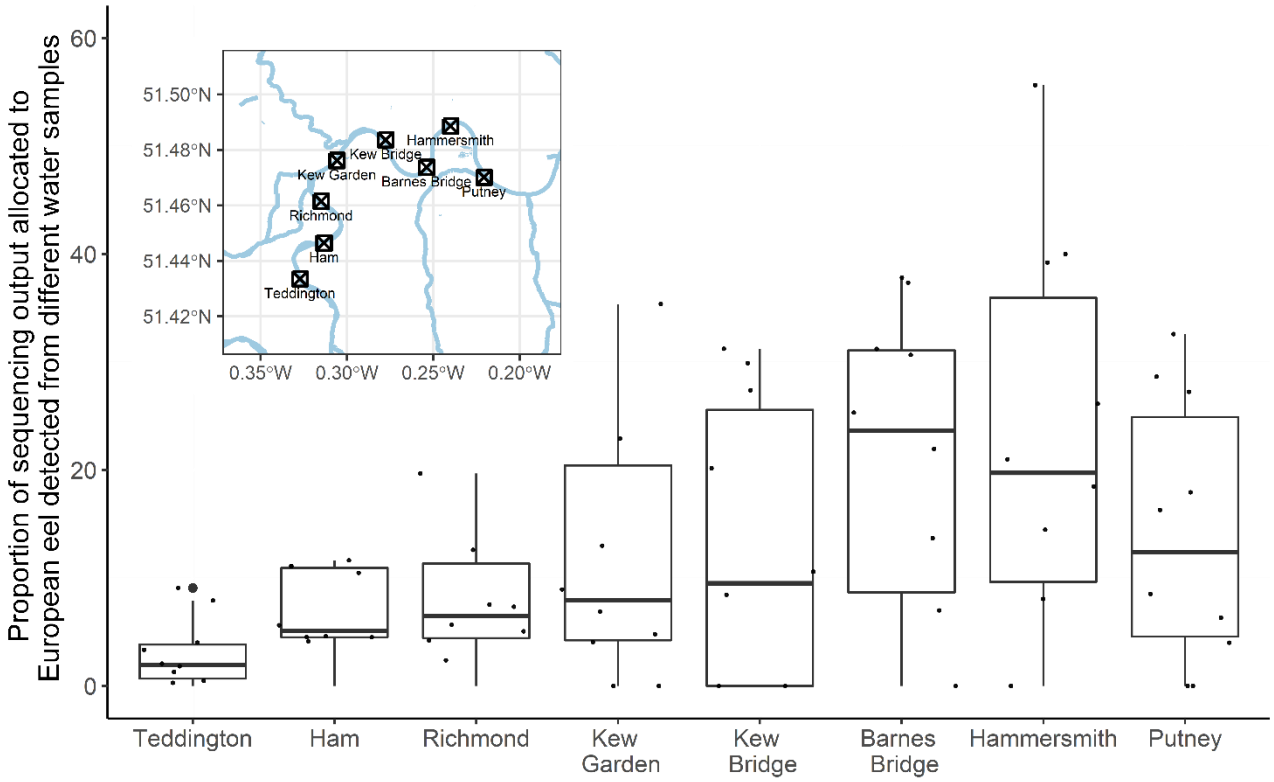
European eel are prolific throughout the Thames river basin district as can be seen within Figure 2-9 below. The species has been recorded at 276 sites within both freshwater and transitional waterbodies. Eel are recorded in several upland streams a significant distance from the tidal Thames including at the River Churn close to the western edge of the catchment. Though European eel are recorded throughout the catchment, the highest densities of individuals are typically recorded within major tributaries of the River Thames within the lower catchment. Sites which record the highest frequency of recorded European eel are located within the River Wandle, River Ash, River Roding, Chetney Marshes, River Hogsmill, River Lee, River Wey, River Thames, River Colne, River Medway, Darent, Mardyke & Fobbing Catchment and Beverley Brook.

Figure 2-9 Fisheries monitoring sites within the Thames River Basin District at which European eel have been captured.



Outputs from eDNA surveys conducted over a nine week repeat sampling period in spring 2022 at eight sampling locations within Reach D of the estuarine Thames Tideway, support the findings of the EA open-source data. Eel eDNA was captured at all eight locations, thereby suggesting their presence and distribution throughout the reach (Figure 2-10).

Figure 2-10 European eel eDNA was detected at all eight sites surveyed within Reach D of the estuarine Thames Tideway during the 2022 monitoring programme



Atlantic Salmon *(Salmo salar)*

Atlantic salmon are relatively sparse within the catchment, being recorded present at only seven monitoring sites with a total of 18 individuals having been captured since 1992 (Figure 2-11). Three sites which record the species are located on the River Kennet with the remaining sites being located on the River Thames.

Outputs from repeat sample surveys conducted in spring 2022, over a nine week period within the estuarine Thames Tideway, confirmed the presence and distribution of Atlantic salmon eDNA at all eight sites surveyed within Reach D (Figure 2-12).

Figure 2-11 Fisheries monitoring sites within the Thames River Basin District at which Atlantic salmon have been captured.

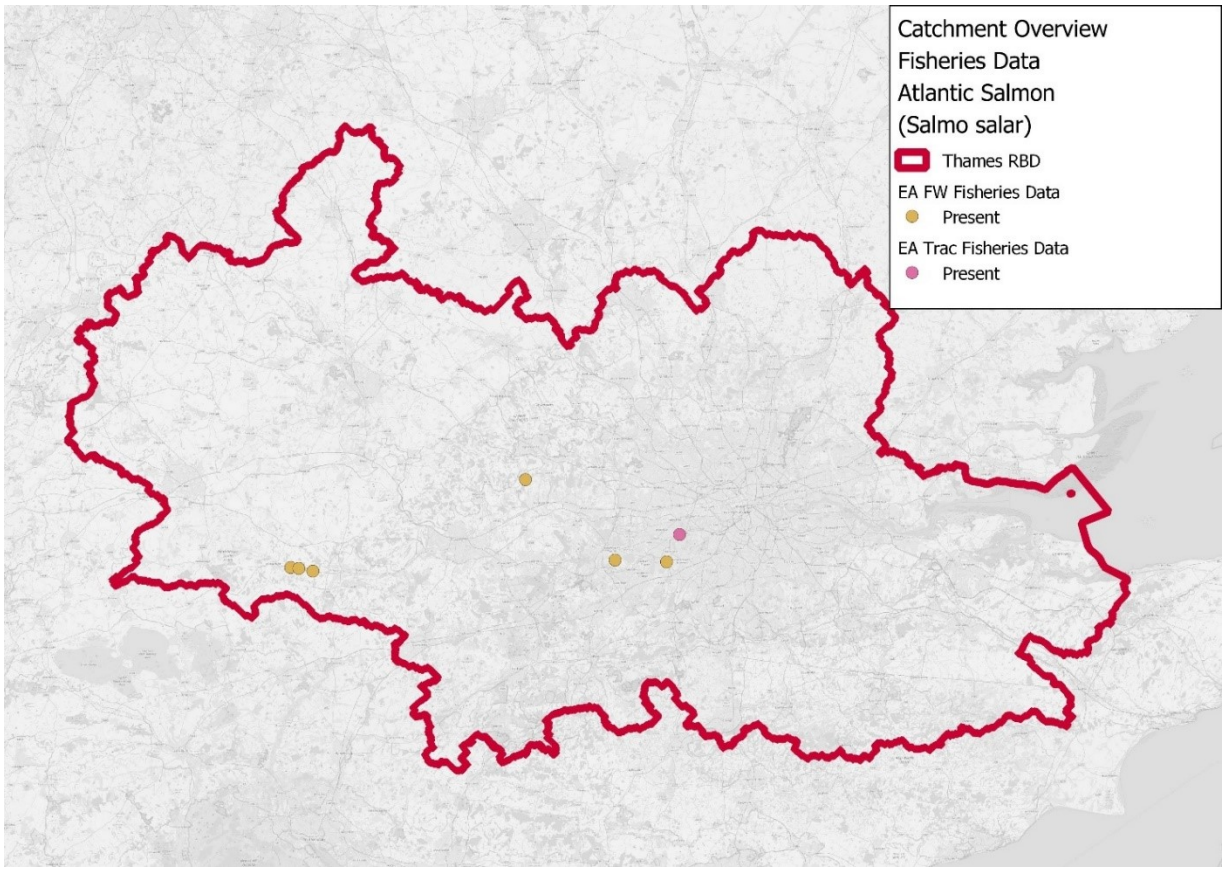
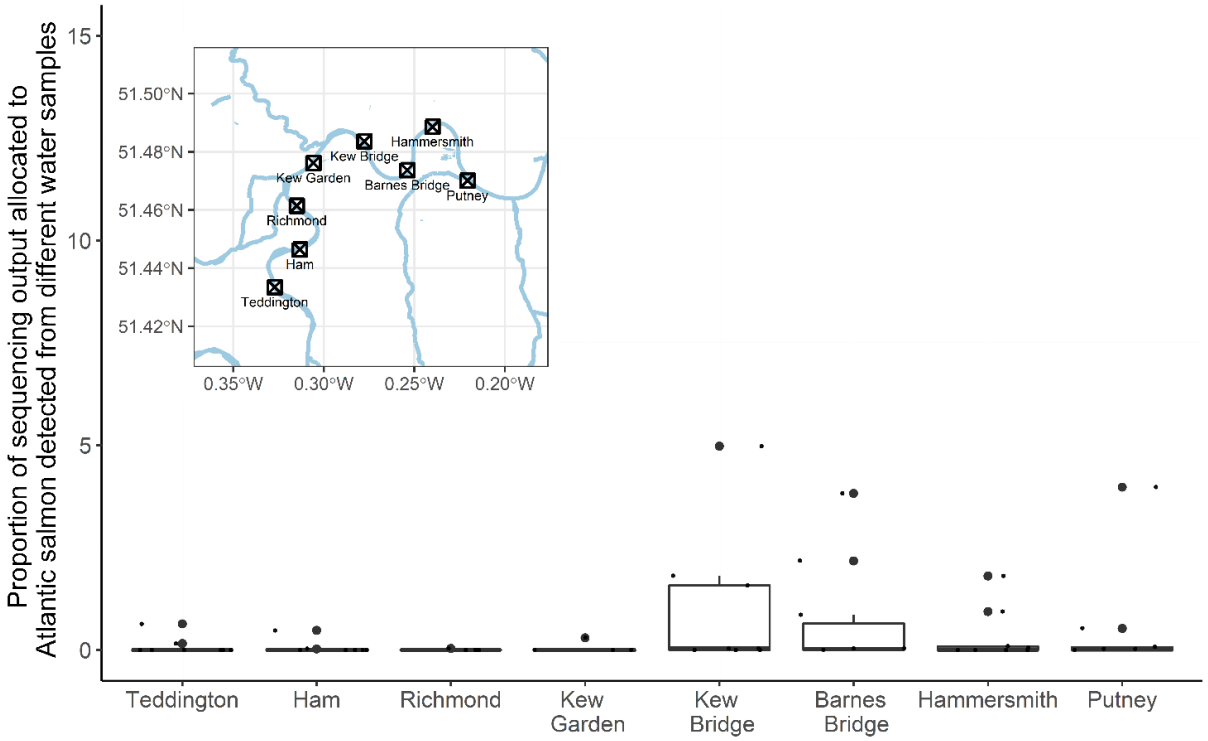


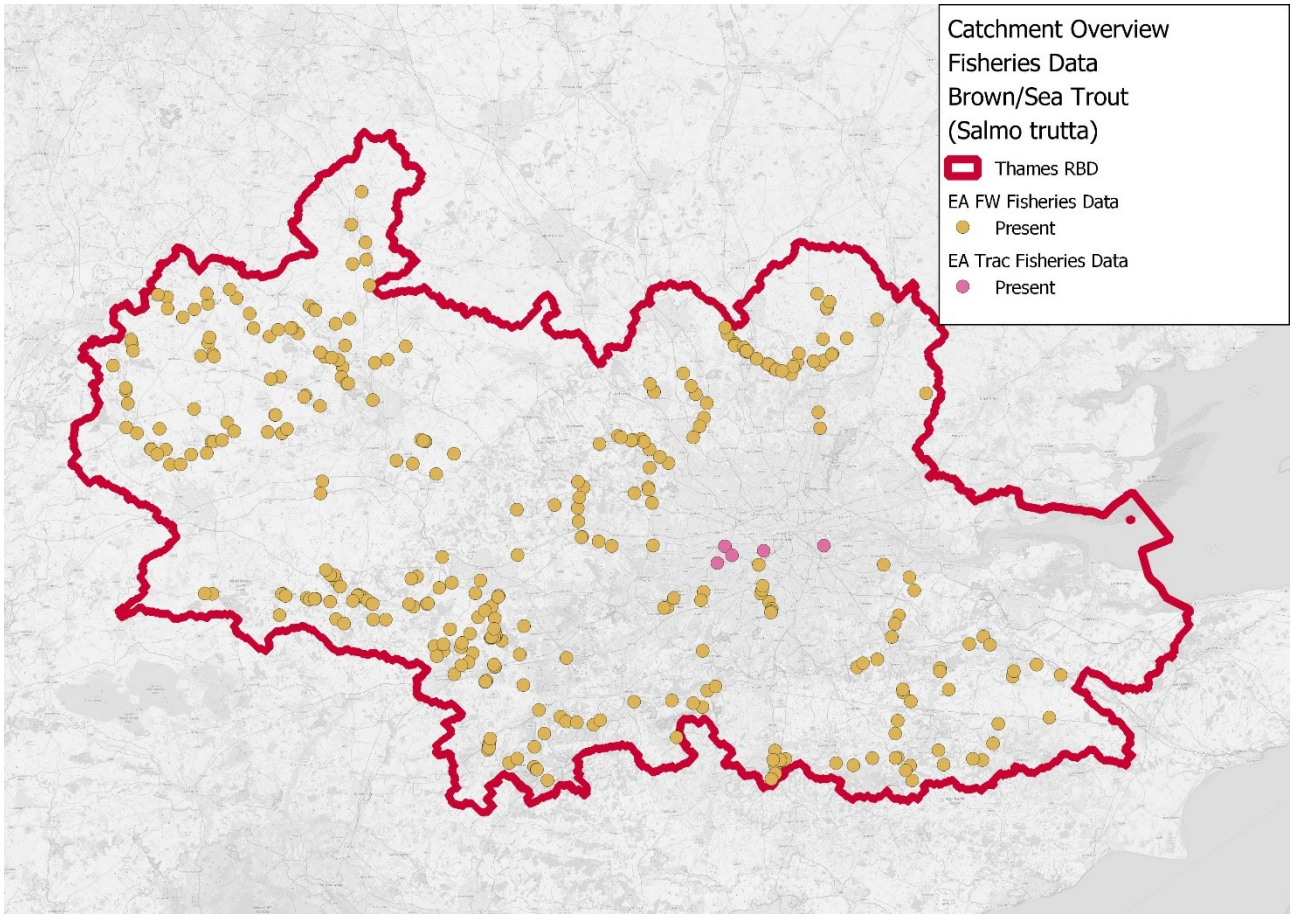
Figure 2-12 Atlantic salmon eDNA was detected at all eight sites within Reach D of the estuarine Thames Tideway during the 2022 monitoring programme



Brown/Sea Trout *(Salmo trutta)*

Brown trout are prolific within the catchment being recorded at 337 monitoring sites since 1978 (Figure 2-13). However, it is not possible to distinguish between freshwater resident brown and anadromous sea trout with the EA's freshwater or TRaC monitoring dataset. Therefore, the proportion of the recorded brown trout which exhibit anadromous life cycle is not known, but there is a network of fish passes suited to aiding the migration of sea trout to spawning habitat in the catchment, with reports of individuals having been captured in headwater spawning grounds, upstream of the study reaches[23].

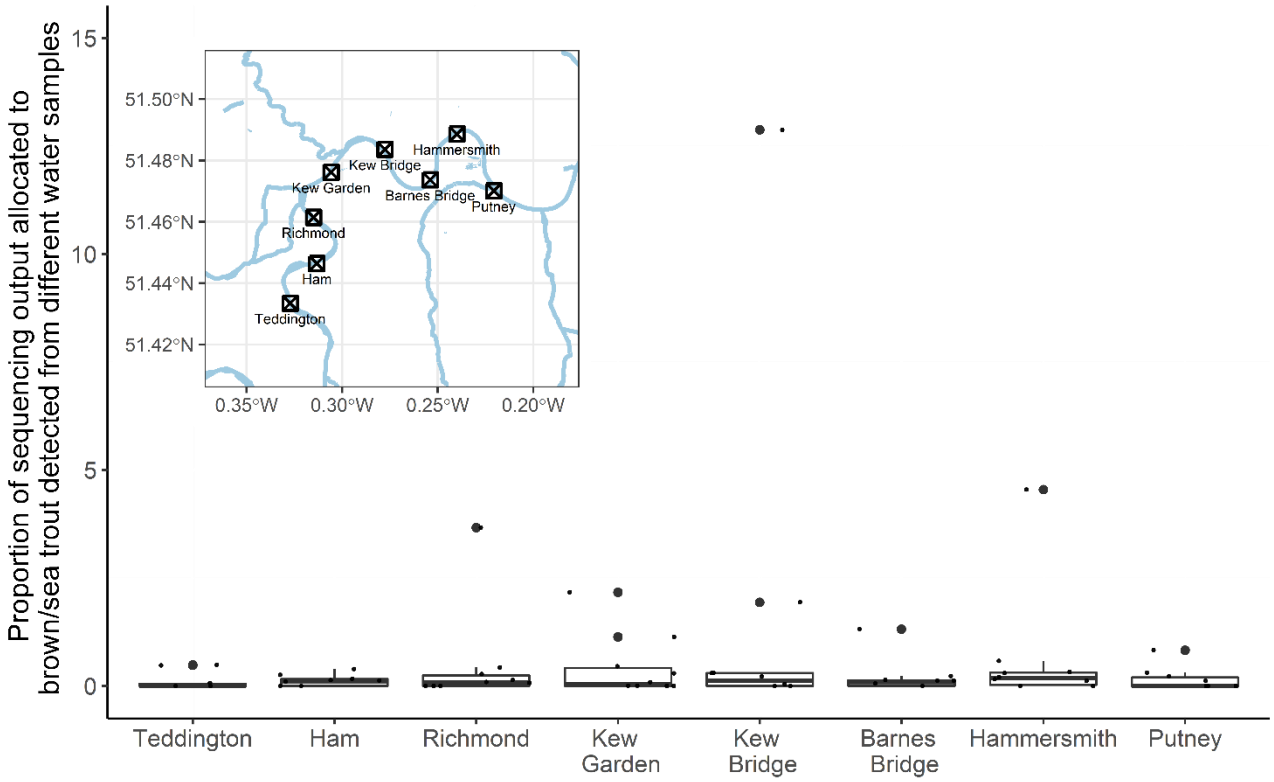
Figure 2-13 Fisheries monitoring sites within the Thames River Basin District at which Brown/Sea trout have been captured.



Outputs from repeat sample surveys conducted in spring 2022, over a nine week period within the estuarine Thames Tideway, confirmed the presence and distribution of brown/sea trout eDNA at all eight sites surveyed within Reach D (Figure 2-14).

[23] Steve Sheridan (2022). EA. As per comms.

Figure 2-14 Brown/sea trout eDNA was detected at all eight sites within Reach D of the estuarine Thames Tideway during the 2022 monitoring programme



River Lamprey (*Lampetra fluviatilis)*

Survey data for the River Thames catchment shows *Lampetra sp.* are sparse within the catchment and only being recorded present at only 16 freshwater monitoring sites (Figure 2-15). A total of *Lampetra sp.* 129 individuals have been captured since 1993, with the majority of the recorded occurrences located at sites within or along tributaries of the River Medway. Several sites are located upon tributaries of the River Mole which flows into the River Thames as the River Ember near Hampton Court. However, it should be noted that *Lampetra sp* such as river and brook lamprey are not distinguished within the dataset, meaning that the portion of records which are migratory river lamprey as opposed to resident brook lamprey is not known.

Outputs from repeat sample surveys conducted in spring 2022 over a nine week period within the estuarine Thames Tideway, confirmed the presence and distribution of *Lampetra* sp. eDNA at all eight sites surveyed within Reach D (Figure 2-16). As per the EA dataset, similarly, river and brook lamprey could not be distinguished using eDNA, as species identification was based on a limited number of reference matches, with supporting matches only available at the genus level. Subsequently, the portion of outputs which are migratory river lamprey as opposed to resident brook lamprey, are again, not known.

Figure 2-15 Fisheries monitoring sites within the Thames River Basin District at which river/brook lamprey (recorded as *Lampetra sp.*) have been captured.

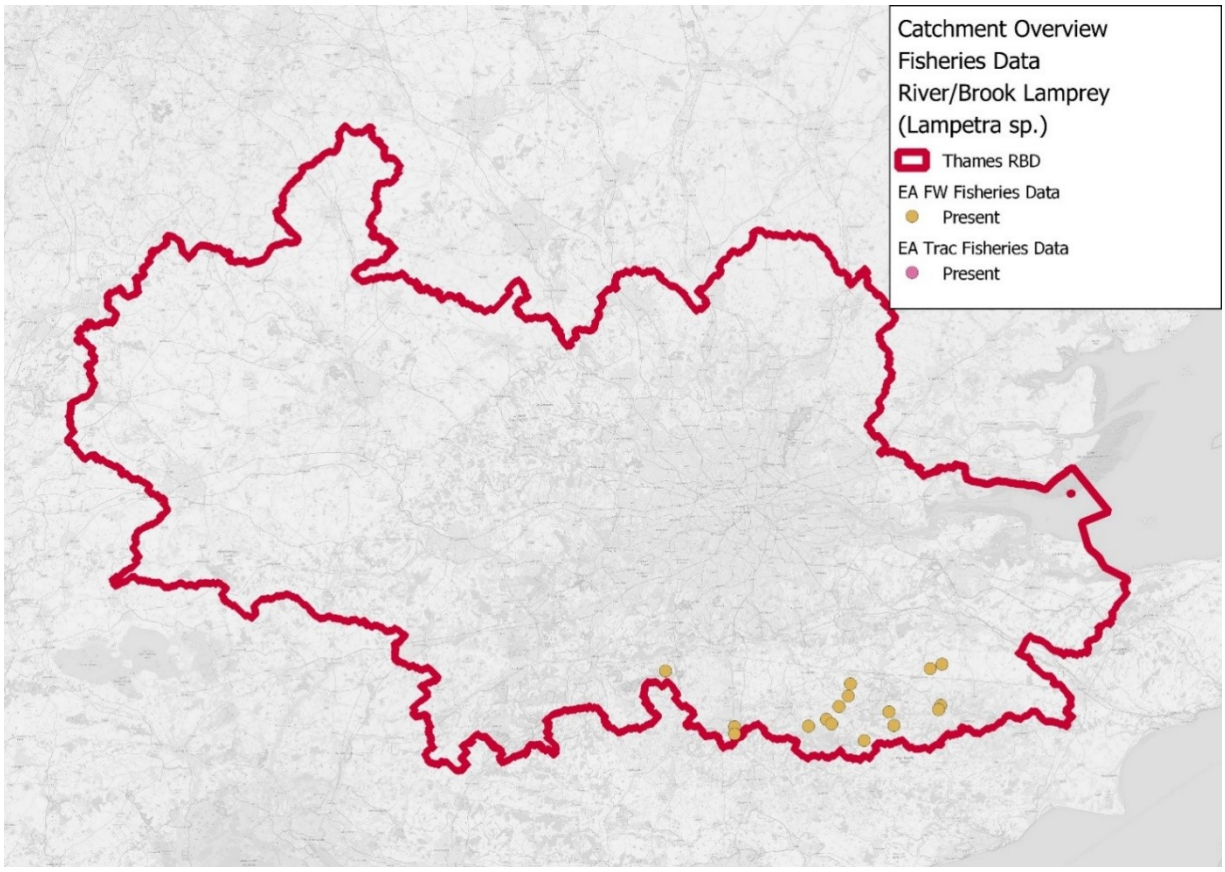
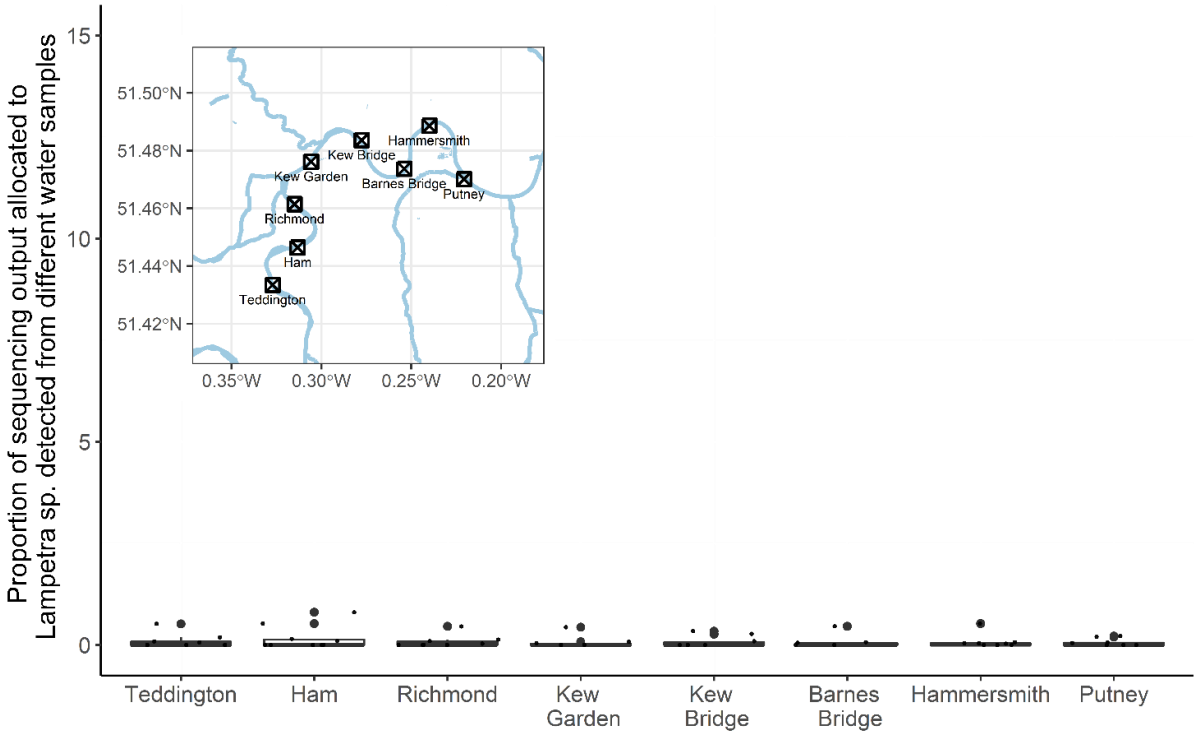


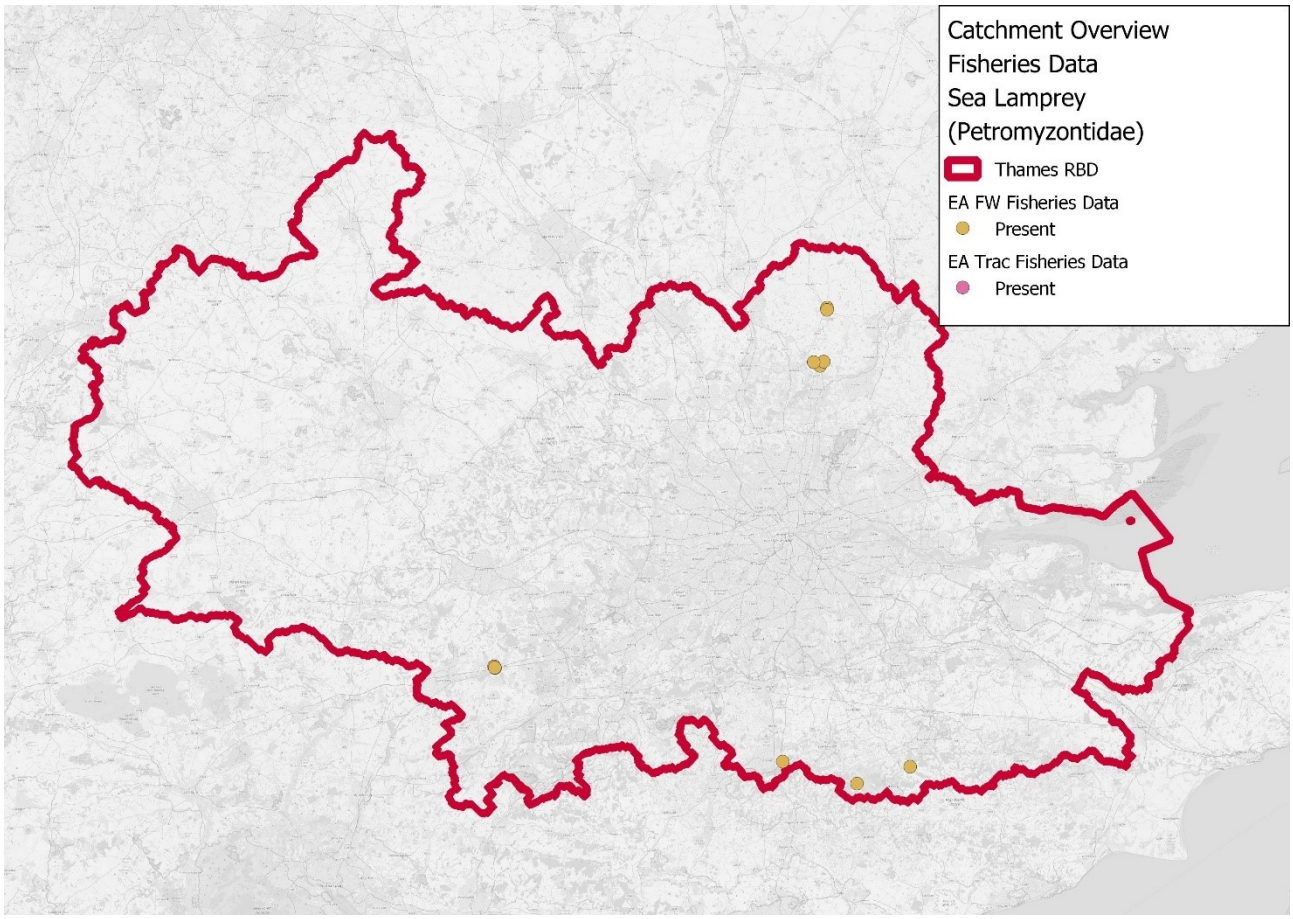
Figure 2-16 *Lampetra* sp. (river/ brook lamprey) eDNA was detected at all eight sites within Reach D of the estuarine Thames Tideway during the 2022 monitoring programme



Sea Lamprey (Petromyzontidae)

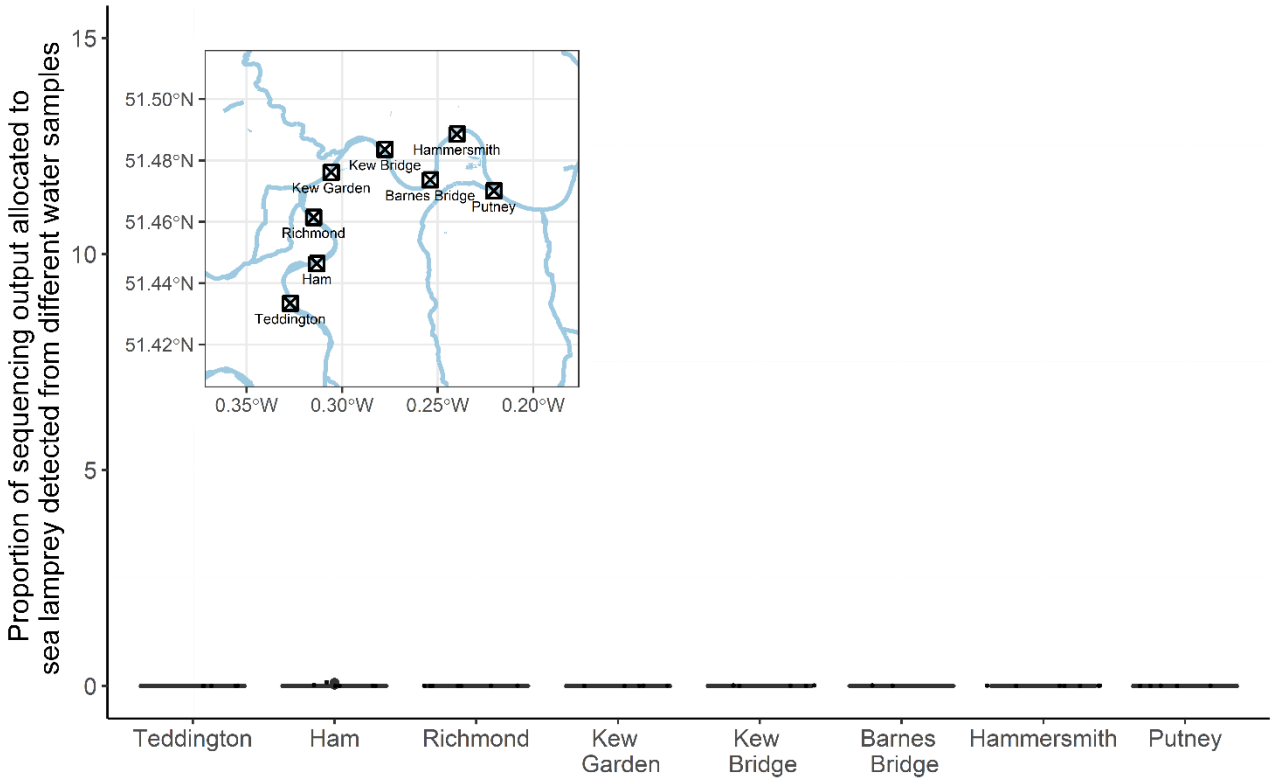
Similarly, to river lamprey, sea lamprey are recorded infrequently within the catchment. Survey data for the River Thames catchment shows Petromyzontidae are recorded present at only 11 freshwater monitoring sites with a total of 50 individuals having been captured within the dataset (Figure 2-17). The majority of the recorded occurrences of Petromyzontidae are located at sites within or along tributaries of the River Medway and River Lee. Several records are recorded within tributaries of the River Medway and one recorded occurrence is located within a tributary of the River Loddon and a tributary of the River Mole. However, the accuracy of the data for Sea lamprey is questionable, at none of the sites in which Petromyzontidae are recorded are there records of Lampetra sp. recorded during the same surveys, despite Lampetra sp. occurring in other years at the same sites. As such confidence in the sea lamprey data for the River Thames is very low.

Figure 2-17 Fisheries monitoring sites within the Thames River Basin District at which sea lamprey (recorded as Petromyzontidae) are recorded.



While confidence in the EA sea lamprey records is low, outputs from repeat sample eDNA surveys conducted in spring 2022, over a nine week period within the estuarine Thames Tideway, however, confirmed the presence of sea lamprey eDNA at a single site. Detections were confirmed within Reach D at Ham (TQ 17314 73285), on week 6 (23rd March 2022) and week 8 (14th April 2022), respectively (Figure 2.18).

Figure 2-18 Sea lamprey eDNA was detected at one (Ham) of the eight sites within Reach D of the estuarine Thames Tideway during the 2022 monitoring programme



Twaite Shad (Alosa fallax)

There are no records of twaite shad within the EA Ecology & Fish Data Explorer. Historically twaite shad were present throughout the Thames Tideway[24] and following water quality improvements during the 1980's there are several sizes classes now evident >15 cm in the Lower Tideway below West Thurrock[25]. A single 12 cm twaite shad was captured during a fish rescue within a cofferdam during the construction of the Tideway Tunnel at Blackfriars[26].

The 2022 eDNA monitoring programme did not detect any presence of twaite shad eDNA within Reach D of the estuarine Thames Tideway.

2.7 EUROPEAN SMELT

2.7.1 Overview

European smelt are present throughout the Thames Tideway as can be seen within Figure 2-19. The species has been recorded at 11 sites within Upper, Middle and Lower transitional waterbodies and at a further 45 sites within the Thames estuary[27]. Smelt gather below Gravesend between January and March prior to migrating upstream to spawn in March to April[28]. Mass spawning takes place on sub-tidal gravels just below the low tide mark, mainly at night between Battersea and Wandsworth and after spawning the adult fish then

[24] Wheeler, A. (1979). The tidal Thames. The history of a river and its fishes. Routledge & Kegan Paul, ISBN 0 7100 0200 9.

[25] Colclough, S.R., Gray, G., Bark, A. & Knights, B. (2002). Fish and fisheries of the tidal Thames: management of the modern resource, research aims and future pressures. Journal of Fish Biology (2002) 60.

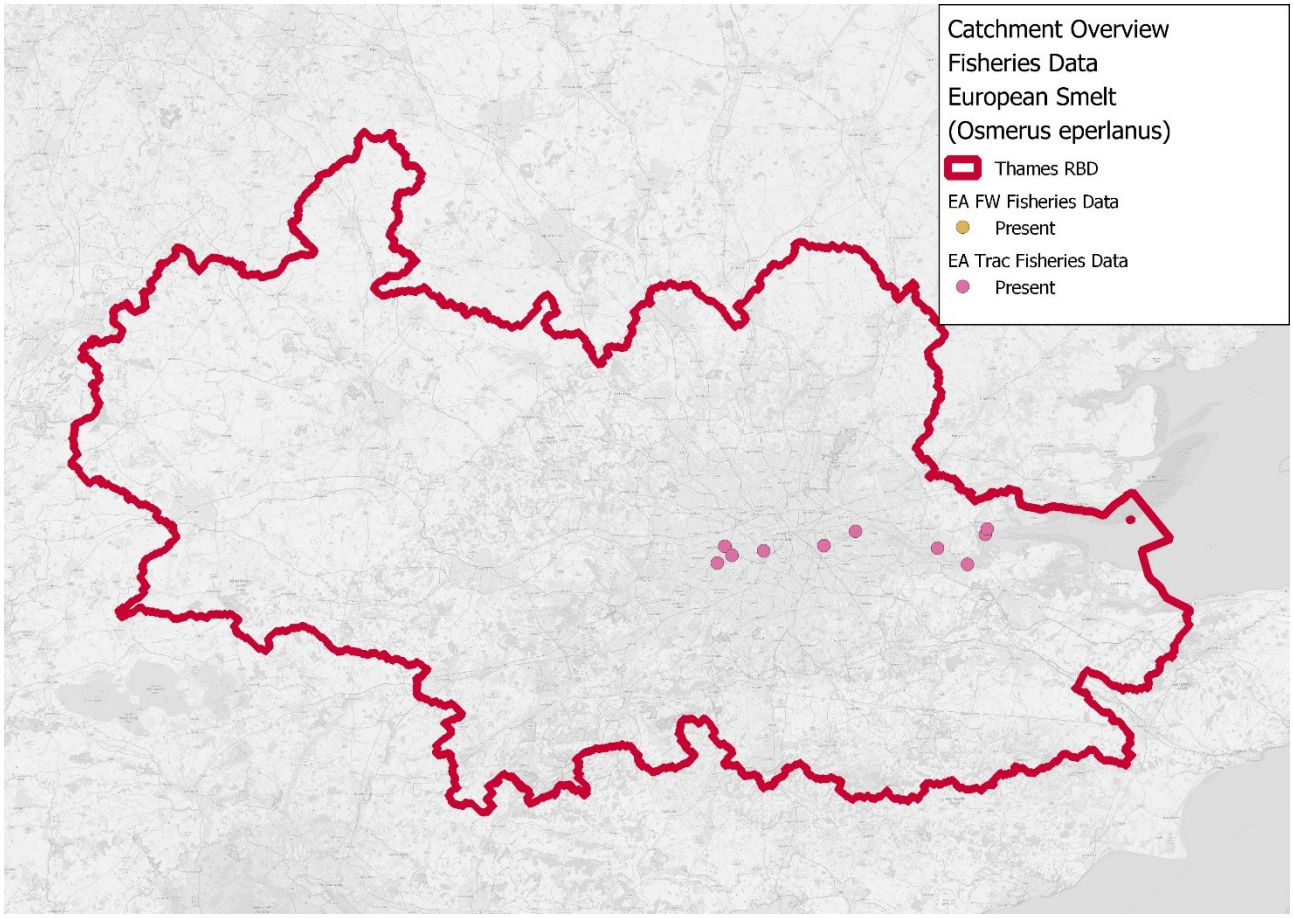
[26] Tom Cousins, Environment Agency: Pers.Comm via email 9th September 2021.

[27] Coates, S., Waugh, A., Anwar, A., Robson, M., (2007). Efficacy of a multi-metric fish index as an analysis tool for the transitional fish component of the WFD. Marine Pollution Bulletin 55, 225–240.

[28] Colclough, S.R. & Coates, S.A. (2013). The status of Smelt Osmerus eperlanus (L.) in rivers and estuaries in England and Wales. Environment Agency, Bristol.

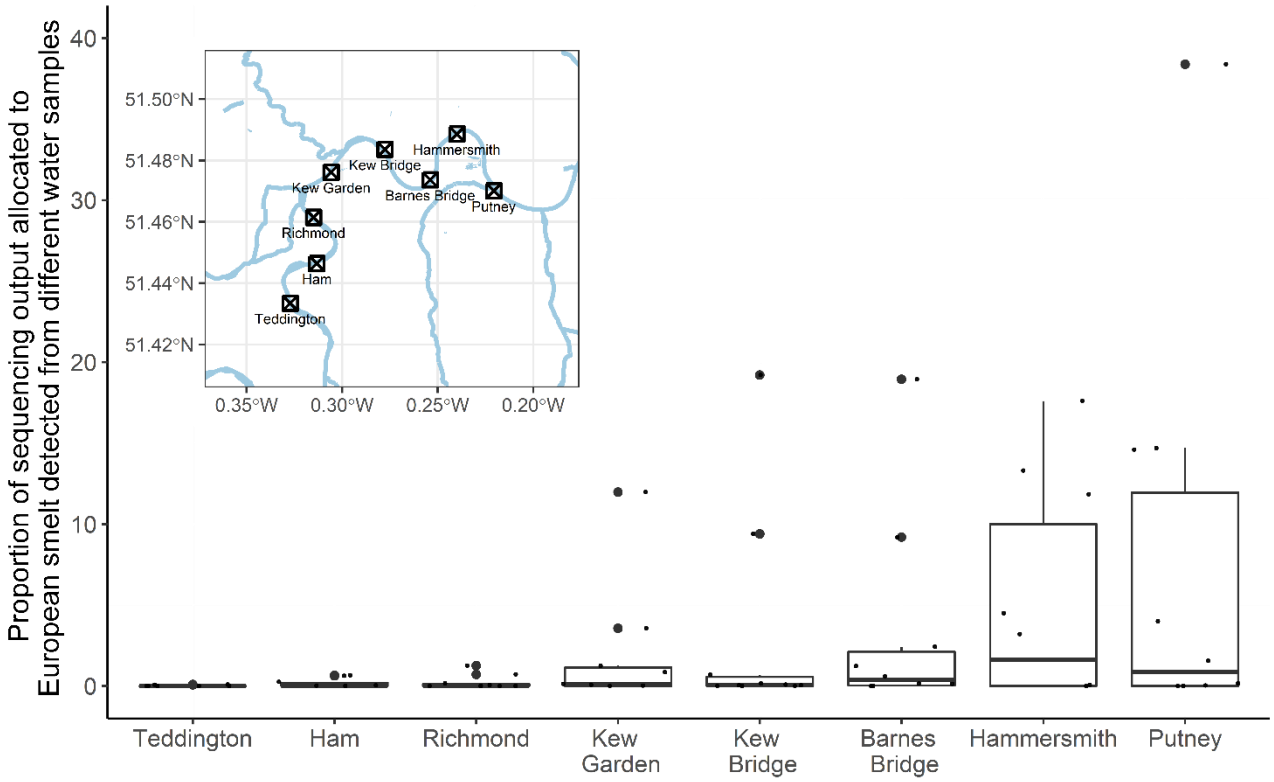
descend to the lower estuary. The smelt eggs initially adhere to the sub-tidal gravels but then sheer off and move passively with the tidal flow.

Figure 2-19 Fisheries monitoring sites within the Thames River Basin District at which European smelt have been captured.



Environmental DNA outputs from repeat sample surveys conducted in spring 2022, over a nine week period within the estuarine Thames Tideway, confirmed the presence and distribution of European smelt at all eight sites surveyed within Reach D (Figure 2.20).

Figure 2-20 European smelt were detected at all eight sites within Reach D of the estuarine Thames Tideway during the 2022 eDNA monitoring programme



2.8 OLFACTORY

2.8.1 Overview

To inform the assessment for each of the tasks set out in Table 1-1 the London Effluent Reuse Water Quality Assessment Report has been used and full details of this assessment is to be found within this report[29]. The olfaction suite of chemical determinands for the freshwater River Thames was assessed for exceedance of their LOD during the monitoring period. Those determinands that did not exceed LOD have not been presented or analysed further.

2.8.2 Freshwater River Thames

Reach A – Shepperton Weir to Affinity Water Walton Intake

The following data sources have been used to establish the olfactory inhibitors reference conditions for the freshwater River Thames:

- Thames Water WFD, EQSD and olfaction analytical suites – Spot sample data (01/2021-02/2022) at six sites: Hampton intake, Surbiton intake, Kingston, Teddington, Walton (Thames Water intake) and Walton (Affinity Water intake)

Of the 53 determinands in the olfactory suite, 27 were found to be consistently below the LOD, leaving 26 determinands for analysis. It should be noted that data availability is not consistent across those determinands at all sites and dates.

Reach B – Affinity Water Walton Intake to Thames Water Walton Intake

Data sources as per Reach A.

[29] Ricardo (2022). London Effluent Reuse Strategic Resource Option, Gate 2 Water Quality Assessment Report

Reach C – Thames Water Walton Intake to Teddington Weir

Data sources as per Reach A.

2.8.3 Estuarine Thames Tideway

Reach D – Teddington Weir to Battersea Park

The following data sources were used to establish the olfactory inhibitors supporting information for the estuarine Thames Tideway:

- Thames Water WFD, EQSD and olfaction analytical suites – Spot sample data (01/2021-02/2022) at one site: Kew Bridge

The olfaction suite of chemical determinands for the estuarine Thames Tideway was assessed for exceedance of their LOD during the monitoring period. Those determinands that did not exceed LOD have not been presented or analysed further.

Of the 53 determinands in the olfactory suite, 29 were found to be consistently below the LOD, with two determinands having no available data, leaving 24 determinands for analysis.

Reach E – Battersea Park to Tower Bridge

Data sources as per Reach D.

Reach F Tower Bridge to 3km seawards of Beckton STW

Data sources as per Reach D.

2.8.4 Freshwater River Lee

Reach G – Newmans Weir on the Enfield Island Loop to Chingford Abstractions

The following data sources have been used to establish the olfactory inhibitors reference conditions for the River Lee:

- Thames Water WFD, EQSD and olfaction analytical suites – Spot sample data (01/2021-02/2022) at one site at Enfield Island.

The olfaction suite of chemical determinands for the freshwater River Lee was assessed for exceedance of their LOD during the monitoring period. Those determinands that did not exceed LOD have not been presented or analysed further.

Reach H – Chingford Abstractions to Three Mills Lock

Data sources as per Reach G.

2.8.5 Estuarine Tidal River Lee

Reach I - Estuarine Bow Creek (tidal Lee) Reach I: Three Mills Lock to Thames Tideway

Data sources as per Reach G.

3. FISH ASSESSMENT OF BECKTON WATER RECYCLING SCHEME

3.1 INTRODUCTION

This section sets out the assessment for the tasks set out in Table 1-1 relevant to the Beckton water recycling scheme. The study area for each task has been set out per task as it is not consistent across tasks. The Beckton water recycling scheme assessment for each of the following tasks has been set out in the following sections:

- Freshwater Fish
- Weir pool/marginal habitat (including Sunbury creek)
- Estuarine Fish (including European eel)
- Migratory Fish (including European eel)
- European Smelt
- Olfactory cues

These assessments have been conducted utilising the Physical Environment[2] and Water Quality Gate 2 Assessment[29] Reports, where full details of the impact assessments determined are to be found.

Summary of physical environment impacts associated with a Beckton water recycling scheme

The full assessment of the Gate 2 physical environment impacts of the Beckton water recycling schemes includes an assessment of:

- Velocity and flow,
- Outfall design,
- Wetted habitat,
- Fish pass and barrier passability, and
- Estuarine sediment.

Table 3-1 shows a high-level summary of these impacts, which are also briefly described as follows:

Velocity and flow

The Beckton water recycling scheme is expected to result in major impacts (all scheme sizes) to flow conditions within the Lee Diversion Channel. These are described in the ~100m reach of heavily modified channel of the Enfield Island Loop between a Beckton water recycling outfall and the existing intake to King George V Reservoir. There may also be impacts in the remaining ~500m heavily modified reach of the Enfield Island Loop downstream to the confluence with the Lee Diversion Channel but the effects cannot be quantified as they are entirely dependent on the abstraction regime operated for the Thames Water intakes.

Outfall design

The potential impacts predicted for outfall design are negligible for all scheme sizes. While this was not set out in detail at Gate 2, the extent of flow increase, a 0.3m/s exit velocity and the shallow channel depth would result in full dispersal of plume within metres of the outfall in a heavily modified channel.

Wetted habitat

For the 300 Ml/d scheme size there are no predicted changes in wetted width, but a ~120% increase in mean flow velocity in ~100m reach of heavily modified channel of the Enfield Island Loop at very low flow conditions modelled. There are indiscernible changes in exposure of estuarine wetted habitat.

Fish pass and barrier passability

The potential impacts predicted for fish pass and barrier passability are negligible for all scheme sizes.

Estuarine sediment

The potential impacts predicted for estuarine sediment are negligible for all scheme sizes, with negligible changes in suspended solids concentration within the estuary.

Table 3-1 Summary of potential physical environment impacts for Beckton water recycling schemes

Size	Flow	Outfall design	Wetted habitat	Barrier passability	Estuarine sediment
100 Ml/d	Major. 80% increase in very low flows(Q95) in ~100m reach of Enfield Island Loop, with 0-80% increase in flows downstream in ~500m reach of Enfield Island Loop and downstream Lee Diversion. Zero change beyond Flanders Weir.	Negligible. Not set out in detail at Gate 2 but due to extent of flow increase, a 0.3m/s exit velocity and the shallow channel depth would result in full dispersal of plume within metres of the outfall in a heavily modified channel.	Minor. Minor. No change in water level or water width, and 0.08m/s increase in mean flow velocity in ~100m reach of heavily modified channel of the Enfield Island Loop at very low flow conditions. Unknown change downstream in a largely artificial channel without aquatic habitat. Indiscernible change in intertidal exposure in the estuarine Thames Tideway	Negligible. One low barrier, KGV North Weir, in the Enfield Island Loop with potential for increase in depth of water over crest and reduction in head difference both of which reduce any barrier effect.	Negligible. Negligible changes in suspended sediment concentration within the Thames Tideway from final effluent flow reductions at Beckton STW.
200 Ml/d	Major. 160% increase in very low flows (Q95) in ~100m reach of Enfield Island Loop, with 0-160% increase in flows downstream in ~500m reach of Enfield Island Loop and downstream Lee Diversion. Zero change beyond Flanders Weir.		Moderate. No change in water width and 0.15m/s increase in mean flow velocity in ~100m reach of heavily modified channel of the Enfield Island Loop at very low flow conditions. Unknown change downstream in a largely artificial channel without aquatic habitat. Indiscernible change in intertidal exposure in the estuarine Thames Tideway		
300 Ml/d	Major. 240% increase in very low flows (Q95) in ~100m reach of Enfield Island Loop, with 0-240% increase in flows downstream in ~500m reach of Enfield Island Loop and downstream Lee Diversion. Zero change beyond Flanders Weir.		Moderate. No change in water width and 0.23m/s increase in mean flow velocity in ~100m reach of heavily modified channel of the Enfield Island Loop at very low flow conditions. Unknown change downstream in a largely artificial channel without aquatic habitat. Indiscernible change in intertidal exposure in the estuarine Thames Tideway		

Summary of water quality impacts associated with a Beckton water recycling scheme

The full assessment of the Gate 2 water quality impacts of the Beckton water recycling schemes includes an assessment of:

- Water temperature,
- General physico-chemical,
- WFD chemicals,
- Environmental Quality Standards Directive (EQSD) chemicals, and
- Olfactory water quality.

Table 3-2 shows a high-level summary of these impacts, which are also briefly described below.

Water temperature

Within the freshwater Lee Diversion Channel, over the annual period, the 98th percentile for the water temperature in 1 in 5-year (A82) moderate-low flow year scenario reduced by 0.2°C to 21.5°C and in the 1 in 20 (M96) very low flow year scenario the 98th percentile was reduced by 1.7°C to 20.0°C as a result of a 300 Ml/d Beckton water recycling scheme..

In the upper Thames Tideway, modelling predicts no change in temperature.

General physico-chemical

Within the freshwater Lee Diversion Channel, it is predicted that there may be minor positive changes in ammoniacal nitrogen and phosphorus within the 300 Ml/d scheme size, comprising decreases in concentrations.

Dissolved oxygen saturation shows modelled minor positive changes with an increase in the annual 10th percentile in the 1 in 5 (A82) moderate-low flow year scenario from 113.1% to 114.1% and the annual 10th percentile in the 1 in 20 (M96) very low flow year scenario increasing from 113.1% to 116.5% as a result of a 300 Ml/d Beckton water recycling scheme.

Within the estuarine Thames Tideway, it is predicted that there may be negligible changes to salinity, with maximum increases of 0.7 ppt. Dissolved inorganic nitrogen (DIN) decreases in concentration during scheme on periods, with reductions in concentration of up to 100 µmol/l.

WFD chemicals

Within the freshwater Lee Diversion Channel the recycled water associated with the Beckton water recycling scheme would have been treated by reverse osmosis. As a result the recycled water is without chemicals, except those added by the re-mineralisation process. The in-river assessment assumes no addition of chemicals.

Under the 100 Ml/d scheme (A82), negligible impacts are predicted, with no exceedances in the upper Thames Tideway. No further exceedances are predicted within the estuarine Thames under the M96 scenario.

For the 200 Ml/d scheme (A82), negligible impacts are predicted, with a no exceedances in the upper Thames Tideway. No further exceedances are predicted within the estuarine Thames under the M96 scenario.

Under the 300 Ml/d scheme (A82), negligible impacts are predicted, with a maximum of 1 additional chemical exceeding the standard within the upper Thames Tideway, respectively. No further exceedances are predicted within the estuarine Thames under the M96 scenario.

EQSD chemicals

Within the estuarine Thames tideway negligible impacts are predicted with one additional chemical exceeding the standard under the 100, 200 and300 Ml/d scheme size under both A82 and M96 scenarios.

Olfactory water quality

Within both the freshwater Lee Diversion Channel negligible impacts are predicted with three and one additional exceedances occurring from the reference conditions respectively under the 300 Ml/d scheme size.

Table 3-2 Summary of potential water quality impacts for Beckton water recycling schemes

Size	Water temperature	General physico-chemical	WFD chemicals	EQSD chemicals	Olfactory water quality
100 Ml/d	Freshwater Lee Negligible change in water temperature. Thames Tideway No change.	Freshwater Lee Dissolved oxygen: No deterioration. No other data available Thames Tideway Dissolved oxygen: No data available DIN: Reductions in DIN during scheme on Salinity: Negligible salinity increases inferred from larger schemes modelling	Thames Tideway 14 WFD chemicals exceeded the standard in the baseline scenario. With the scheme in operation (A82) no further chemicals exceeded the standard. Under the M96 scenario no further chemicals exceeded the standard.	Thames Tideway With the scheme in operation (A82), one further chemical exceeded the standard. Under the M96 scenario one further chemical exceeded the standard.	Negligible Olfactory water quality inferred from larger schemes modelling.
200 Ml/d	Freshwater Lee Diversion: Negligible change in water temperature. Thames Tideway No change.	Freshwater Lee Dissolved oxygen: No deterioration. No other data available Thames Tideway Dissolved oxygen: No data available DIN: Reductions in DIN during scheme on Salinity: Negligible salinity increases inferred from larger schemes modelling.	Thames Tideway 14 WFD chemicals exceeded the standard in the baseline scenario. With the scheme in operation (A82), no further chemicals exceeded the standard. Under the M96 scenario no further chemicals exceeded the standard.	Thames Tideway With the scheme in operation (A82), one further chemical exceeded the standard.	Negligible Olfactory water quality inferred from larger schemes modelling.

Size	Water temperature	General physico-chemical	WFD chemicals	EQSD chemicals	Olfactory water quality
300 Ml/d	Freshwater Lee Negligible change in water temperature. Thames Tideway No change.	Freshwater Lee Dissolved oxygen: No deterioration. Ammonia: No deterioration. Phosphate: No deterioration. Langelier Saturation Index: Corrosive value not advisable. Thames Tideway Dissolved oxygen: No data available DIN: Reductions in DIN during scheme on Salinity: Negligible salinity increases inferred from larger schemes modelling.	Thames Tideway 14 WFD chemicals exceeded the standard in the baseline scenario. With the scheme in operation (A82), one further chemical exceeded the standard. Under the M96 scenario no further chemicals exceeded the standard.	Thames Tideway With the scheme in operation (A82), one further chemical exceeded the standard. Under the M96 scenario one further chemical exceeded the standard.	Freshwater Lee A82 has two exceedances of LoD which were also present at baseline, one improvement and three new pressures. M96 exhibits the same changes as for A82, with one less additional pressure. Thames Tideway A82 has four exceedances of LoD which were also present at baseline, one improvement and one new pressure. M96 exhibits the same changes as for A82.

3.2 FRESHWATER FISH

3.2.1 Overview

The following reaches have been assessed in relation to all life stages of freshwater fish in relation to thermal preferenda, water quality, spawning requirements and fluvial habitat in order to evaluate each scheme. It should be noted that Reach A to Reach C are above Teddington Weir and are not considered further within the assessment.

3.2.2 Freshwater Lee Diversion Channel

Reach G – Newmans Weir on the Enfield Island Loop to Chingford Abstractions

Velocity and flow impacts upon the fish community

Mean velocity in Enfield Island loop is most likely to increase with increased flow, although there may be increases in wetted width, where this is not constrained by bank section, with limited changes in water depth. A summary of the range and types of increase that could be expected from flow addition into the channel (based on a channel width of ~18m and a constant water level and constant wetted area of 15m^2) are shown in Table 3-3.

Table 3-3 Contextualisation of likely changes in mean velocity in the Enfield Island Loop for an illustrative flow without Beckton water recycling scheme (126 Ml/d) and with flow additions from Beckton water recycling scheme (flow statistic based on CAMS naturalised series at AP14)

	Without Beckton water recycling scheme (<Q100)	100 Ml/d Beckton water recycling scheme (Q99)	200 Ml/d Beckton water recycling scheme (Q85)	300 Ml/d Beckton water recycling scheme (Q65)
Illustrative flow	126 Ml/d	226 Ml/d	326 Ml/d	426 Ml/d
Mean velocity	0.10 m/s	0.18 m/s	0.25 m/s	0.33 m/s

The Lee Diversion Channel around and downstream of Enfield Island Loop is an artificial channel designed to convey flood flows during periods of high flows, although it does convey some limited flows under low and normal flow conditions, particularly between Enfield Island Loop and Chingford. The Lee Diversion Channel is, for most of its length, composed of vertical to near vertical concrete banks and a concrete bed and therefore flow changes have not been assessed due to the lack of appreciable habitats.

Although the Enfield Island Loop and the Lee Diversion Channel are artificial channels with limited to no appreciable diversity, both channels still constitute habitat for several fish species, evidenced by survey data. Data within the reach is lacking with only one survey event, surveys in 2021 captured six species within the reach including gudgeon, perch, pike, minnow, dace and roach.

During operation, flows downstream of the discharge outfall within the Enfield Island Loop are likely to exceed flow preferences for juvenile life-stages of the species known to be present within the River Lee. The morphology of the watercourse within this reach is such that there are not likely to be low pressure flow areas in which species may seek shelter. However, owing to the management of the artificial diversion channels' system (i.e., Enfield Island Loop and the Lee Diversion Channel are designed for the intended purpose of flood alleviation and as a water transfer channel), there are opportunities for changes in flow to be mediated through the connectivity with additional channels, such as the Lee Navigation, thereby providing fish species with potential refuge from increased flows.

Temperature impacts upon the freshwater fish community

The assessment of water temperature assessment is based upon data collected in the Enfield Island Loop of the Lee Diversion Channel upstream of King George V Reservoir Intake. Water temperature during implementation of the 300 Ml/d scheme volume is within the ranges experienced in the baseline. Over the annual period, the 98th percentile for the 1 in 5-year (A82) moderate-low flow year scenario reduced by 0.2°C

to 21.5°C and in the 1 in 20 (M96) very low flow year scenario the 98th percentile was reduced by 1.7°C to 20.0°C, well within the High WFD status threshold. As a result, there would not be deterioration in water temperature status as a result of a 300 Ml/d Beckton water recycling scheme.

The tolerable range of the fish species within the reach are relatively broad, and the changes to temperature resulting from operation of the scheme are not likely to result in temperature exceeding thresholds. Operation of the scheme may have a positive impact upon temperature, resulting in lower peak temperatures during summer months and reduced temperature variability during operation.

General physiochemical impacts upon the freshwater fish community

No negative impacts on the fish community are anticipated under any scenario in response to minor positive changes in dissolved oxygen saturation within the freshwater Lee Diversion Channel.

Across both flow scenarios there is a clear reduction in ammoniacal nitrogen and phosphate concentration compared to the baseline concentration with the decrease becoming greater with the increase in scheme size. The greatest decreases are experienced when the scheme is on however there is still a slight decrease when the scheme is not on. The 1 in 20 (M96) year scenario is where there is the greatest decrease, particularly with the 300 Ml/d Beckton water recycling scheme where the ammoniacal nitrogen concentration would be sufficiently reduced to cause the WFD status to improve on two occasions, with one of these occasions being when the scheme is not in operation (and just discharging a maintenance flow). Similarly, the 1 in 20 (M96) scenario with the 300 Ml/d scheme would see a reduction in soluble reactive phosphate, causing the WFD status to improve from 'moderate' to 'good' on eight occasions while the scheme is in operation. Overall, there would not be deterioration in the ammonia or phosphate status associated with any of the Beckton water recycling scheme sizes, therefore no impacts to the fish community are anticipated as a result of implementation of the scheme.

WFD chemicals

The Freshwater Lee Diversion Channel is noted to already be exceeding the standard for several WFD and EQSD chemicals under baseline, however, the recycled water associated with the Beckton water recycling scheme would have been treated by reverse osmosis. As a result the recycled water is without chemicals, except those added by the re-mineralisation process. Therefore, the in-river assessment assumes no addition of chemicals.

The concentration at which individual or groups of chemicals may be disruptive to individual fish species are poorly understood, as is the potential role of bioaccumulation. At this stage the significance/magnitude of the impact on freshwater fish cannot be assessed and it is only possible to note an increased risk for potential impacts for the determinants listed. When considering the potential increase in load against the context of the reference conditions, the risk is not considered to be discernible (low confidence). With specific regards to the known impacts on olfaction from these chemicals, these have been described in more detail within Sections 3.7.2 and 4.7.2.

Reach H – Chingford Abstractions to Three Mills Lock

Velocity and flow impacts upon the fish community

Flanders Weir on the Lee Diversion Channel is the downstream limit to flow related impacts, therefore no flow related impacts to the fisheries community are expected as a result of the scheme within Reach H.

Temperature impacts upon the freshwater fish community

The assessment of water temperature assessment is based upon data collected in the Enfield Island Loop of the Lee Diversion Channel upstream of King George V Reservoir Intake. Temperature during implementation of the 300 Ml/d scheme volume is within the ranges experienced in the baseline. Over the annual period, the 98th percentile for the 1 in 5-year (A82) moderate-low flow year scenario reduced by 0.2°C to 21.5°C and in the 1 in 20 (M96) very low flow year scenario the 98th percentile was reduced by 1.7°C to 20.0°C, well within the High WFD status threshold. As a result, there would not be deterioration in water temperature status as a result of a 300 Ml/d Beckton water recycling scheme.

The tolerable range of the species within the Enfield Island Loop are relatively broad, and the changes to temperature resulting from operation of the scheme are not likely to result in temperature exceeding thresholds. Although data for the Lee Diversion Channel within Reach H is not available, the operation of the scheme is not likely to have a greater impact upon temperature than is observed in Reach G. Therefore the impact to fish in the reach is as a consequence of temperature changes is negligeable.

General physiochemical impacts upon the freshwater fish community

Impacts in response to changes in dissolved oxygen saturation are not expected to deviate from those described in Reach G above.

Impacts in response to changes in ammoniacal nitrogen and phosphorus are not expected to deviate from those described in Reach G above, with no impacts to the fish community anticipated as a result of implementation of the scheme.

Across both flow scenarios there is a clear reduction in ammoniacal nitrogen concentration compared to the baseline concentration with the decrease becoming greater with the increase in scheme size. The greatest decreases are experienced when the scheme is on however there is still a slight decrease when the scheme is not on. The 1 in 20 (M96) year scenario is where there is the greatest decrease, particularly with the 300 Ml/d Beckton water recycling scheme where the ammoniacal nitrogen concentration would be sufficiently reduced to cause the WFD status to improve on two occasions, with one of these occasions being when the scheme is not in operation (and just discharging a maintenance flow). Overall, there would not be deterioration in the ammonia status associated with any of the Beckton water recycling scheme sizes, therefore no impacts to the fish community are anticipated as a result of implementation of the scheme.

Across both flow scenarios there is a clear reduction in soluble reactive phosphate concentration compared to the baseline concentration with the decrease becoming greater with the increase in scheme size. The greatest decreases are experienced when the scheme is on however there is still a sizable decrease when the scheme is not on and just discharging a maintenance flow. Overall, there would not be deterioration in the phosphate status associated with any of the Beckton water recycling scheme sizes, therefore no impacts to the fish community are anticipated as a result of implementation of the scheme.

WFD chemicals

The Freshwater Lee Diversion Channel is noted to already be exceeding the standard for several WFD and EQSD chemicals under baseline, however, the recycled water associated with the Beckton water recycling scheme would have been treated by reverse osmosis. As a result the recycled water is without chemicals, except those added by the re-mineralisation process. Thorefore, the in-river assessment assumes no addition of chemicals.
The concentration at which individual or groups of chemicals may be disruptive to individual fish species are poorly understood, as is the potential role of bioaccumulation. At this stage the significance/magnitude of the impact on freshwater fish cannot be assessed and it is only possible to note an increased risk for potential impacts for the determinants listed. When considering the potential increase in load against the context of the reference conditions, the risk is not considered to be discernible (low confidence). With specific regards to the known impacts on olfaction from these chemicals, these have been described in more detail within Sections 3.7.2 and 4.7.2.

3.3 WEIR POOL AND MARGINAL HABITAT

3.3.1 Overview

This section sets out the assessment for the marginal habitats in reaches potentially affected by the Beckton water recycling scheme.

- Freshwater Lee Diversion Channel - Section 3.3.2.

The assessment on impacts to the RCA are based on outputs from the Ammex B.2.4. Aquatic Ecology Assessment Report[30], Annex B.2.5. INNS Report[31], and macrophyte assessment (Section 3.5 in the Aquatic Ecology Assessment Report).

In summary, there is a predicted major increase in very low flows (240%) in the ~100m reach, with zero change beyond Flanders Weir. There is no change in water width in the ~100m reach, with the vertically sided channel

[30] Ricardo (2022). London Effluent Reuse Strategic Resource Option, Gate 2 Aquatic Ecology Assessment Report Draft 2.0. Ref. 4700399659. Ricardo ref. ED13591.

[31] Ricardo (2022). London Effluent Reuse Strategic Resource Option, Gate 2 INNS Assessment Report Draft 1.0. Ref. 4700399659. Ricardo ref. ED13591.

being fulling occupied under all flow conditions. A full summary of predicted physical environment impacts is detailed in Section 3.1, Table 3-1.

3.3.2 Freshwater Lee Diversion Channel

Reach G – Newmans Weir on the Enfield Island Loop to Chingford Abstractions

Site TR_09 covers a 660m reach upstream of the outfall to the reconnection with the Lee Diversion Channel (Table 3-4 provides full details of RCA indicator codes, descriptors and results). Indicator E3, channel bed hydraulic features, was assessed to increase in the section of the river covered by TR_09 in this reach due to the intake and discharge points which has been shown to alter flow patterns, introducing more diversity of flow immediately within the 100m section. C10 and E11 have been assessed to alter for TR_09 to reflect the outcome of the INNS assessment. Although there will be the addition of artificial bank face structures (intake and outfall structures) within the section of the river covered by TR_09, indicators C7-C9 were assessed to be no change as the bank face in these locations are already highly modified channels. Siltation of the channel bed (E7) was also predicted to increase during operation of this scheme.

The assessed changes to the indictor scores were both positive (increased hydraulic feature richness) and negative (increased siltation and NNIPS extent). Overall, the preliminary condition score was reduced to -0.660, however this change does not meet the lower threshold and the condition category for Poor, and therefore remains Fairly Poor river condition category.

The Lee Diversion Channel is, for most of its length, composed of vertical to near vertical concrete banks and a concrete bed. It does not contain any appreciable natural habitat of note for key fish species which could be impacted by the limited and localised change in wetted width and hydraulic habitat distribution from the proposed released flows. The fish community present is typical of a heavily modified reach that is channelised, deep in sections and connected to varying side-channels and intersections.

Table 3-4 Assessed changes in river condition indicators of Reach G during operation of a 300 Ml/d Beckton water recycling scheme. Green shading indicates a positive change (i.e., a higher positive score or a lower negative score), and red shading indicates a negative change (i.e., a lower positive score or a higher negative score). '-' in the operational column indicates no change to the baseline score

Code	Indicator name	Positive / Negative type	TR_09 baseline	TR_09 operational
B1	Bank top vegetation structure	Positive	2	-
B2	Bank top tree feature richness	Positive	1	-
B3	Bank top water related features	Positive	0	-
B4	Bank top NNIPS cover	Negative	0	-
B5	Bank top managed ground cover	Negative	-4	-
C1	Bank face riparian vegetation structure	Positive	2	-
C2	Bank face tree feature richness	Positive	1	-
C3	Bank face natural bank profile extent	Positive	1	-
C4	Bank face natural bank profile richness	Positive	3	-
C5	Bank face natural bank material richness	Positive	1	-
C6	Bank face bare sediment extent	Positive	1	-
C7	Bank face artificial bank profile extent	Negative	-4	-
C8	Bank face reinforcement extent	Negative	-4	-
C9	Bank face reinforcement material severity	Negative	-4	-
C10	Bank face NNIPS cover	Negative	0	-1
D1	Channel margin aquatic vegetation extent	Positive	1	-

Code	Indicator name	Positive / Negative type	TR_09 baseline	TR_09 operational
D2	Channel margin aquatic morphotype richness	Positive	1	-
D3	Channel margin physical feature extent	Positive	1	-
D4	Channel margin physical feature richness	Positive	1	-
D5	Channel margin artificial features	Negative	-1	-
E1	Channel bed aquatic morphotype richness	Positive	2	-
E2	Channel bed tree features richness	Positive	2	-
E3	Channel bed hydraulic features richness	Positive	0	1
E4	Channel bed natural features extent	Positive	0	-
E5	Channel bed natural features richness	Positive	0	-
E6	Channel bed material richness	Positive	3	-
E7	Channel bed siltation	Negative	0	-1
E8	Channel bed reinforcement extent	Negative	0	-
E9	Channel bed reinforcement severity	Negative	0	-
E10	Channel bed artificial features severity	Negative	-2	-
E11	Channel bed NNIPS extent	Negative	0	-1
E12	Channel bed filamentous algae extent	Negative	-3	-
		Preliminary condition score:	-0.482	-0.660
		River condition category:	Fairly Poor	Fairly Poor

3.4 ESTUARINE FISH

3.4.1 Overview

The following reaches have been assessed in relation to all life stages of estuarine fish in relation to thermal preferenda, water quality, spawning requirements and fluvial habitat of to the Beckton water recycling scheme.

3.4.2 Estuarine Thames Tideway

Reach I - Estuarine Bow Creek (tidal Lee) Reach I: Three Mills Lock to Thames Tideway

There is one low barrier, the KGV North Weir, in the Enfield Island Loop with potential for increase in depth of water over the crest and a reduction in head difference both of which reduce any barrier effect. Three Mills Lock is a new lock within the River Lee that was constructed to allow passage of freight for the London 2012 Olympics on the channel and the River Lee northwards, which resulted in stopping the tidal flow. It was constructed between March 2007 and June 2009 and this section of the River Lee is now not accessible to estuarine fish at Three Mills. However, a new lock structure and fish a pass was built on the Prescott Channel built for the 2012 Olympic Games has maintained a degree of free swimming fish access to the lower River Lee, though fish reliant upon tidal stream transport no longer have access to the River Lee above the new. Prior to the construction pf the Queen Elizabeth Olympic Park for the 2012 Olympic Games the River Lee was tidal up to Hackney Marshes. As such, flounder may still be present within this now freshwater reach as flounder can continue to grow in freshwater to sizes circa 30cm in length and 0.5kg in weight. However, flounder will now be unable to migrate downstream from the freshwater River Lee due to the barriers to fish migration and their poor passibility for flatfish species such as flounder.

There are negligible changes in suspended sediment concentration within the Thames Tideway from final effluent flow reductions at Beckton STW and thus negligible changes within Reach I in relation to sediment. As such, there are no potential impacts of the Beckton water recycling scheme in relation to estuarine fish within Reach I.

3.4.3 Estuarine Thames Tideway

Reach D – Teddington Weir to Battersea Park

There is no evidence to suggest that the Beckton water recycling scheme would impact upon this reach. Negligible changes in suspended sediment concentration within the Thames Tideway from final effluent flow reductions at Beckton STW. As such, there are no potential impacts of the Beckton water recycling scheme in relation to estuarine fish within Reach D.

Reach E – Battersea Park to Tower Bridge

There is no evidence to suggest that the Beckton water recycling scheme would impact upon this reach. Negligible changes in suspended sediment concentration within the Thames Tideway from final effluent flow reductions at Beckton STW. As such, there are no potential impacts of the Beckton water recycling scheme in relation to estuarine fish within Reach E.

Reach F Tower Bridge to 3km seawards of Beckton STW

Any impact within this reach would be associated with the reduction in Beckton STW final effluent into the Thames Tideway and any localised impact upon the area within the vicinity of the current outfall location. These impacts are discussed as follows:

Velocity and flow impacts upon the fish community

The decrease in flow associated with the Beckton STW final effluent discharge into the Thames Tideway may act to increase the overall accessible habitat for several species which are likely to be excluded from areas of high flow. These species may include circa 35 estuarine fish species including European eel, smelt, sand goby and flounder. However, conversely increased flows have the potential to be preferred by species such as sea bass. Overall the changes to flows predicted within the London Effluent Reuse SRO Annex B.2.1. Physical Environment Assessment Report are not likely to result in a change to the fish community overall, but may result in minor changes to species distribution at the Beckton STW outfall.

Temperature impacts upon the fish community

The assessment of the water temperature impacts in the estuarine Thames Tideway arising from Beckton STW final effluent reduction concluded there are no predicted impacts upon temperature within the Thames Tideway and thus no predicted impacts upon the freshwater and estuarine fish community in relation to a reduction of final effluent from Beckton STW.

Oxygen Saturation impacts upon the estuarine fish community

The Beckton water recycling scheme Annex B.2.2. Water Quality Assessment report indicates that there will be an increase in dissolved oxygen associated with the Beckton STW final effluent discharge into the Thames Tideway. As such, this may improve the oxygen conditions for circa 35 estuarine fish species in the vicinity of the outfall and improve the overall dissolved oxygen content within the Thames Tideway.

Salinity

An assessment of the salinity impacts in the estuarine Thames Tideway arising from Beckton STW final effluent reduction associated with a Beckton water recycling scheme has been undertaken for the 300 Ml/d size of scheme and A82 and M96 flow scenarios. The modelled data indicates that there is an increase in salinity under the M96 Beckton-300 scenario compared with baseline from approx. 30km downstream of Teddington Weir. Salinity is consistent between baseline and the M96 Beckton-300 scenario in the first 30km downstream of Teddington Weir. The graphs within Section 3.4 of the London Effluent Reuse SRO Annex B.2.2. Water Quality Assessment Report[29] display salinity modelled for the 300 Ml/d Beckton water recycling scheme and so represent the greatest salinity differences associated with the various scheme sizes at Beckton STW. The greatest increase in maximum, mean and minimum salinity from baseline is approx. 0.7ppt, showing minimal difference between flow scenarios

Dissolved inorganic nitrogen impacts upon the fish community.

Across both flow scenarios there is a reduction in DIN concentration during scheme operation compared to the baseline concentration, with the decrease greater under the smaller scheme size. Under the 1 in 5 (A82) scenario with the 300 Ml/d Beckton water recycling scheme, the DIN concentration reduces with some peaks observed in October, however, remains within 'good' WFD status. For the 1 in 20 (M96) scenario under the 300 Ml/d scheme, reductions in DIN concentration are less, with some peaks during the scheme on tipping back into the baseline 'moderate' WFD status. Overall, no deterioration would be expected in DIN status associated with any of the Beckton water recycling scheme sizes, therefore no impacts to the fish community are anticipated as a result of implementation of the scheme.

Modelling predicts negligible changes in suspended sediment concentration within the Thames Tideway from final effluent flow reductions at Beckton STW. As such, there are no potential impacts of the Beckton water recycling scheme in relation to estuarine fish within Reach F.

3.5 MIGRATORY FISH

3.5.1 Overview

The following reaches have been assessed in relation to all life stages of migratory fish in relation to thermal preferenda, water quality, spawning requirements and fluvial habitat of to evaluate the Beckton water recycling scheme.

3.5.2 Freshwater Lee Diversion Channel

European eel are known to be present throughout the River Lee catchment area and the EA Ecology & Fish Data Explorer indicates that Sea lamprey (recorded as Petromyzontidae) have been captured within the Upper Lee catchment. The presence and reliability of EA records for Petromyzontidae in the upper Lee is subject to ongoing discussion as juvenile lamprey amoecetes are notoriously difficult to identify and recent developments in eDNA would be able to confirm their presence. There is one low barrier, the KGV North Weir, in the Enfield Island Loop with potential for increase in depth of water over the crest and a reduction in head difference both of which reduce any barrier effect. It is unknown what the passibility of this weir is to juvenile European eel moving upstream but it is considered that there would be no change in adult migrating European eel during autumn spate flows within the freshwater Lee Diversion Channel.

Flow velocities have already been considered within Section 3.2.2 and Table 3-3 presents the mean flows and maximum velocities for the Enfield Island Loop to the Chingford Abstraction. During operation flows

downstream of the discharge outfall within the Enfield Island Loop are likely to exceed flow preferences for European eel. The morphology of the watercourse within this reach is such that there not likely to be low pressure flow areas created by the marginal roughness of the channel in which European eel would seek to shelter. It is likely that the maximus velocities predicted for each of the Beckton water recycling scheme will exceed the maximum swimming speed for juvenile European eel and that this section of channel would become a hydraulic barrier to upstream eel migration and/or movements during time of the scheme being in operation.

3.5.3 Estuarine Thames Tideway

There are no records of migratory fish species within the Thames Tideway via the EA Ecology & Fish Data Explorer. It is noted that adult and juvenile Twaite shad, Atlantic salmon, sea trout, sea lamprey and river lamprey are present within the tideway in low numbers, with occasional records being presented to the Environment Agency.

The existing Beckton STW outfall into the Thames Tideway is circa 95 m from Barking Creek, which is the tidal section of the River Roding. A reduction of final effluent from Beckton STW outfall is predicted to have minimal changes in salinity from current baseline within the Thames Tideway and negligible changes in suspended sediment concentration within the Thames Tideway. As such, there are no predicted impacts to any migratory fish species within the Thames Tideway that may be utilising Barking Creek or any migratory fish that may choose to utilise the tidal section of the River Lee (Bow Creek).

Three Mills Lock and Bow Locks now cuts off the section of the Bow Back Rivers from the tidal Lee. Prior to the construction pf the Queen Elizabeth Olympic Park for the 2012 Olympic Games the River Lee was tidal up to Hackney Marshes. As such, migratory fish such entering the tidal section of the River Lee are restricted in their movement to freshwater and currently it is considered that only European eel are able to migrate within Reach H.

There are negligible changes in suspended sediment concentration and minimal changes in salinity within the Thames Tideway from final effluent flow reductions at Beckton STW. As such, there are no potential impacts of the Beckton water recycling scheme in relation to estuarine fish within Reach I and Reach F.

3.6 EUROPEAN SMELT

3.6.1 Overview

Smelt are known to spawn within tidal freshwater reaches and there are no known records to suggest that smelt spawn within the Middle Thames Tideway, Barking Creek and Bow Creek. Smelt are known to spawn in the Thames Tideway in Reach D between Battersea Park and Putney Bridge. Adult smelt migrate from Lower Tideway, through the Middle Tideway to access the Upper Tideway to spawn. After spawning the adults return down river to the Lower Tideway and once hatched juvenile smelt move with tidal currents and eventually down river into the Middle and Lower Tideway. There are records of juvenile and adult smelt within Bow Creek and Barking Creek.

There are negligible changes in suspended sediment concentration and minimal changes in salinity within the Thames Tideway from final effluent flow reductions at Beckton STW. As such, there is no evidence to suggest that the Beckton water recycling scheme would impact upon European smelt or their migration within Reach D, Reach E and Reach F of the Thames Tideway or within the tidal section of the River Lee (Reach I).

3.7 OLFACTORY

3.7.1 Overview

An initial screening assessment has been undertaken to identify potential new or increased pressures to the study areas[32]. This assessment uses reconcentration calculations utilising measured Beckton STW final effluent concentrations and discharge flows in order to compare in-river concentrations to baseline and highlights determinands which exceed or approach (within 10% of) the EQS (if applicable) under both mean and 95th percentile concentrations during scheme on periods. This assessment is intended as a guide for future investigations, see Section 6 of the London Effluent Reuse SRO Gate 2 Annex B.2.2. Water Quality

[32] Ricardo (2021). Technical Note: London Effluent Reuse SRO Migratory fish of the Thames RBD: risk to olfactory cues.

Assessment Report, as the olfactory suite for monitoring was updated at Gate 2 and that data will be made available for Gate 3.

3.7.2 Freshwater Lee Diversion Channel

Reach G – Newmans Weir on the Enfield Island Loop to Chingford Abstractions

Within the Beckton 1 in 5 year (A82) model scenario 26 chemical determinands within the olfaction suite were identified as exceeding the LOD in the freshwater Lee Diversion Channel under reference conditions. Of these 26 determinands, 11 were analysed against the EQS for reference conditions and the A82 and 1 in 20 year (M96) flow Beckton-300 scenario (See Table 3.6 within the London Effluent Reuse SRO Gate 2 Annex B.2.2. Water Quality Assessment Report). Against reference conditions dissolved copper, dissolved mercury, permethrin, pirimicarb and dissolved zinc remained above the standard under the A82 Beckton-300 scenario, and dissolved copper, permethrin, pirimicarb and dissolved zinc remaining above the standard under the M96 Beckton-300 scenario. Dissolved chromium (III) exhibits a decrease in concentrations to below the standard under both the A82 and M96 Beckton-300 scenarios. There are three additional pressures under both the A82 and M96 Beckton-300 scenarios, with dissolved mercury, permethrin and pirimicarb concentrations increasing to above the standard.

The impacts on olfaction from these chemicals have been described in Section 4.7.2, while dissolved mercury is described below:

Dissolved mercury

The literature regarding mercury salts provides evidence that mercury, similarly to copper, blocks the olfactory response of salmonids. At concentrations of around 27µg/L brief exposure to mercuric chloride was shown to eliminate response to amino acids in Atlantic salmon for up to 1-hour post-exposure[33]. There are no examples of literature available that document the effect of mercury on the olfactory response of European eel specifically, though exposure to methylmercury chloride at low concentrations of 0.1µg/L has been shown to accumulate in the olfactory bulb of glass eel over periods of 8hrs or less[34].

Olfactory cue dilution

In addition to olfactory inhibition resulting from chemical inhibitors, impacts to the river volume may infer some impact to olfactory homing responses in all migratory species during marine to freshwater migration. Olfactory homing cues vary dependent upon species, though in general migratory species respond to imprinted natal stream chemistry and conspecific olfactory cues. During the Beckton water recycling scheme flow would be augmented within the Lee Diversion Channel which receives flows from the River Lee and upstream tributaries. The extent to which migratory species utilise the Lee Diversion Channel is not known however the scheme may increase flows within the channel by up to 80% which may be interpreted as an 80% dilution in olfactory cues.

The impacts to natal homing migrations resulting from alterations to water odour properties are well understood for salmonids. Several studies demonstrate that salmonids exhibit a stronger homing response to undiluted natal stream waters when compared to dilute natal stream waters[35]. A stronger homing response is likely to result in a decrease in migration time, and therefore a dilution of olfactory cues is likely to result in an increased migration time. Consequently dilute olfactory cues would decrease energy available for reproduction and potentially reduce fitness. Impacts to European eel and lamprey are not as well understood, however, until such a time that updated research becomes available, it is assumed for the purposes of this report that the impact of olfactory cue dilution will be in line with those recorded for salmonids.

Though olfactory cues play an important role in the migration of anadromous and catadromous fish species, so too do visual, social and geomagnetic cues. To what extent olfaction is guiding the migration of salmonids has been shown to be dependent upon distance from the homing stream[36]. Tributaries known to support brown

[33] At concentrations of around 27µg/L brief exposure to mercuric chloride was shown to eliminate response to amino acids in Atlantic salmon for up to 1-hour post-exposure.

[34] Monperrus, M., Pécheyran, C. and Bolliet, V., (2020). Imaging differential mercury species bioaccumulation in glass eels using isotopic tracers and laser ablation inductively coupled plasma mass spectrometry. Applied Sciences, 10(7), p.2463.

[35] Drenner, S.M., Harrower, W.L., Casselman, M.T., Bett, N.N., Bass, A.L., Middleton, C.T. and Hinch, S.G., 2018. Whole-river manipulation of olfactory cues affects upstream migration of sockeye salmon. Fisheries Management and Ecology, 25(6), pp.488-500.

[36] Ueda, H., Kaeriyama, M., Mukasa, K., Urano, A., Kudo, H., Shoji, T., Tokumitsu, Y., Yamauchi, K. and Kurihara, K., 1998. Lacustrine sockeye salmon return straight to their natal area from open water using both visual and olfactory cues. Chemical Senses, 23(2), pp.207-212.

trout populations as evidence by catch data are not known to occur within 18 km upstream of the discharge outfall. Therefore, given the location of the outfall it may be assumed that olfaction plays a reduced role for natal stream homing in salmonids within the Lee catchment downstream of the discharge outfall and, that impacts to olfactory cue resulting from dilution are likely to be minor. However, impacts to the olfactory homing cues for migratory species resulting from the Beckton water recycling scheme cannot be determined with certainty from the information available.

3.7.3 Estuarine Thames Tideway

Reach D – Teddington Weir to Battersea Park

Within the A82 Model 24 chemical determinands within the olfaction suite were identified as exceeding the LOD in the estuarine Thames Tideway under reference conditions. Of these 24 determinands, 15 were analysed against the EQS for both reference conditions and the A82 Beckton-300 scenario. Table 3.7 within the London Effluent Reuse SRO Gate 2 Annex B.2.2. Water Quality Assessment Report[29] shows the exceedances of the EQS for these determinands.

As above, the assessment concludes dissolved copper, dissolved mercury, permethrin and dissolved zinc remained above the standard under the A82 Beckton-300 scenario. Pirimicarb exhibits a decrease in concentrations to below the standard under the A82 Beckton-300 scenario.

There is one additional pressure under the A82 Beckton-300 scenario, with total cadmium concentrations increasing to above the standard.

Total cadmium

While there is no literature specific to the effects of cadmium on European eel olfaction, olfactory impairment has been studied in several salmonid species including rainbow trout[37] and brown trout[38] and is understood to be a general-purpose olfactory toxicant for all freshwater fish[39].

It is noted, however, that the standard and impacts from metal concentrations are against the dissolved fraction, while it is the total fraction which increased in concentration to constitute a possible risk to olfaction. Subsequently, impacts on olfaction resulting from the scheme cannot be determined with certainty from the information available.

Reach E – Battersea Park to Tower Bridge

The assessment of Reach D is considered representative of Reach E.

Reach F Tower Bridge to 3km seawards of Beckton STW

The assessment of Reach D is considered representative of Reach F.

Reach I - Estuarine Bow Creek (tidal Lee) Reach I: Three Mills Lock to Thames Tideway

The assessment of Reach D is considered representative of Reach I.

3.8 SUMMARY OF FISH ASSESSMENT OF THE BECKTON WATER RECYCLING SCHEME

From the results it is evident that the potential changes in flow are not considered to be of a magnitude to affect the fish communities within the freshwater River Lee, Tidal River Lee or Thames Tideway, though they are likely to result in temporary changes to species distribution and barriers to migratory European eel within the Enfield Island Loop to Chingford Abstraction. Additionally the potential changes in flows are not likely to result in impacts to migratory species associated with the Thames Estuary.

The results of the water quality modelling indicate that temperature changes within the Enfield Island Loop of the Lee Diversion Channel upstream of King George V Reservoir Intake are unlikely to result in changes to the freshwater fish community. Impacts to temperature are not expected to lead to a reduction in WFD status or exceed the thermal tolerances of species present but may result in impacts to the behaviour of fish species

[37] Dew, W.A., Veldhoen, N., Carew, A.C., Helbing, C.C. and Pyle, G.G., (2016). Cadmium-induced olfactory dysfunction in rainbow trout: Effects of binary and quaternary metal mixtures. Aquatic Toxicology, 172, pp.86-94.

[38] Tjälve, H., Gottofrey, J. and Björklund, I., (1986). Tissue disposition of 109Cd2+ in the brown trout (Salmo trutta) studied by autoradiography and impulse counting. Toxicological & Environmental Chemistry, 12(1-2), pp.31-45.

[39] McKeown, B. A. (1984) Fish Migration. Croom Helm, London

particular at or close to the discharge location where temperatures are highest. Though, these impacts are likely to be dependent upon the ambient temperature in the River Lee. Temperature increases below the mixing zone may result in changes to metabolic rate, gonad development, embryonic development, hatch rate and overall survival of most species to a varying degree. Species and life-stages tolerant to a broader range of temperatures including warmer water, may show increased success compared to less thermally plastic species, this may lead to changes to the community structure downstream of the discharge outfall. There are no predicted impacts upon temperature within the Thames Tideway and thus no predicted impacts upon the estuarine fish community.

Impacts to ammonia concentrations are not likely to impact the freshwater and estuarine fish population. A number of WFD and EQSD priority substances have been identified as likely to exceed standards during the scheme, the extent to which these chemicals will impact the freshwater or estuarine fish community is not yet understood. However, several olfactory inhibitors have been highlighted including dissolved copper, cypermethrin, permethrin, pirimicarb and dissolved zinc which may impact olfaction in the estuarine Thames Tideway.

4. FISH ASSESSMENT OF MOGDEN WATER RECYCLING SCHEME

4.1 INTRODUCTION

This section sets out the assessment for the tasks set out in Table 1-1 relevant to the Mogden water recycling scheme. The study area for each task has been set out per task as it is not consistent across tasks. The Mogden water recycling scheme assessment for each of the following tasks has been set out in the following sections:

- Freshwater fish
- Weir pool/marginal habitat (including Sunbury creek)
- Estuarine fish (including European eel)
- Migratory fish (including European eel)
- European smelt
- Olfactory cues

Potential impact pathways resulting from implementation of the scheme fall are summarised below:

- Increased velocities and the resulting impact on the upstream and/or downstream migration of Atlantic salmon, sea trout, shad, smelt, lamprey and European eel.
- Increased velocities and the resulting impact on the local migration of coarse fish and brown trout to spawning areas.
- Loss/decrease in habitat quantity and quality due to changes in hydraulics (i.e. increased velocity and depth) resulting in increased competition for space.
- Loss of juvenile and adult habitats within margins due to increase wetted width and velocities, including habitats for lamprey ammocoetes.
- Risk of displacement of juvenile fish due to increased flows.
- Changes in water quality could have a direct impact on fish populations (e.g. mortality as a result of localised dissolved oxygen sags).
- Changes in the availability of food (biofilm, macrophytes, macroinvertebrates) due to increased flows and changes in water quality.

These assessments have been conducted utilising the Gate 2 London Effluent Reuse Annex B.2.1. Physical Environment Assessment Report[2] and Annex B.2.2. Water Quality[29] Assessment Report, where full details of the impact assessments determined are to be found.

Summary of physical environment impacts associated with a Mogden water recycling scheme

The full assessment of the Gate 2 physical environment impacts of the Mogden water recycling schemes includes an assessment of:

- Velocity and flow,
- Outfall design,
- Wetted habitat,
- Fish pass and barrier passability,
- Richmond Pound drawdown, and
- Estuarine sediment.

Table 4-1 shows a high-level summary of these impacts, which are also briefly described below.

Velocity and flow

The Mogden water recycling scheme is expected to result in moderate impacts (200 Ml/d and 150 Ml/d scheme sizes) to minor impacts (100 Ml/d and 50 Ml/d scheme sizes) to flow conditions within the River Thames, the

main flow increase is likely to occur between Walton Bridge outfall and Thames Water Walton intake. The area of increased velocity is spatially restricted to the outfall area and in the discharge plume.

Outfall design

The potential impacts predicted for outfall design are negligible for all scheme sizes. At the 200 Ml/d scheme size increased velocities from the plume of 0.05-0.075 m/s stretches downstream to around 260 m for discharge into 970 Ml/d river flow (Q91) scenario.

Wetted habitat

The potential impacts predicted for wetted habitat are negligible for all scheme sizes, with very minor increases in flow velocities in Sunbury Weir pool modelled, no changes in wetted habitats modelled in Molesey Weir pool and negligible changes in exposure of estuarine wetted habitat.

Fish pass and barrier passability

The potential impacts predicted for fish pass and barrier passability are negligible for all scheme sizes, with a maximum change of between 0-0.04m in river levels for scheme when compared to baseline under the 200 Ml/d scheme size.

Richmond Pound drawdown

The potential impacts predicted for Richmond Pound drawdown are negligible for all scheme sizes, with negligible changes to the physical environment.

Estuarine sediment

The potential impacts predicted for estuarine sediment are negligible for all scheme sizes, with negligible changes in suspended solids concentration within the estuary.

Table 4-1 Summary of potential physical environment impacts for Mogden water recycling schemes

Size	Flow	Outfall design	Wetted habitat	Richmond Pound drawdown	Estuarine sediment
50 Ml/d	Minor 5% increase in very low flows (Q95) with main flow increase affecting 3.4km reach (Walton Bridge outfall to Walton intake) and no change 5.4km downstream of outfall (Hampton intake)	Negligible Plume velocity characteristics inferred from larger schemes modelling.	Very minor increase in flow velocities in Sunbury Weir pool inferred from larger schemes modelling. No change in wetted habitats modelled in Molesey Weir pool as no expected change in flows over Molesey Weir. Negligible changes in exposure of estuarine wetted habitat inferred from larger schemes modelling.	Negligible changes in physical environment within Richmond Pound.	Negligible changes in suspended solids concentration within the estuary.
100 Ml/d	Minor 11% increase in very low flows (Q95) with main flow increase affecting 3.4km reach (Walton Bridge outfall to Walton intake) and no change 5.4km downstream of outfall (Hampton intake)				
150 Ml/d	Moderate 16% increase in very low flows (Q95) with main flow increase affecting 3.4km reach (Walton Bridge outfall to Walton intake) and no change 5.4km downstream of outfall (Hampton intake)				
200 Ml/d	Moderate 21% increase in very low flows (Q95) with main flow increase affecting 3.4km reach (Walton Bridge outfall to Walton intake) and no change 5.4km downstream of outfall (Hampton intake)	Negligible. Increased velocities from plume of (0.05-0.075m/s) stretches downstream to around 260m for discharge into 970 Ml/d (Q91) scenario.	Very minor increase in flow velocities in Sunbury Weir pool modelled. No change in wetted habitats modelled in Molesey Weir pool as no expected change in flows over Molesey Weir. Negligible changes in exposure of estuarine wetted habitat.		

Summary of water quality impacts associated with a Mogden water recycling scheme

The full assessment of the Gate 2 water quality impacts of the Mogden water recycling schemes includes an assessment of:

- Water temperature,
- General physico-chemical,
- WFD chemicals,
- Environmental Quality Standards Directive (EQSD) chemicals,
- Olfactory water quality, and
- Richmond Pound drawdown

Table 4-2 shows a high-level summary of these impacts, which are also briefly described below.

Water temperature

Within the freshwater River Thames it is predicted that a maximum temperature change of 1.1°C may occur, achieving a maximum modelled temperature of 19.8 °C, therefore with respect to WFD, it is anticipated that at least 'Good' WFD status (23°C, 98%ile) will always be achieved with peak river temperatures estimated at 19.8°C - 19.9°C for the Mogden water recycling scheme) and that 'High' WFD status for salmonid category rivers (20°C, 98%ile) is likely.

In the Upper Thames Tideway, modelling predicts less warming in areas associated with the Mogden STW outfall, due to less effluent in the watercourse at these locations as a consequence of the Mogden water recycling scheme, with temperature reductions predicted of a maximum of 1°C.

General physico-chemical

Within the freshwater River Thames, it is predicted that there may be minor changes in ammoniacal nitrogen from the 200 Ml/d scheme size, comprising decreases in concentration around the Reuse outfall and small increases in concentration downstream ranging from 15.54% change at the 25%ile to 0.33% change at the 90%ile at Teddington weir. Suspended solids show a minor reduction around the outfall, before increasing downstream with the most elevated increases being observed at the 25%ile.

For both dissolved oxygen saturation and phosphorus concentrations negligible changes are predicted with small (max change -0.01% at the 50%ile) and moderate (max change -7.45% at the 75%ile) reductions around the outfall respectively. Phosphorus concentrations continue to reduce downstream while dissolved oxygen saturation increases with distance from the outfall.

Within the upper Thames Tideway dissolved oxygen concentration increases, though this represents a maximum difference from reference conditions of 0.5 mg/l. Salinity also increases with a maximum increase of 1.3 ppt, while DIN decreases with a maximum reduction of 25 µMol/l.

WFD chemicals

Within the freshwater River Thames the recycled water associated with the Mogden water recycling scheme would have been treated by reverse osmosis. As a result the recycled water is without chemicals, except those added by the re-mineralisation process. The in-river assessment assumes no addition of chemicals

Within the upper Thames Tideway minor impacts are also predicted with only eight additional chemicals exceeding the standard under the 200 Ml/d scheme size.

EQSD chemicals

Within the upper Thames Tideway negligible impacts are also predicted with only three additional chemicals exceeding the standard under the 200 Ml/d scheme size.

Olfactory water quality

Within both the freshwater River Thames and upper Thames Tideway negligible impacts are predicted with no additional exceedances occurring from the reference conditions.

Richmond Pound drawdown

Negligible changes occur in the Richmond Pound with maximum increases in salinity of 0.55ppt and maximum (initial) temperature increases of 0.1°C. Temperature also displays maximum decreases of 1°C, suspended

sediment decreases by a maximum of 0.045 and 0.015 kg/m3 under A82 and M96 respectively, and dissolved oxygen increases by a maximum of 0.5 mg/l.

Table 4-2 Summary of potential water quality impacts for Mogden water recycling schemes

Size	Water temperature	General physico-chemical	WFD chemicals	EQSD chemicals	Olfactory water quality	Richmond Pound Drawdown
50 Ml/d	Freshwater: Negligible	Negligible general physio-chemical characteristics inferred from larger schemes modelling.	Negligible WFD chemicals inferred from larger schemes modelling.	Negligible EQSD chemicals inferred from larger schemes modelling.	Negligible Olfactory water quality inferred from larger schemes modelling.	Negligible Richmond Pound characteristics inferred from larger schemes modelling.
100 Ml/d	Freshwater: Negligible					
150 Ml/d	Freshwater: Negligible					
200 Ml/d	Freshwater: Negligible Estuarine: Difference of around 1ºC	Freshwater Thames *Ammoniacal nitrogen:* A82; minor changes with both increases and decreases on pressure. M96; added pressure at 90%ile. M96 future; minor added pressure. *Oxygen saturation:* A82; reduced pressure at Mogden water recycling outfall. M96; minor changes with reduction at Mogden water recycling outfall. M96 future; increase in pressure. *Suspended Solids:* A82; Minor increase in pressure from suspended solids at 25%ile, minor decrease at 75%ile. M96; increase in pressure across all percentiles.M96 future; decrease in pressure across all percentiles. *Phosphorous:* Decrease in pressure across all scenarios and percentiles. *Water temperature:* Minor increase in pressure across all scenarios and percentiles. *Hardness:* Increase in 48mg/l *ANC:* No change affected by scheme in operation. *pH:* No change affected by scheme in operation. *Langelier Saturation Index:* LSI of 0 is achievable. Thames Tideway DO: An increase in DO under both scenarios Salinity: Increase in salinity under both scenarios	Thames Tideway 12 determinands were exceeding standards under baseline conditions of which seven remained above standard under A82 and eight new pressures were above standard. The same occurs in the M96 scenario with one additional pressure.	Thames Tideway A82 and M96 estuary and freshwater; three new chemical exceedances.	Freshwater Thames A82 and M96 have four exceedances which is the same number present at baseline. Thames Tideway A82 and M96 have five exceedances which is the same number present at baseline.	Salinity: Negligible changes, with a maximum increase of 0.55 ppt under both A82 and M96. Suspended sediment: Negligible changes, with a maximum decrease of 0.045 and 0.015 kg/m^3 under A82 and M96 respectively. Dissolved oxygen: Negligible changes, with a maximum increase of 0.5 mg/l under both A82 and M96. Temperature: Negligible changes, with a maximum increase of 0.1°C under both A82 and M96, and maximum decreases of 1°C under both A82 and M96.

Size	Water temperature	General physico-chemical	WFD chemicals	EQSD chemicals	Olfactory water quality	Richmond Pound Drawdown
		DIN: Decrease in pressure with a decrease in DIN under both scenarios.				

4.2 FRESHWATER FISH

4.2.1 Overview

The following reaches have been assessed in relation to all life stages of freshwater fish in relation to thermal preferenda, water quality, spawning requirements and fluvial habitat in order to evaluate the 200 Ml/d Mogden water recycling scheme.

4.2.2 Freshwater River Thames

Reach A – Shepperton Weir to Affinity Water Walton Intake

No Impacts to reach due to the downstream location of the Mogden water recycling outfall within Reach B.

Reach B – Affinity Water Walton Intake to Thames Water Walton Intake

Velocity and flow impacts upon the fish community

At the Mogden water recycling outfall river flow would be increased by 200 Ml/d, representing a 21% increase in river flow. For the other sizes of Mogden water recycling scheme flow increases locally at Walton Bridge would be 16% for a 150 Ml/d scheme; 11% for a 100 Ml/d scheme; and 5% for a 50 Ml/d scheme. For lower river flows at Walton Bridge the proportion flow increase from the additional release from a Mogden water recycling scheme would be higher.

The augmented river flow conditions would remain the same over Sunbury Weir. At Thames Waters' existing Walton and Hampton intakes a significant proportion of the augmented flow would be abstracted, in addition to river flows abstracted under reference conditions. In the representative date shown, all augmented flow is re-abstracted at the Thames Water Walton intake and there are no flow differences downstream of there as consequence of the Mogden water recycling scheme. In total 3.4 km of freshwater River Thames would be subject to flow augmentation which encompasses the entirety of Reach B downstream of the discharge outfall. Where there is some re-abstraction at the Hampton intake, a further 2.0 km of freshwater River Thames would be subject to flow augmentation.

The model suggests the increased velocity of the plume rapidly declines by ~150 m downstream of the discharge, with remaining flow velocities in the channel ranging from 0.025-0.05 m/s, similar to upstream of the proposed discharge point, although a small tongue of higher velocities (0.05-0.075 m/s) persists for ~250 m downstream on the right bank. Localised increases in flows immediately adjacent to the discharge outfall may act to reduce the overall accessible habitat for several species which are likely to be excluded from areas of high flow. These species may include common bream, pike or tench. Conversely increased flows have the potential to be preferred by species such as dace, chub, stone loach and barbel. Overall the changes to flows predicted are not likely to result in a change to the fish community overall, but may result in minor changes to species distribution in the immediate vicinity of the discharge outfall during operation.

Minor increases in wetted width during low flow conditions may increase available habitat within the channel, providing opportunity for smaller species which are able to utilise shallow marginal areas for juveniles which are likely to find shelter from predation in such areas. As noted in the Annex B.2.1. Physical Environment Assessment Report, much of this increase in wetted width would be within Sunbury weir pool, so may provide limited availability to most aquatic species.

Temperature impacts upon the freshwater fish community

At lowest flows (600 Ml/d) the Mogden water recycling scheme would operate at the mean temperature difference between the indicative Mogden water recycling scheme discharge and the river temperature (16.9^{o}C) which, during these times, is +3.0^{o}C. During the coldest river temperatures, the Mogden water recycling scheme would operate at times that would correspond moderate flows (780 Ml/d). The mean temperature difference between the Mogden effluent (as a proxy for the recycled water) and the river temperature (8.9 ^{o}C) during these times is +6.1^{o}C. Either of those conditions could describe the 2% exceedance statistic for a plume, and as such have been included in model parameterisation.

At more typical flows (950 Ml/d) mean river temperatures are 16.9 ^{o}C, with a mean temperature difference between the Mogden effluent and river temperature of +3.3 ^{o}C.

Under a 200 Ml/d discharge the maximum modelled river temperature was 19.9 ^{o}C with a maximum change of 1.1 ^{o}C once the effluent is fully mixed with the River Thames. During maintenance flow only periods, with a

discharge of 50 Ml/d, the maximum modelled temperature was 19.8^{o}C, the maximum change identified was 0.3^{o}C.

The tolerable range of the species within the reach are relatively broad, and changes of up to 1.1 ^{o}C downstream of the mixing zone are not likely to exceed the maximum tolerable range for most species. However, temperatures of 19.9 ^{o}C as predicted under the 200 Ml/d discharge scenario are likely to exceed the preferable temperature ranges for migratory salmonid species including, brown trout and Atlantic salmon. Impacts of temperature upon Migratory species will be address is Section 3.5.

Temperature increases close to the discharge outfall of up to 6.1 ^{o}C are likely to result in impacts to the behaviour of fish species dependent upon the temperature of the wider River Thames, during colder periods a warmer effluent may act to attract species whereas in warmer periods increase temperatures at the outfall may elicit avoidance behaviours. Temperature changes of 1.1^{o}C overall will result in changes to metabolic rate, embryonic development and hatch rate of most species. Temperature changes within this scale have been shown to impact gonad development, spawning timing, egg incubation, fry size and over winter mortality for a number of species present within the reach. For more thermophilic species such as bleak or chub these relatively minor temperature changes may result in competitive advantages when compared to species such as perch or pike. The majority of species typically spawn between March and June and therefore the scheme is not likely to operate during peak spawning periods for most species, however several species are known to spawn later in the year such as barbel, bream, chub and minnow.

In summary the scheme may be detrimental within the area of the thermal plume to cold water species such as brown trout, minnow, perch, pike and roach but beneficial to species belonging to warm water guilds such as bleak, common bream, chub and tench.

General physiochemical impacts upon the freshwater fish community

Negligible reductions to dissolved oxygen (max change -0.01% at the 50%ile) are predicted close to the outfall. Dissolved oxygen reductions of this scale are not likely to result in any immediate changes to community structure or the behaviour of individuals.

Ammoniacal nitrogen within Reach B is not likely to be impacted negatively by the scheme. Under the scenarios assessed Ammoniacal nitrogen concentrations are expected to decrease close to the outfall by as much as 7.4%. Reductions in ammonia to this extent are not likely to result in any measurable impact to the fish community.

A step increase of total phosphorus concentrations are expected across all scenarios at approx. 6.6 km upstream of Teddington Weir, downstream of the River Mole. However, at the 75th and 50th percentiles, total phosphorus concentrations are considerably lower for the 1 in 5 (A82) flow scenario, under the 200 Ml/d Mogden water recycling scheme, compared with reference conditions, thereby indicating a slight reduction in pressure. For the 25th percentile, the scheme exhibits lower concentrations than reference from the Mogden water recycling outfall, until approx. 6.6 km upstream of Teddington where concentrations become consistent across both scenarios. Subsequently, changes in phosphorus are not likely to result in any measurable impact to the fish community or behaviour.

WFD chemicals

The Freshwater River Thames is noted to already be exceeding the standard for several WFD and EQSD chemicals under baseline, however, the recycled water associated with the Mogden water recycling scheme would have been treated by reverse osmosis. As a result the recycled water is without chemicals, except those added by the re-mineralisation process. Therefore, the in-river assessment assumes no addition of chemicals. The concentration at which individual or groups of chemicals may be disruptive to individual fish species are poorly understood, as is the potential role of bioaccumulation. At this stage the significance/magnitude of the impact on freshwater fish cannot be assessed and it is only possible to note an increased risk for potential impacts for the determinants listed. When considering the potential increase in load against the context of the reference conditions, the risk is not considered to be discernible (low confidence). With specific regards to the known impacts on olfaction from these chemicals, these have been described in more detail within Section 4.7.2.

Reach C – Thames Water Walton Intake to Teddington Weir

Velocity and flow impacts upon the fish community

At the Mogden water recycling outfall, river flow would be increased by 200 Ml/d, representing a 21% increase in river flow. For the other sizes of Mogden water recycling scheme flow increases locally at Walton Bridge would be 16% for a 150 Ml/d scheme; 11% for a 100 Ml/d scheme; and 5% for a 50 Ml/d scheme. For lower river flows at Walton Bridge the proportion flow increase from the additional release from a Mogden water recycling scheme would be higher. The augmented river flow conditions would remain the same over Sunbury Weir. At Thames Water's existing Walton and Hampton intakes a significant proportion of the augmented flow would be abstracted, in addition to river flows abstracted under reference conditions. In the representative date shown, all augmented flow is re-abstracted at the Walton intake and there are no flow differences downstream of there as consequence of the Mogden water recycling scheme. In total 3.4km of freshwater River Thames would be subject to flow augmentation which ecompasses the entirety of Reach A downstream of the discharge outfall. Where there is some re-abstraction at the Hampton intake, a further 2 km of freshwater River Thames would be subject to flow augmentation.

The model suggests the increased velocity of the plume rapidly declines by ~150m downstream of the discharge, with remaining flow velocities in the channel range from 0.025-0.05m/s, similar to upstream of the proposed discharge point, although a small tongue of higher velocities (0.05-0.075m/s) persists for ~250m downstream on the right bank. Therefore, There are likely to be no measurable velocity increases which are likely to impact the fish community with Reach C.

Temperature impacts upon the freshwater fish community

Under a 200 Ml/d discharge the maximum modelled temperature was identified as 19.9^{o}C with a maximum change of 1.1 ^{o}C once the effluent is fully mixed with the River Thames, which will be achieved before reaching Reach C. During maintenance flow only periods with a discharge of 50 Ml/d the maximum modelled temperature was identified as 19.8^{o}C the maximum change identified was 0.3^{o}C.

The tolerable range of the species within the reach are relatively broad, and changes of up to 1.1^{o}C downstream of the mixing zone are not likely to exceed the maximum tolerable range for most species. However, temperatures of 19.9 ^{o}C as predicted under the 200 Ml/d discharge scenario are likely to exceed the preferable temperature ranges for migratory salmonid species including, brown trout and Atlantic salmon. Impacts of temperature upon Migratory species will be address is Section 4.5.

Temperature changes of 1.1^{o}C overall will result in changes to metabolic rate, embryonic development and hatch rate of most species. Temperature changes within this scale have been shown to impact gonad development, spawning timing, egg incubation, fry size and over winter mortality for a number of species present within the reach. For more thermophilic species such as bleak or chub these relatively minor temperature changes may result in competitive advantages when compared to species such as perch or pike. The majority of species typically spawn between March and June and therefore the scheme is not likely to operate during peak spawning periods for most species, however several species are known to spawn later in the year such as barbel, bream, chub and minnow.

In summary the scheme may be detrimental to cold water species such as minnow, perch, pike and roach but beneficial to species belonging to warm water guilds such as bleak, common bream, chub and tench.

General physiochemical impacts upon the freshwater fish community

Negligeable reductions to dissolved oxygen (max change -0.01% at the 50%ile) are predicted close to the outfall. Dissolved oxygen reductions of this scale are not likely to result in any immediate changes to community structure or the behaviour of individuals.

Ammoniacal nitrogen within Reach C is not likely to be impacted negatively by the scheme. Under the scenarios assessed Ammoniacal nitrogen concentrations are expected to decrease close to the outfall by as much as 7.4%. Reductions in ammonia to this extent are not likely to result in any measurable impact to the fish community downstream in Reach C.

Impacts in response to changes in phosphorus concentration within Reach C are not expected to deviate from those described in Reach B above, and therefore are not likely to result in any measurable impact to the fish community or behaviour.

WFD chemicals

The Freshwater River Thames is noted to already be exceeding the standard for several WFD and EQSD chemicals under baseline, however, the recycled water associated with the Mogden water recycling scheme would have been treated by reverse osmosis. As a result the recycled water is without chemicals, except those added by the re-mineralisation process. Therefore, the in-river assessment assumes no addition of chemicals. The concentration at which individual or groups of chemicals may be disruptive to individual fish species are poorly understood, as is the potential role of bioaccumulation. At this stage the significance/magnitude of the impact on freshwater fish cannot be assessed and it is only possible to note an increased risk for potential impacts for the determinants listed. When considering the potential increase in load against the context of the reference conditions, the risk is not considered to be discernible (low confidence). With specific regards to the known impacts on olfaction from these chemicals, these have been described in more detail within Section 4.7.2.

4.3 WEIR POOL AND MARGINAL HABITAT

4.3.1 Overview

This section sets out the assessment for the marginal habitats in reaches potentially affected by the Mogden water recycling scheme.

- Freshwater River Thames - Section 4.3.2

The assessment on impacts to the RCA are based on outputs from the Annex B.2.1. Physical Environment Assessment Report[2], Annex B.2.5. INNS Report[31], and the macrophyte assessment (Section 4.5 of the Aquatic Ecology Assessment Report[30]). The assessment assumes Scenario 1 (600 Ml/d at 200 Ml/d discharge) from Annex B.2.1.Physical Environment Assessment Report.

In summary, there is a predicted moderate increase in flow during very low flows periods (Q98), main flow increase affecting a 3.4 km reach (Walton Bridge outfall to Thames Water Walton intake) and no change 5.4 km downstream of outfall (Thames Water Hampton intake). There is negligible change in wetted habitats including weir pool habitat. A full summary of predicted physical environment impacts is detailed in Section 4.1, Table 4-1.

It is not likely that the introduction or transfer of INNS will occur during the operation of this scheme, as the water would be advanced treated effluent, which eliminates all pathways that are likely to introduce or transfer INNS during normal operation.

4.3.2 Freshwater River Thames

Reach A – Shepperton Weir to Affinity Water Walton Intake

TR_01 (and Reach A entirely) is located approximately 1.2km upstream of the Mogden water recycling discharge point on the freshwater River Thames. Therefore, there are no assessed changes to the RCA and thus no predicted changes in weir pool habitat and marginal habitat within this reach. This RCA can be used as a reference condition point where there are likely to be no measurable impacts on the fish community.

Reach B – Affinity Water Walton Intake to Thames Water Walton Intake

The assessed changes in river condition indicators for RCAs within Reach B are presented in Table 4-3.

Although there will be the addition of artificial bank face structures (outfall) within the section of the river covered by TR_02, indicators C7-C9 were assessed to be no change as the bank face in these locations are already modified channels.

Indicator E3, channel bed hydraulic features, was assessed to increase in the section of the river covered by TR_02 in this reach due to the discharge which has been shown to alter flow patterns, introducing more diversity of flow immediately downstream. This change in flow velocity rapidly declines by ~150m downstream of the discharge, with remaining flow velocities similar to upstream. Therefore, the predicted change in E3 is not applied to TR_03 and TR_04 which are located approximately 1.8km and 2.3km downstream of the outfall respectively. The fish community present in this reach is typical of a heavily modified reach and is unlikely to be impacted by limited and localised change in hydraulic habitat distribution from the proposed released flows.

Table 4-3 Assessed changes in river condition indicators within Reach B during operation of the 200 Ml/d the Mogden water recycling scheme. Green shading indicates a positive change (i.e., a higher positive score or a lower negative score), and red shading indicates a negative change (i.e., a lower positive score or a higher negative score). '-' in the operational column indicates no change to the baseline score.

Code	Indicator name	Positive / Negative type	TR_02 baseline	TR_02 operational	TR_03 baseline	TR_03 operational	TR_04 baseline	TR_04 operational
B1	Bank top vegetation structure	Positive	3	-	3	-	3	-
B2	Bank top tree feature richness	Positive	0	-	2	-	1	-
B3	Bank top water related features	Positive	0	-	0	-	0	-
B4	Bank top NNIPS cover	Negative	0	-	0	-	0	-
B5	Bank top managed ground cover	Negative	-4	-	-3	-	-4	-
C1	Bank face riparian vegetation structure	Positive	2	-	3	-	2	-
C2	Bank face tree feature richness	Positive	1	-	4	-	1	-
C3	Bank face natural bank profile extent	Positive	0	-	3	-	1	-
C4	Bank face natural bank profile richness	Positive	0	-	4	-	1	-
C5	Bank face natural bank material richness	Positive	1	-	4	-	0	-
C6	Bank face bare sediment extent	Positive	1	-	3	-	0	-
C7	Bank face artificial bank profile extent	Negative	-4	-	0	-	-4	-
C8	Bank face reinforcement extent	Negative	-4	-	0	-	-4	-
C9	Bank face reinforcement material severity	Negative	-4	-	0	-	-4	-
C10	Bank face NNIPS cover	Negative	0	-	0	-	0	-
D1	Channel margin aquatic vegetation extent	Positive	1	-	2	-	2	-
D2	Channel margin aquatic	Positive	1	-	1	-	1	-

Code	Indicator name	Positive / Negative type	TR_02 baseline	TR_02 operational	TR_03 baseline	TR_03 operational	TR_04 baseline	TR_04 operational
	morphotype richness							
D3	Channel margin physical feature extent	Positive	0	-	2	-	0	-
D4	Channel margin physical feature richness	Positive	0	-	2	-	0	-
D5	Channel margin artificial features	Negative	-2	-	0	-	0	-
E1	Channel bed aquatic morphotype richness	Positive	0	-	0	-	0	-
E2	Channel bed tree features richness	Positive	0	-	2	-	1	-
E3	Channel bed hydraulic features richness	Positive	0	1	2	-	4	-
E4	Channel bed natural features extent	Positive	0	-	2	-	0	-
E5	Channel bed natural features richness	Positive	0	-	1	-	0	-
E6	Channel bed material richness	Positive	0	-	3	-	0	-
E7	Channel bed siltation	Negative	0	-	0	-	0	-
E8	Channel bed reinforcement extent	Negative	0	-	0	-	0	-
E9	Channel bed reinforcement severity	Negative	0	-	0	-	0	-
E10	Channel bed artificial features severity	Negative	-2	-	0	-	-3	-
E11	Channel bed NNIPS extent	Negative	0	-	0	-	0	-
E12	Channel bed filamentous algae extent	Negative	0	-	0	-	0	-
Preliminary condition score:			-1.012	-0.096	2.032	No change	-0.567	No change
River condition category:			Poor	Fairly Poor	Fairly Good	No change	Fairly Poor	No change

Reach C – Thames Water Walton Intake to Teddington Weir

In accordance with the Annex B.2.1. Physical Environment Assessment Report, there is no predicted changes in the flows 5.4km downstream of the outfall (Hampton intake). As TR_05, TR_06, TR_07 and TR_08 are all downstream of this location, and there are negligible predicted changes to all other indicators, there is no assessed changes to the RCAs (Table 4-3).

There is no assessed change to indicators for TR_05, TR_06, TR_07 and TR_08 based on the operation of this scheme.

Subsequently, there are likely to be no measurable changes in weir pool or marginal habitat that are likely to impact the fish community within this reach.

4.4 ESTUARINE FISH

4.4.1 Overview

The following reaches have been assessed in relation to all life stages of estuarine fish in relation to thermal preferenda, water quality, spawning requirements and fluvial habitat of to evaluate each Mogden water recycling scheme. An additional assessment of the Mogden water recycling scheme at 200 Ml/d for the Richmond pound drawdown water quality is also included.

4.4.2 Estuarine Thames Tideway

Reach D – Teddington Weir to Battersea Park

Velocity and flow impacts upon the fish community

The decrease in flow associated with the Mogden STW final effluent discharge array on the bed of the Thames Tideway opposite Isleworth Ait may act to increase the overall accessible habitat for several species which are likely to be excluded from areas of high flow. These species may include common goby and flounder. However, conversely increased flows have the potential to be preferred by species such as sea bass. Overall the changes to flows predicted within the Annex B.2.1. Physical Environment Assessment Report are not likely to result in a change to the fish community overall but may result in minor changes to species distribution at the Mogden STW outfall.

Temperature impacts upon the freshwater fish community

An assessment of the water temperature impacts in the estuarine Thames Tideway arising from Mogden STW final effluent reduction associated with a Mogden water recycling scheme has been undertaken for the 200 Ml/d size of scheme. There are no predicted impacts upon temperature within the Upper Tideway and thus no predicted impacts upon the estuarine fish community in relation to a reduction of final effluent from Mogden STW.

Oxygen Saturation impacts upon the freshwater fish community

An assessment of the dissolved oxygen concentration impacts in the estuarine Thames Tideway arising from Mogden STW final effluent reduction associated with a Mogden water recycling scheme has been undertaken for the 200 Ml/d size of scheme. The modelled data displayed in Figure 4.45 and Figure 4.46 of the London Effluent Reuse SRO Annex B.2.2. Water Quality Assessment Report[29] indicate that there is more dissolved oxygen in the upper Tideway in areas associated with the Mogden STW outfall, due to less effluent in the water course at these locations. Under the 5th percentile this represents a difference in dissolved oxygen of less than 0.5 mg/l. While under the 50th percentile the represented difference is less, at approximately 0.25 mg/l. as such, there are no predicted impacts to estuarine fish community within Reach D due to an increase in dissolved oxygen concentrations.

Dissolved inorganic nitrogen impacts upon the fish community

Across both flow scenarios under the Mogden water recycling scheme at 200 Ml/d, there is a reduction in DIN concentration during the scheme on period, with DIN status in the estuarine Thames Tideway from Mogden Effluent reflecting ‘good’ WFD status under both scenarios. As such, there are no predicted impacts to estuarine fish community within Reach D in response to changes in DIN concentration.

Richmond Pound drawdown

Potential impacts predicted for Richmond Pound drawdown are negligible for all scheme sizes, with negligible changes modelled regarding temperature (max. increase of 0.1 °C and max. decrease of 1 °C under both schemes), salinity (max increase of 0.55 ppt under both schemes), suspended sediment (max. decrease of 0.45 and 015 kg/m^3 under A82 and M96, respectively), and dissolved oxygen (max. increase 0.5 mg/l under both schemes).

Reach E – Battersea Park to Tower Bridge

There is no evidence to suggest that reduction in flows associated with the Mogden STW final effluent reduction would impact upon this reach. This is due to predicted negligible changes in wetted habitat, water level and suspended sediment concentration.

Reach F Tower Bridge to 3km seawards of Beckton STW

There is no evidence to suggest that reduction in flows associated with the Mogden STW final effluent reduction would impact upon this reach. This is due to predicted negligible changes in wetted habitat, water level and suspended sediment concentration.

4.5 MIGRATORY FISH

4.5.1 Overview

The following reaches have been assessed in relation to all life stages of migratory fish in relation to thermal preferenda, water quality, spawning requirements and fluvial habitat of to evaluate each Mogden water recycling scheme. An additional assessment of the Mogden water recycling scheme at 200 Ml/d for the Richmond Pound drawdown water quality is also included.

4.5.2 Freshwater River Thames

Within this reach of the River Thames upstream of Teddington Weir, the migratory fish considered include Atlantic salmon, sea trout, river lamprey, and European eel. There, is no evidence to suggest that sea lamprey, smelt and twaite shad access this freshwater reach of the River Thames.

Temperature, velocity and flow impacts have been previously discussed within the freshwater fish section of this report (Section 4.2.2). The following sections draw upon the same conclusions but interpret them in relation to migratory fish as follows:

Velocity and flow impacts upon the migratory fish community

At the Mogden water recycling outfall at Walton Bridge river flow would be increased by 21% for the 200 Ml/d scheme, 16% for the 150 Ml/d scheme, 11% for a 100 Ml/d scheme, and 5% for a 50 Ml/d scheme. The model suggests the increased velocity of the plume rapidly declines by ~150m downstream of the discharge, with remaining flow velocities in the channel range from 0.025-0.05m/s, similar to upstream of the proposed discharge point, although a small tongue of higher velocities (0.05-0.075m/s) persists for ~250m downstream on the right bank. Localised increases in flows immediately adjacent to the discharge outfall may act to reduce the overall accessible habitat for migratory species such as lamprey or even attract salmonid species towards the increase in flow.

Changes in water level within the River Thames can affect the operation of fish passes in relation to migratory fish at Sunbury Weir, Molesey Weir and Teddington Weir. Modelled water level data at each of these weirs under varying river flows and respective Mogden water recycling schemes have been extracted and used to understand changes against the baseline and how these could impact barrier possibility (Section 4.5 of the Annex B.2.1. Physical Environment Assessment Report). At Sunbury Weir fish pass the data show that under the three different river flows and the 200 Ml/d outfall release there is minor change in water level of between 0.04m to 0.02m upstream of the weir, with no recorded change downstream of the weir. At Molesey Weir fish pass the data show that under the three different river flows and the 200 Ml/d outfall release there is no predicted change in water level upstream or downstream of the weir.

At Teddington Weir for the Mogden water recycling scheme there would be no change in flows as consequence of operation of the scheme. There would also be no change in flows at Molesey Weir and there would be no influence by Mogden water recycling scheme on water level management or water level within the Molesey-Teddington reach. As such, it is considered that there would be no change in the passability of migratory fish

through the Teddington Weir fish pass and the European eel elver pass, or further upriver at the Sunbury and Molesey fish passes.

Temperature impacts upon the migratory fish community

Temperature has been previously discussed within the freshwater fish section of this report (Section 4.2.2). In relation to salmonid fish e.g. Atlantic salmon and sea trout, an increase in river temperature can influence the instream habitat they choose, the areas they avoid and any spawning or migratory cues i.e. their thermal preferenda.

Salmonid fish are sensitive to temperature and are considered to be Arctic–Boreal[40] species, whereas lamprey and shad species are considered to be Lusitanian species[41]. At lowest flows (600 Ml/d) the Mogden water recycling scheme would operate at the mean temperature difference between the indicative Mogden water recycling scheme discharge and the river temperature (16.9 ^{o}C) which, during these times, is +3.0^{o}C. During the coldest river temperatures, the Mogden water recycling scheme would operate at times that would correspond moderate flows (780 Ml/d). The mean temperature difference between the Mogden effluent (as a proxy for the recycled water) and the river temperature during (8.9 ^{o}C) these times is +6.1^{o}C. Either of those conditions could describe the 2% exceedance statistic for a plume, and as such have been included in model parameterisation.

Section 4.3 of the Annex B.2.2. Water Quality Assessment Report undertakes an analysis of temperature extremes to support assessment of 3D modelling of discharge plume, through discussion with the Environment Agency. The Environment Agency has advised that a discharge plume of 2^{o}C or more temperature uplift cannot occupy more than 25% of the cross-sectional area of the river for more than 2% of the time.

Temperature effects at the discharge locations and downstream have been modelled by HR Wallingford and are sumarised within Table 4-4. In relation to the 3D modelling of the discharge the majority of the modelled scenarios comply with the EA guidance. However, the 200 Ml/d scheme at 780 Ml/d river flow scenario indicates that 25 m downstream of the outfall 47.2% of the channel is affected by the plume and the 150 Ml/d Mogden water recycling scheme at 780 Ml/d river flow indicates that 25 m downstream of the outfall 31.4% of the channel is affected by the plume. As such, migratory salmonid fish in these scenarios may not be able to migrate through this reach and or be delayed in relation to their migration within this reach of the freshwater River Thames.

[40] Distribution from the Arctic Circle through the northern temperate zone to southern United Kingdom.

[41] Distribution covers warmer latitudes, approximately from the Mediterranean to the southern United Kingdom (≈ 51^{o} N).

Table 4-4 High level summary of the river modelled temperature changes and extent in relation to the Mogden water recycling 200 Ml/d, 150 Ml/d and 100 Ml/d schemes[42]

Scenario	Temperature change at Walton outfall	Temperature change 25m downstream of outfall	Temperature change 50m downstream of outfall	Temperature change 75m downstream of outfall	Temperature change 100m downstream of outfall
200 Ml/d Mogden water recycling scheme at 600 Ml/d river flow	13.4% of the channel is affected by a temperature increase of >2ºC.	0% of the channel is affected by a temperature increase of >2ºC	0% of the channel is affected by a temperature increase of >2ºC	0% of the channel is affected by a temperature increase of >2oC.	0% of the channel is affected by a temperature increase of >2ºC
200 Ml/d Mogden water recycling scheme at 780 Ml/d river flow	24% of the channel is affected by a temperature increase of >2ºC	47.2% of the channel is affected by a temperature increase of >2ºC	9.8% of the channel is affected by a temperature increase of >2ºC	0% of the channel is affected by a temperature increase of >2ºC	0% of the channel is affected by a temperature increase of >2ºC
200 Ml/d Mogden water recycling scheme at 950 Ml/d river flow	11.3% of the channel is affected by a temperature increase of >2ºC	0% of the channel is affected by a temperature increase of >2ºC	0% of the channel is affected by a temperature increase of >2ºC	0% of the channel is affected by a temperature increase of >2ºC	0% of the channel is affected by a temperature increase of >2ºC
150 Ml/d Mogden water recycling scheme at 780 Ml/d river flow	12.7% of the channel is affected by a temperature increase of >2ºC	31.4% of the channel is affected by a temperature increase of >2ºC	0% of the channel is affected by a temperature increase of >2ºC	0% of the channel is affected by a temperature increase of >2ºC	0% of the channel is affected by a temperature increase of >2ºC
100 Ml/d Mogden water recycling scheme at 300 Ml/d river flow	1.3% of the channel is affected by a temperature increase of >2ºC	0% of the channel is affected by a temperature increase of >2ºC	0% of the channel is affected by a temperature increase of >2ºC	0% of the channel is affected by a temperature increase of >2ºC	0% of the channel is affected by a temperature increase of >2ºC

[42] Full details of this assessment and the HR Wallingford modelling are contained within the Annex B.2.2. Water Quality Assessment Report.

4.5.3 Estuarine Thames Tideway

There is no evidence to suggest that there are any potential impacts associated with the Mogden water recycling scheme below Richmond Pound. Furthermore, within Richmond Pound the impacts of the scheme are considered to be negligible. Further down the Thames Tideway and in the vicinity of the Mogden STW final effluent outfall, migratory species such as Atlantic salmon, seat trout, twaite shad and European eel may be present and use tidal flows to aid migration and movement within this reach of the Thames Tideway. If migrating up-river, then these fish species are highly likely to utilise flood tides or if migrating down-river they are likely to utilise ebb-tides. This concept of 'tidal stream transport' has been well documented[43] and there is no evidence to suggest that a reduction in flows associated with a Mogden STW final effluent would impact upon migratory fish movements or migration within the Thames Tideway.

During periods of slack water associated with either high and/or low tide then any migratory fish within the location of the Mogden STW outfall may choose to rest during slack water or continue their migration up river. These periods of slack water may only be 30 minutes per tide and given the dissolved oxygen improvements arising from Mogden STW final effluent reduction and no temperature impacts predicted at the proposed Mogden STW outfall location (Section 4.4.2) there are no predicted impacts upon migratory fish within the Thames Tideway.

Section 4.8 of the London Effluent Reuse SRO Annex B.2.1. Physical Environment Assessment Report[2] states that there are negligible changes in suspended solids concentration within the Thames Tideway. Therefore no negative impact on migratory fish is expected under any current modelling scenario, therefore no adverse impacts on the fish community are expected.

4.6 EUROPEAN SMELT

4.6.1 Overview

The following reaches have been assessed in relation to all life stages of European smelt in relation to thermal preferenda, water quality, spawning requirements and fluvial habitat to evaluate each Mogden water recycling scheme. An additional assessment of the Mogden water recycling scheme at 200 Ml/d for the Richmond pound drawdown water quality is also included.

4.6.2 Estuarine Thames Tideway

Reach D – Teddington Weir to Battersea Park

Smelt are known to spawn within Reach D between Battersea Park and Putney Bridge[44]. After spawning adult fish return down river to the outer estuary and results from the 2022 smelt survey indicate that smelt spawned sometime during mid-February, which is the earliest ever recorded within the Thames Tideway.

At the time of spawning the smelt eggs initially adhere to the sub-tidal gravels but then sheer off and move with the tidal flow. As such, smelt eggs are influenced by tidal currents and move throughout Reach D on each tide until they hatch and are able to utilise tidal stream transport. 0+ (young of the year) fish can be taken as far upstream as Richmond by late June and most of the juvenile fish descend to the lower estuary by the early autumn[45]. It should be noted that the net mass flow of water within the Thames is always down river i.e. from the Upper to Lower Tideway, and this helps to explain why there are large numbers of 0+ smelt recorded during each autumn within the Middle Tideway at Greenwich.

Fish eggs and their larval stages are considered to be sensitive to water quality, siltation and sedimentation. As highlighted within Section 4.4.2 then there are no predicted changes to temperature by the Mogden water recycling scheme and dissolved oxygen levels within the location of the Mogden STW final effluent outfall are predicted to increase. Furthermore Section 4.8 of the London Effluent Reuse SRO Annex B.2.1. Physical Environment Assessment Report[2] states that there are negligible changes in suspended solids concentration within the estuary. Therefore no negative impact upon the smelt population within Reach D are expected.

[43] Elliott, M. & Hemingway, K. (2002). Fishes in Estuaries. Blackwell Science Ltd. ISBN:9780632057337.

[44] Atkins (2022) Smelt Ichthyoplankton Surveys. Ichthyoplankton survey report_v2.0.

[45] Colclough, S.R. & Coates, S.A. (2013). The status of Smelt Osmerus eperlanus (L.) in rivers and estuaries in England and Wales. Environment Agency, Bristol.

Reach E – Battersea Park to Tower Bridge

Smelt are known to spawn within Reach E between Battersea Park and the mouth of the River Wandle[46]. As discussed within Reach D smelt spawned during mid-February 2022 and after spawning adult fish return down river. As previously discussed, smelt eggs are influenced by tidal currents and will move throughout Reach E on each tide until they hatch and are able to utilise tidal stream transport.

Fish eggs and their larval stages are considered to be sensitive to water quality and siltation and sedimentation. Within Reach E there are no predicted changes to temperature and dissolved oxygen levels by the Mogden water recycling scheme and negligible changes in suspended solids concentration within the Thames Tideway are predicted. Therefore no negative impacts upon the smelt population are expected within Reach E.

Reach F Tower Bridge to 3km seawards of Beckton STW

Smelt do not spawn in Reach F but adult fish will migrate through this reach and juvenile and 0+ fish will utilise tidal stream transport to migrate through this reach of the Thames Tideway.

Juvenile fish and their larval stages are considered to be sensitive to water quality and siltation and sedimentation have been previously discussed. Within Reach F there are no predicted changes to temperature and dissolved oxygen levels by the Mogden water recycling scheme and negligible changes in suspended solids concentration within the Thames Tideway are predicted. Therefore no negative impacts upon the smelt population are expected within Reach F.

4.7 OLFACTORY

4.7.1 Overview

An initial screening assessment has been undertaken to identify potential new or increased pressures to the study areas[47]. This assessment uses reconcentration calculations utilising measured Mogden STW final effluent concentrations and discharge flows in order to compare in-river concentrations to baseline and highlights determinands which exceed or approach (within 10% of) the EQS (if applicable) under both mean and 95th percentile concentrations during scheme on periods. This assessment is intended as a guide for future investigations, see Section 6 of the London Effluent Reuse SRO Gate 2 Annex B.2.2. Water Quality Assessment Report[29], as the olfactory suite for monitoring was updated at Gate 2 and that data will be made available for Gate 3.

4.7.2 Freshwater River Thames

Reach A – Shepperton Weir to Affinity Water Walton Intake

The proposed Mogden water recycling discharge is located within Reach B and there are no upstream impacts associated with this discharge in relation to olfaction within Reach A. As such, olfactory cues in relation to freshwater and migratory species have not been considered further within this reach

Reach B – Affinity Water Walton Intake to Thames Water Walton Intake

Within the Mogden A82 model scenario 26 chemical determinands within the olfaction suite were identified as exceeding the LOD in the freshwater River Thames under reference conditions. Of these 26 determinands, 10 were analysed against the EQS for both reference conditions and the 1 in 5 year (A82) flow Mogden-200 scenario (See Table 4.7 within the London Effluent Reuse SRO Gate 2 Annex B.2.2. Water Quality Assessment Report). Under reference conditions, four chemical determinands were identified as exceeding the standard. Of these, dissolved copper, pirimicarb and dissolved zinc remained above the standard under the A82 Mogden-200 scenario. Dissolved chromium (III) exhibits a decrease in concentrations to below the standard under the A82 Mogden-200 scenario. There is one additional pressure under the A82 Mogden-200 scenario, with permethrin concentrations increasing to above the standard.

Dissolved copper

In studies of fish olfactory toxicity, copper has been the subject of a large body of research and copper avoidance has been observed in several species of salmonids at very low concentrations (chinook salmon, 0.7µg/L), however, avoidance appears to be concentration specific. In the majority of studies, copper toxicity

[46] Atkins (2022) Smelt Ichthyoplankton Surveys. Ichthyoplankton survey report_v2.0.
[47] Ricardo (2021). Technical Note: London Effluent Reuse SRO Migratory fish of the Thames RBD: risk to olfactory cues.

is based upon the presence of dissolved copper salts ($CuSO_4$, $CuCl_2$), however, in recent years the prevalence of copper nanoparticles has been the subject of study as copper nanoparticles become more prevalent in industrial applications and consequently are released to the environment. In summary, the evidence suggests that copper is a general-purpose olfactory toxicant for all freshwater fish[48].

Permethrin

Permethrin is highly toxic to fish in the aquatic environment, working as a neurotoxin by inhibiting sodium (Na) ion channels. Olfactory nerves utilise sodium channels to convey information across membranes. Permethrin causes efflux through both the extracellular space and from the intracellular space through the axonal membrane[49]. Though the exact concentrations at which olfaction is inhibited by permethrin is not known.

Pirimicarb

Pirimicarb is a carbamate pesticide which inhibits acetylcholinesterase activity, affecting, amongst other systems, the olfaction systems in fish. While the exact concentrations at which olfaction is inhibited by pirimicarb is not known, experiments into cytotoxicity suggest concentrations of 22 – 66 mg/l induce LC50[50] regardless of exposure time[51].

Dissolved zinc

It is well understood that metals are effective at blocking neurological pathways, within the literature zinc is known to be an olfaction inhibitor.

The Mogden water recycling 1 in 20 year (M96) flow series indicates that the olfaction suite of chemical determinands in the freshwater River Thames under the M96 Mogden-200 scenario compared with reference conditions are the same as those described for the A82 Mogden-200 scenario.

Olfactory cue dilution

In addition to olfactory inhibition resulting from chemical inhibitors, impacts to the river volume may infer some impact to olfactory homing responses in all migratory species during marine to freshwater migration. Olfactory homing cues vary dependent upon species, though in general migratory species respond to imprinted natal stream chemistry and conspecific olfactory cues. At the Mogden water recycling outfall at Walton Bridge, river flow would be augmented by 200 Ml/d, in some scenarios this represents a 21% increase in river flow, which may be interpreted as a 21% reduction in olfactory cue concentration.

The impacts to natal homing migrations resulting from alterations to water odour properties are well understood for salmonids. Several studies demonstrate that salmonids exhibit a stronger homing response to undiluted natal stream waters when compared to dilute natal stream waters[35]. A stronger homing response is likely to result in a decrease in migration time, and therefore a dilution of olfactory cues is likely to result in an increased migration time. Consequently dilute olfactory cues would decrease energy available for reproduction and potentially reduce fitness. Impacts to European eel and lamprey are not as well understood, however it is assumed for the purposes of this report that the impact of olfactory cue dilution will be in line with those recorded for salmonids.

Though olfactory cues play an important role in the migration of anadromous and catadromous fish species, so too do visual, social and geomagnetic cues. To what extent olfaction is guiding the migration of salmonids has been shown to be dependent upon distance from the homing stream[36]. Tributaries known to support brown trout populations within 12 km of the lower Thames include the rivers Wey, Bourne, Colne, and Mole[52]. However, given the size of the catchment and location of the outfall in the lower River Thames it may be assumed that impacts to olfactory cue resulting from dilution are likely to be minor. However, impacts to the olfactory homing cues for migratory species resulting from the Mogden water recycling scheme cannot be determined with certainty from the information available.

[48] Tierney, K.B., Baldwin, D.H., Hara, T.J., Ross, P.S., Scholz, N.L. and Kennedy, C.J., (2010). Olfactory toxicity in fishes. Aquatic toxicology, 96(1), pp.2-26

[49] Henderson, R., Strichartz, G. 1974. Ion fluxes through the sodium channels of garfish olfactory nerve membranes. Journal of physiology, 238(2), pp 329-342.

[50] Lethal concentration 50 (LC50) is the concentration at which a chemical will kill 50% of laboratory animals exposed to it under proper testing conditions

[51] Vera-Candioti, J., Soloneski, S., Larramendy, M. 2015. Pirimicarb-based formulation-induced genotoxicity and cytotoxicity in the freshwater fish Cnesterodon decemmaculatus (Jenyns, 1842) (Pisces, Poeciliidae). Toxicol Ind Health, 31(11) pp 1051-60

[52] Steve Sheridan (2022). EA. As per comms.

Reach C – Thames Water Walton Intake to Teddington Weir

The assessment of Reach B is considered representative of Reach C.

4.7.3 Estuarine Thames Tideway

Reach D – Teddington Weir to Battersea Park

Within the A82 Model 24 chemical determinands within the olfaction suite were identified as exceeding the LOD in the estuarine Thames Tideway under reference conditions. Of these 24 determinands, 15 were analysed against the EQS for both reference conditions and the A82 Mogden-200 scenario. Table 4.8 within the Annex B.2.2. Gate 2 Water Quality Assessment Report[29] shows the exceedances of the EQS for these determinands.

As above, the assessment concludes the same five chemicals (dissolved copper, cypermethrin, permethrin, pirimicarb and dissolved zinc) are at risk of affecting olfaction in the estuarine Thames Tideway. The impacts on olfaction from these chemicals have been described above in Section 4.7.2.

Reach E – Battersea Park to Tower Bridge

The assessment of Reach D is considered representative of Reach E.

Reach F Tower Bridge to 3km seawards of Beckton STW

The assessment of Reach D is considered representative of Reach F.

4.8 SUMMARY OF FISH ASESSMENT OF MOGDEN WATER RECYCLING SCHEME

From the results it is evident that the potential changes in flow are not considered to be of a magnitude to affect the resident fish communities within the freshwater River Thames or Thames Tideway, though they may result in temporary changes to species distribution. However, localised increase in flow may act to reduce the overall accessible habitat for migratory species or may act as an attractant during migrations as species respond to flow related cues during freshwater migrations. Additionally the potential changes in flows are not likely to result in impacts to migratory species associated with the Thames Estuary.

The results of the water quality modelling indicate that the water quality and temperature changes within the freshwater River Thames are likely to result in changes to the freshwater fish community. Impacts to temperature are not likely to exceed the thermal tolerances of species present but may result in impacts to the behaviour of fish species particular at or close to the discharge location where temperatures are highest. Reaches A, B and C fall within the WFD Lower Thames Operational Catchment, which is formed by 17 water bodies and includes the Thames (Cookham to Egham) and the Thames (Egham to Teddington) water bodies[53]. The current WFD status of temperature within these water bodies is moderate which for WFD salmonid waters[54] equates to river temperature as a 98 %tile not exceeding 28^{o}C . For river temperature to achieve good then river temperature as a 98 %tile should not exceed 23^{o}C

Impacts to fish behaviour may also extend to migratory species such as Atlantic salmon and sea trout, where avoidance of warmer waters may prevent upstream migration due to the extent of cross-sectional impacts at the discharge location. Though, these impacts are likely to be dependent upon the ambient temperature in the wider River Thames. Temperature increases below the mixing zone may result in changes to metabolic rate, gonad development, embryonic development, hatch rate and overall survival of most species to a varying degree. Species tolerant of warmer climates may show increased success compared to species indicative of colder climates, this may lead to localised changes to the community structure downstream of the discharge outfall. There are no predicted impacts upon temperature within the Upper Tideway and thus no predicted impacts upon the estuarine fish community.

The results of the HR Wallingford thermal plume modelling indicate that the 200 Ml/d scheme at 780 Ml/d river flow scenario (25m downstream of the outfall) 47.2% of the River Thames channel is affected by the plume and the likewise the 150 Ml/d Mogden water recycling scheme at 780 Ml/d river flow indicates at 25 m

[53] https://environment.data.gov.uk/catchment-planning/

[54] The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015

downstream of the outfall 31.4% of the channel is affected by the plume. As the plume under these model scenarios exceeds 25% then these scheme sizes are non-compliant with current EA thermal plume guidance. As such, it is likely that under these scenarios both Atlantic salmon and sea trout will be impacted by the Mogden water recycling scheme of 150 Ml/d and 200 Ml/d for limited periods of time under rare flow conditions. Temperature impacts in relation to migratory *Lampetra sp.* are not considered to be an issue given that they are warm water Lusitanian species

Impacts to dissolved oxygen are not likely to effect fish communities in the freshwater River Thames or estuarine Thames Tideway, similarly ammonia is not likely to impact the freshwater and estuarine fish population. A number of WFD and EQSD priority substances have been identified as likely to exceed standards through operation of the scheme, the extent to which these chemicals will impact the freshwater or estuarine fish community is not yet understood. However, several olfactory inhibitors have been highlighted including dissolved copper, cypermethrin, permethrin, pirimicarb and dissolved zinc which may impact olfaction in the estuarine Thames Tideway.

5. FISH ASSESSMENT OF TEDDINGTON DRA SCHEME

5.1 INTRODUCTION

This section sets out the assessment for the tasks set out in Table 1-1 relevant to the Teddington DRA scheme. The study area for each task has been set out per task as it is not consistent across tasks. The Teddington DRA scheme assessment for each of the following tasks has been set out in the following sections:

- Freshwater Fish
- Weir pool/marginal habitat (including Sunbury creek)
- Estuarine Fish (including European eel)
- Migratory Fish (including European eel)
- European Smelt
- Olfactory cues

Potential impact pathways resulting from implementation of the Teddington DRA scheme are summarised below:

- Increased velocities and the resulting impact on the upstream and/or downstream migration of Atlantic salmon, sea trout, shad, smelt, lamprey and European eel.
- Increased velocities and the resulting impact on the local migration of coarse fish and brown trout to spawning areas.
- Loss/decrease in habitat quantity and quality due to changes in hydraulics (i.e. increased velocity and depth) resulting in increased competition for space.
- Loss of juvenile and adult habitats within margins due to increase wetted width and velocities, including habitats for lamprey ammocoetes.
- Risk of displacement of juvenile fish due to increased flows.
- Changes in water quality could have a direct impact on fish populations (e.g. mortality as a result of localised dissolved oxygen sags).
- Changes in the availability of food (biofilm, macrophytes, macroinvertebrates) due to increased flows and changes in water quality.

These assessments have been conducted utilising the London Effluent Reuse SRO Annex B.2.1. Physical Environment Assessment Report[2] and Annex B.2.2. Water Quality Assessment[29] Report, where full details of the impact assessments determinands are to be found.

Summary of physical environment impacts associated with a Teddington DRA scheme

The full assessment of the Gate 2 physical environment impacts of the Teddington DRA schemes includes an assessment of:

- Velocity and flow,
- Outfall design,
- Wetted habitat,
- Fish pass and barrier passability,
- Richmond Pound drawdown, and
- Estuarine sediment.

Table 5-1 shows a high-level summary of these impacts, which are also briefly described below.

Velocity and flow

The Teddington DRA scheme is expected to result in major impacts (150 Ml/d and 100 Ml/d scheme sizes) to flow conditions within the River Thames, with a 50% to 33% reduction in exceptionally low flows for 250m between the intake and outfall. For the smaller scheme sizes (75 Ml/d and 50 Ml/d scheme sizes), moderate impacts are expected to flow conditions within the River Thames, with a 25% to 17% reduction in exceptionally low flows for 250m between intake and outfall.

Outfall design

The potential impacts predicted for outfall design are negligible for both assessed scheme sizes with very negligible changes in water level or velocities modelled between the intake and the outfall.

Wetted habitat

The potential impacts predicted for wetted habitat are negligible for both assessed scheme sizes, with very negligible changes in water level or velocities modelled between the intake and the outfall and negligible changes in exposure of wetted habitat.

Fish pass and barrier passability

The potential impacts predicted for fish pass and barrier passability are negligible for both assessed scheme sizes, with a negligible change in water levels for scheme when compared to baseline under the 75 Ml/d scheme size.

Richmond Pound drawdown

The potential impacts predicted for Richmond Pound drawdown are negligible for both assessed scheme sizes, with negligible changes in wetted habitat, water level and suspended sediment concentration.

Estuarine sediment

The potential impacts predicted for estuarine sediment are negligible for both assessed scheme sizes, with negligible changes in wetted habitat, water level and suspended sediment concentration within the estuary.

Table 5-1 Summary of potential physical environment impacts for Teddington DRA schemes

Size	Flow	Outfall and intake design	Wetted habitat	Fish pass and barrier passability	Richmond Pound drawdown	Estuarine sediment
50 Ml/d	Moderate 17% reduction in exceptionally low flows for 250m between intake and outfall (300 Ml/d upstream of intake)	Negligible change in velocities at intake or outfall inferred from larger scheme modelling assessment of negligible	Negligible change in water level or velocities between intake and outfall inferred from larger scheme modelling assessment of negligible	Negligible water level change inferred from larger scheme modelling assessment of negligible	Negligible change in wetted habitat, water level and suspended sediment concentration.	Negligible change in wetted habitat, water level and suspended sediment concentration.
75 Ml/d	Moderate 25% reduction in exceptionally low flows for 250m between intake and outfall (300 Ml/d upstream of intake)	Negligible change in velocities at intake or outfall modelled.	Negligible change in water level or velocities between intake and outfall modelled. Negligible change in wetted habitat.	Negligible water level change modelled		
100 Ml/d	Major 33% reduction in exceptionally low flows for 250m between intake and outfall (300 Ml/d upstream of intake)	Negligible change in velocities at intake or outfall modelled.	Negligible change in water level or velocities between intake and outfall modelled. Negligible change in wetted habitat.	Negligible water level change modelled		
150 Ml/d	Major 50% reduction in exceptionally low flows for 250m between intake and outfall (300 Ml/d upstream of intake)	Negligible change in velocities at intake or outfall modelled.	Negligible change in water level or velocities between intake and outfall modelled. Negligible change in wetted habitat.	Negligible water level change modelled		

Summary of water quality impacts associated with a Teddington DRA scheme

The full assessment of the Gate 2 water quality impacts of the Mogden water recycling schemes includes an assessment of:

- Water temperature,
- General physico-chemical,
- WFD chemicals,
- Environmental Quality Standards Directive (EQSD) chemicals,
- Olfactory water quality, and
- Richmond Pound drawdown.

Table 5-2 shows a high-level summary of these impacts, which are also briefly described below.

Water temperature

Within the freshwater River Thames, it is predicted that a maximum temperature change of 0.98°C may occur, achieving a maximum modelled temperature of 19.73°C. Negligible impacts are predicted in the estuarine Thames Tideway.

General physico-chemical

Within the freshwater River Thames, it is predicted that there may be minor changes in ammoniacal nitrogen within the 150 Ml/d, 100 Ml/d, 75 Ml/d and 50 Ml/d scheme size, comprising maximum changes in concentration of 43% (a maximum concentration of 0.07 mg/l, indicative of high status) at Teddington weir. Suspended solids show positive impacts with large decreases in concentration. There are no modelled impacts in dissolved oxygen saturation except at 150Ml/d which display a negligible decrease in concentration. Biochemical oxygen demand shows minor increases in concentration (remaining at at least good status) under the 100 Ml/d, 75 Ml/d and 50 Ml/d schemes, with positive impacts displayed at 150 Ml/d.

Within the estuarine Thames Tideway, it is predicted that there will be a decrease in dissolved inorganic nitrogen under all scheme sizes with negligible impacts to dissolved oxygen.

WFD chemicals

Within the freshwater River Thames minor impacts are predicted with only three additional chemicals exceeding the standard (A82 and M96) under the 150 Ml/d, 100 Ml/d, 75 Ml/d and 50 Ml/d scheme sizes.

Within the estuarine Thames Tideway this will be reduced due to reduced discharge flow rate.

EQSD chemicals

Within the freshwater River Thames negligible impacts are predicted with only one additional chemical exceeding the standard (A82 and M96) under the 150 Ml/d, 100 Ml/d, 75 Ml/d and 50 Ml/d scheme sizes.

Within the estuarine Thames Tideway this will be reduced due to reduced discharge flow rate.

Olfactory water quality

Within the freshwater River Thames negligible impacts are predicted with two additional exceedances and one reduced pressure occurring from the reference conditions under the 150 Ml/d, 100 Ml/d, 75 Ml/d and 50 Ml/d scheme sizes.

Within the estuarine Thames Tideway this will be reduced due to reduced discharge flow rate.

Richmond Pound drawdown

Negligible impacts have been inferred from the Mogden effluent Reuse scheme at 200 Ml/d modelling.

Table 5-2 Summary of potential water quality impacts for Teddington DRA schemes

Size	Water temperature	General physico-chemical	WFD chemicals	EQSD chemicals	Olfactory water quality	Richmond Pound Draw Down
50 Ml/d	Freshwater Thames Maximum change 0.7°C Thames Tideway Negligible impacts	Freshwater Thames Dissolved oxygen: No change. Ammoniacal Nitrogen: Minor impacts under A82 and M96. BOD: Minor impacts under A82 and M96. Suspended solids: Positive impacts under A82 and M96. ANC: No indication that ANC is affected by scheme in operation. pH: No significant difference. Thames Tideway DO: Negligible impacts inferred from Mogden effluent Reuse scheme at 200 Ml/d modelling DIN: Decrease in concentration during scheme on period, average 58.6 µMol/l (A82) and 51.7 µMol/l (M96).	Freshwater Thames Eight determinands decreased to be below the standard. 11 continued to exceed standards under the A82 scenario and three new pressures exceeded standards. The same occurs in the M96 scenario with three additional pressures. Thames Tideway Within the estuarine Thames Tideway this will be reduced due to reduced discharge flow rate.	Freshwater Thames Only one determinand exceeds standard under reference conditions and there is one additional pressure under A82 scenario. The changes remained the same under the M96 scenario. Thames Tideway Within the estuarine Thames Tideway this will be reduced due to reduced discharge flow rate.	River Thames A82 and M96 both have 10 exceedances with two new pressures and one reduced pressure compared to the reference conditions. Thames Tideway Within the estuarine Thames Tideway this will be reduced due to reduced discharge flow rate.	Negligible impacts inferred from Mogden effluent Reuse scheme at 200 Ml/d modelling

Size	Water temperature	General physico-chemical	WFD chemicals	EQSD chemicals	Olfactory water quality	Richmond Pound Draw Down
75 Ml/d	Freshwater Thames Maximum change 1.1°C Thames Tideway Negligible impacts	Freshwater Thames Dissolved oxygen: No change. Ammoniacal Nitrogen: Minor impacts under A82 and M96. BOD: Minor impacts under A82 and M96. Suspended solids: Positive impacts under A82 and M96. ANC: No indication that ANC is affected by scheme in operation. pH: No significant difference. Thames Tideway DO: Negligible impacts inferred from Mogden effluent Reuse scheme at 200 Ml/d modelling DIN: Decrease in concentration during scheme on period, average 55.6 µMol/l (A82) and 48.5 µMol/l (M96).	Freshwater Thames Eight determinands decreased to be below the standard. 11 continued to exceed standards under the A82 scenario and three new pressures exceeded standards. The same occurs in the M96 scenario with three additional pressures. Thames Tideway Within the estuarine Thames Tideway this will be reduced due to reduced discharge flow rate.	Freshwater Thames Only one determinand exceeds standard under reference conditions and there is one additional pressures under A82 scenario. The changes remained the same under the M96 scenario. Thames Tideway Within the estuarine Thames Tideway this will be reduced due to reduced discharge flow rate.	Freshwater Thames A82 and M96 both have 10 exceedances with two new pressures and one reduced pressure compared to the reference conditions. Thames Tideway Within the estuarine Thames Tideway this will be reduced due to reduced discharge flow rate.	

Size	Water temperature	General physico-chemical	WFD chemicals	EQSD chemicals	Olfactory water quality	Richmond Pound Draw Down
100 Ml/d	<u>Freshwater Thames</u> Maximum change 1.5°C <u>Thames Tideway</u> Negligible impacts	Freshwater Thames: Dissolved oxygen: No change. Ammoniacal Nitrogen: Minor impacts under A82 and M96. BOD: Minor impacts under A82 and M96. Suspended solids: Positive impacts under A82 and M96. ANC: No indication that ANC is affected by scheme in operation. pH: No significant difference. Estuarine Thames DO: Negligible impacts inferred from Mogden effluent Reuse scheme at 200 Ml/d modelling DIN: Decrease in concentration during scheme on period, average 52.5 µMol/l (A82) and 45.3 µMol/l (M96).	Freshwater: Eight determinands decreased to be below the standard. 11 continued to exceed standards under the A82 scenario and three new pressures exceeded standards. The same occurs in the M96 scenario with three additional pressures Estuarine Thames: Within the estuarine Thames Tideway this will be reduced due to reduced discharge flow rate.	Freshwater River Thames: Only one determinand exceeds standard under reference conditions and there is one additional pressures under A82 scenario. The changes remained the same under the M96 scenario. Estuarine Thames: Within the estuarine Thames Tideway this will be reduced due to reduced discharge flow rate.	Estuarine Thames: Within the estuarine Thames Tideway this will be reduced due to reduced discharge flow rate.	

Size	Water temperature	General physico-chemical	WFD chemicals	EQSD chemicals	Olfactory water quality	Richmond Pound Draw Down
150 Ml/d	Freshwater Thames: Maximum change 2.2°C Estuarine Thames Tideway: Negligible impacts	Freshwater Thames: Dissolved oxygen: Negligible impacts Ammoniacal Nitrogen: Minor impacts under A82 and M96. BOD: Positive impacts under A82 and M96. Suspended solids: Positive impacts under A82 and M96. ANC: No indication that ANC is affected by scheme in operation. pH: No significant difference. Estuarine Thames DO: Negligible impacts inferred from Mogden effluent Reuse scheme at 200 Ml/d modelling DIN: Decrease in concentration during scheme on period, average 46.4 µMol/l (A82) and 38.8 µMol/l (M96).	Freshwater: Eight determinands decreased to be below the standard. 11 continued to exceed standards under the A82 scenario and three new pressures exceeded standards. The same occurs in the M96 scenario with three additional pressures. Estuarine Thames: Within the estuarine Thames Tideway this will be reduced due to reduced discharge flow rate.	Freshwater River Thames: Only one determinand exceeds standard under reference conditions and there is one additional pressure under A82 scenario. The changes remained the same under the M96 scenario. Estuarine Thames: Within the estuarine Thames Tideway this will be reduced due to reduced discharge flow rate.	Estuarine Thames: Within the estuarine Thames Tideway this will be reduced due to reduced discharge flow rate.	

5.2 FRESHWATER FISH

5.2.1 Overview

The following reaches have been assessed in relation to all life stages of freshwater fish in relation to thermal preferenda, water quality, spawning requirements and fluvial habitat in order to evaluate each scheme. It should be noted that Reach A and Reach B are upstream of the Teddington DRA and are not considered further within the assessment.

5.2.2 Freshwater River Thames

Reach C – Thames Water Walton Intake to Teddington Weir

Velocity and flow impacts upon the fish community

It is important to note that when operational for water resources purposes (scheme on period) flow changes associated with a Teddington DRA scheme (i.e. 150 Ml/d for a 150 Ml/d Teddington DRA scheme; 100 Ml/d for a 100 Ml/d Teddington DRA scheme; 75 Ml/d for a 75 Ml/d Teddington DRA scheme; and 50 Ml/d for a 50 Ml/d Teddington DRA scheme) would be exclusively within the ~250m reach between the intake and outfall, with no change at Teddington Weir and the upstream extent of Reach C. When the scheme is not on for water resources purposes, the 25% maintenance flow (i.e. 37.5 Ml/d for a 150 Ml/d Teddington DRA scheme; 25.0 Ml/d for a 100 Ml/d Teddington DRA scheme; 18.75 Ml/d for a 75 Ml/d Teddington DRA scheme; and 12.5 Ml/d for a 50 Ml/d Teddington DRA scheme) flow changes associated with a Teddington DRA scheme would be exclusively flow increases downstream of the outfall to Teddington Weir, with no change between the intake and outfall.

Under the developed Scenario 1 simulation with a River Thames flows of 300 Ml/d a spatially limited increase in flow velocities occurs at the point of discharge (0.1-0.3m/s), with flow velocities increasing by 0.05-0.075m/s immediately downstream of the outfall and concentrated against the right bank for ~100m downstream. Generally, the velocities across the channel range from 0-0.025m/s, indicating still to very slow-moving flow. Apart from at the intake itself, there are no significant changes in flow velocities here. Velocity vectors remain predominantly in a downstream direction, although show a slight deflection towards the outfall as upstream flow passes by.

Localised increases in flows immediately adjacent to the discharge outfall may act to reduce the overall accessible habitat for several species which are likely to be excluded from areas of high flow. These species may include common bream, pike or tench. Conversely increased flows have the potential to be preferred by species such as dace, chub, stone loach and barbel. Overall the changes to flows predicted are not likely to result in a change to the fish community overall, but may result in minor changes to species distribution in the immediate vicinity of the discharge outfall during operation.

Temperature impacts upon the freshwater fish community

The modelled data indicates that the warmest river temperatures occur during July and August peaking at 19.7°C. Warmest effluent temperatures are seen during scheme in operation periods in August and September peaking at 20.7°C. The maximum temperature difference at low river flows at Teddington (scheme in operation) is 8.9°C. The maximum temperature difference between the River Thames and the Teddington DRA discharge of 10.4°C is during periods of plant maintenance only, at the lower rate of 18.75 Ml/d or 12.5 Ml/d.

Under a 50 Ml/d discharge the maximum modelled temperature was identified as 19.71°C with a maximum change of 0.7°C. During plant maintenance only times where the discharge is 12.5 Ml/d the maximum change identified was 0.05°C.

Under a 75 Ml/d discharge the maximum modelled temperature was identified as 19.73°C with a maximum change of 1.1°C. During plant maintenance only times where the discharge is 18.75 Ml/d the maximum change identified was 0.07°C.

Under a 100 Ml/d discharge the maximum modelled temperature was identified as 19.8°C with a maximum change of 1.5°C. During plant maintenance only times where the discharge is 25 Ml/d the maximum change identified was 0.07°C.

Under a 150 Ml/d discharge the maximum modelled temperature was identified as 19.8°C with a maximum change of 2.2°C. During plant maintenance only times where the discharge is 37.5 Ml/d the maximum change identified was 0.1°C.

The tolerable range of the species within the reach are relatively broad, and changes downstream of the mixing zone are not likely to exceed the maximum tolerable range for most species. However, temperatures of 19.8 ^{o}C as predicted under both the 100 Ml/d and 150 Ml/d discharge scenarios, are likely to exceed the preferable temperature ranges for migratory salmonid species including, brown trout and Atlantic salmon. Impacts of temperature upon Migratory species will be address is Section 5.5.

Temperature increases close to the discharge outfall of up to 10.4^{o}C are likely to result in impacts to the behaviour of fish species dependent upon the temperature of the wider River Thames, during colder periods a warmer effluent may act to attract species whereas in warmer periods increase temperatures at the outfall may elicit avoidance behaviours. Temperature changes below the mixing zone will result in minor changes to metabolic rate, embryonic development and hatch rate of most species. Temperature changes within this scale may impact gonad development, spawning timing, egg incubation, fry size and over winter mortality for a number of species present within the reach. For more thermophilic species such as bleak or chub these relatively minor temperature changes may result in competitive advantages when compared to species such as perch or pike. The majority of species typically spawn between March and June and therefore the scheme is not likely to operate during peak spawning periods for most species, however several species are known to spawn later in the year such as barbel, bream, chub and minnow.

In summary the scheme may result in minor changes to the fitness of cold-water species such as minnow, perch, pike and roach but beneficial to species belonging to warm water guilds such as bleak, common bream, chub and tench.

General physiochemical impacts upon the freshwater fish community

No changes to dissolved oxygen are predicted under the A82 scenario, under the M96 scenario oxygen at Teddington Weir is anticipated to increase by 1%. Therefore, no impacts to the fish community are likely to occur as a result of changes to dissolved oxygen.

Ammoniacal nitrogen under the A82 and M96 scenarios are predicted to increase by 30% and 43% respectively during scheme operation. The maximum predicted concentration under both scenarios is 0.08 mg/l (under the A82 scenario). Concentrations increases of this magnitude are within “High” WFD status for the river type, therefore no impacts to the fish community are anticipated as a result of increases to ammonia concentration.

The treated effluent associated with the Teddington DRA is subject to tertiary treatment at Mogden STW. An assessment has been undertaken of the WFD compliance of a Teddington DRA scheme sized at 50 Ml/d, 75 Ml/d, 100 Ml/d, or 150 Ml/d. No potential for status deterioration or introducing impediments to target status were identified in the Thames (Egham to Teddington) WFD water body (GB106039023232). However, minor changes to physico-chemical water quality were noted. As such there are no predicted impacts upon the fish community due to phosphorous.

WFD chemicals

Of the 13 chemicals exceeding the standard under reference conditions, the following three are increased under the A82 and M96 Teddington DRA scenarios.

- Cypermethrin
- Hexachlorocyclohexane
- Total chlorine

Despite the increases, it must be noted that the assessments represent potential risk of exceedance only as additional treatment is not considered.

In addition to the WFD chemicals described there are additional pressures under the Teddington DRA scenario, with the concentrations of the following EQSD chemical determinand increasing to above the standard.

- Pirimicarb

The concentration at which individual or groups of chemicals may be disruptive to individual fish species are poorly understood, as is the potential role of bioaccumulation. At this stage the significance/magnitude of the impact on freshwater fish cannot be assessed and it is only possible to note an increased risk for potential impacts for the determinants listed. When considering the potential increase in load against the context of the reference conditions, the risk is not considered to be discernible (low confidence). With specific regards to the

known impacts on olfaction from these chemicals, these have been described in more detail within Section 4.7.2.

5.3 WEIR POOL AND MARGINAL HABITAT

5.3.1 Overview

This section sets out the assessment for the marginal habitats in reaches potentially affected by the Teddington DRA scheme.

- Freshwater River Thames - Section 5.3.2

The assessment on impacts to the RCA are based on outputs from the Annex B.2.1. Physical Environment Assessment Report[2], Annex B.2.5. INNS Report[31], and macrophyte assessment (Section 5.5 of the Annex B.2.4. Aquatic Ecology Assessment Report[30]).

In summary, there is a predicted moderate (25%) reduction in exceptionally low flows for 250 m between the intake and outfall locations. Negligible changes in velocity, water level, wetted habitat. The assessment assumes Scenario 1 (300 Ml/d at 200 Ml/d discharge, noting the maximum size of the Teddington DRA scheme is smaller than this) from Annex B.2.1. Physical Environment Assessment Report. A full summary of predicted physical environment impacts is detailed in Section 5.1, Table 5-1.

5.3.2 Freshwater River Thames

Reach C – Thames Water Walton Intake to Teddington Weir

TR_05, TR_06 are located approximately 6.9 km and 6.3 km upstream of the Teddington DRA intake/discharge points on the freshwater River Thames. TR_07 is located on a side channel of the freshwater River Thames, to the west of Trowlock Island and is unaffected by this scheme. Therefore, there are no assessed changes to these RCA.

Although there will be the addition of artificial bank face structures (intake and outfall structures) within the section of the river covered by TR_08, indicators C7-C9 were assessed to be no change as the bank face in these locations are already modified channels (Table 5-3).

Indicator E3, channel bed hydraulic features, was assessed to increase in the section of the river covered by TR_08 in this reach due to the intake and discharge points which has been shown to alter flow patterns, introducing more diversity of flow immediately within the 250 m section. E11 has been assessed to alter for TR_08 to reflect the outcome of the INNS assessment (Table 5-3).

Due to negligible predicted changes in wetted width, there are no assessed changes to the channel margin natural indicators, i.e., D1-D4.

The assessed changes to the indictor scores for TR_08 were both positive (increased hydraulic feature richness) and negative (increased NNIPS extent). Overall, the preliminary condition score was reduced to -0.753, however this change does not meet the lower threshold and the condition category for Poor for this river type, and therefore remains Fairly poor river condition category. It is not expected that any appreciable natural habitat of note for key fish species would be impacted by the limited and localised change in wetted width and hydraulic habitat distribution from the proposed released flows, as the reach is already dominated by modified channel features.

The assessed changes in river condition indicators for RCAs within Reach C are presented in Table 5-3 below.

Table 5-3 Assessed changes in river condition indicators of Reach C during operation of the 75 Ml/d Teddington DRA scheme. Green shading indicates a positive change (i.e., a higher positive score or a lower negative score), and red shading indicates a negative change (i.e., a lower positive score or a higher negative score). '-' in the operational column indicates no change to the baseline score

Code	Indicator name	Positive / Negative type	TR_05 baseline	TR_05 operational	TR_06 baseline	TR_06 operational	TR_07 baseline	TR_07 operational	TR_08 baseline	TR_08 operational
B1	Bank top vegetation structure	Positive	3	-	2	-	2	-	2	-
B2	Bank top tree feature richness	Positive	0	-	0	-	0	-	0	-
B3	Bank top water related features	Positive	0	-	2	-	2	-	2	-
B4	Bank top NNIPS cover	Negative	0	-	0	-	0	-	0	-
B5	Bank top managed ground cover	Negative	-4	-	-3	-	-4	-	-4	-
C1	Bank face riparian vegetation structure	Positive	2	-	3	-	1	-	2	-
C2	Bank face tree feature richness	Positive	0	-	2	-	1	-	1	-
C3	Bank face natural bank profile extent	Positive	0	-	0	-	0	-	0	-
C4	Bank face natural bank profile richness	Positive	0	-	0	-	0	-	0	-
C5	Bank face natural bank material richness	Positive	1	-	1	-	0	-	1	-
C6	Bank face bare sediment extent	Positive	0	-	1	-	0	-	1	-
C7	Bank face artificial bank profile extent	Negative	-4	-	-4	-	-4	-	-4	-
C8	Bank face reinforcement extent	Negative	-4	-	-4	-	-4	-	-4	-
C9	Bank face reinforcement material severity	Negative	4	-	-4	-	-4	-	-4	-
C10	Bank face NNIPS cover	Negative	0	-	0	-	0	-	0	-
D1	Channel margin aquatic vegetation extent	Positive	0	-	1	-	0	-	1	-
D2	Channel margin aquatic morphotype richness	Positive	0	-	0	-	0	-	1	-
D3	Channel margin physical feature extent	Positive	0	-	1	-	0	-	0	-
D4	Channel margin physical feature richness	Positive	0	-	1	-	0	-	0	-
D5	Channel margin artificial features	Negative	-3	-	-2	-	0	-	-1	-
E1	Channel bed aquatic morphotype richness	Positive	0	-	0	-	0	-	0	-
E2	Channel bed tree features richness	Positive	0	-	0	-	1	-	0	-
E3	Channel bed hydraulic features richness	Positive	3	-	0	-	0	-	0	1

Code	Indicator name	Positive / Negative type	TR_05 baseline	TR_05 operational	TR_06 baseline	TR_06 operational	TR_07 baseline	TR_07 operational	TR_08 baseline	TR_08 operational
E4	Channel bed natural features extent	Positive	0	-	0	-	0	-	0	-
E5	Channel bed natural features richness	Positive	0	-	0	-	0	-	0	-
E6	Channel bed material richness	Positive	0	-	0	-	0	-	0	-
E7	Channel bed siltation	Negative	0	-	0	-	0	-	0	-
E8	Channel bed reinforcement extent	Negative	0	-	0	-	0	-	0	-
E9	Channel bed reinforcement severity	Negative	0	-	0	-	0	-	0	-
E10	Channel bed artificial features severity	Negative	-4	-	0	-	0	-	0	-
E11	Channel bed NNIPS extent	Negative	0	-	0	-	0	-	0	-1
E12	Channel bed filamentous algae extent	Negative	0	-	0	-	0	-	0	-
	Preliminary condition score:		-1.296	No change	-0.571	No change	-0.862	No change	-0.729	-0.753
	River condition category:		Poor	No change	Fairly Poor	No change	Fairly Poor	No change	Fairly Poor	Fairly Poor

5.4 ESTUARINE FISH

5.4.1 Overview

The following reaches have been assessed in relation to all life stages of estuarine fish in relation to thermal preferenda, water quality, spawning requirements and fluvial habitat of to the Teddington DRA 75 Ml/d scheme.

5.4.2 Estuarine Thames Tideway

Reach D – Teddington Weir to Battersea Park

There is no evidence to suggest that the Teddington DRA scheme would impact upon this reach. This is due to negligible changes in the physical environment within Richmond Pound and negligible changes in wetted habitat, water level and suspended sediment concentrations within Reach D.

Reach E – Battersea Park to Tower Bridge

There is no evidence to suggest that the Teddington DRA scheme would impact upon this reach. This is due to negligible changes in wetted habitat, water level and suspended sediment concentrations.

5.5 MIGRATORY FISH

5.5.1 Overview

The following reaches have been assessed in relation to all life stages of migratory fish in relation to thermal preferenda, water quality, spawning requirements and fluvial habitat of to evaluate each Teddington DRA scheme.

5.5.2 Freshwater River Thames

Within this reach of the River Thames upstream of Teddington Weir, the migratory fish considered include Atlantic salmon, sea trout, river lamprey, and European eel. There, is no evidence to suggest that sea lamprey, smelt and twaite shad access this freshwater reach of the River Thames.

Migratory species such as Atlantic salmon, seat trout and European eel utilise the fish pass, elver pass and weir structure at Teddington to facilitate their migratory phase. It is not known if river lamprey migrates through the fish pass at Teddington Weir but EA records suggest that there are low numbers of Lampetra sp. Have been recorded within the freshwater river Thames. The fish pass at Teddington is considered to be impassable to twaite shad given that the original design and specification of the Denil fish pass was to facilitate the upstream migration of Atlantic salmon[55].

Velocity and flow impacts upon the migratory fish community

Table 5.1 within the Annex B.2.1. Physical Environment Assessment Report[2] shows that under the three different river flows and the 75 Ml/d outfall release there is no predicted change in water level upstream of Teddington Weir. As such, it is considered that the fish pass at Teddington does not change in relation to efficacy or impact upon the passage of migratory fish during scheme operation.

Temperature impacts upon the migratory fish community

Section 5 of the Annex B.2.2. Water Quality Report[3] considers the water temperature impacts arising from the Teddington DRA discharge into the freshwater River Thames for the four sizes of DRA scheme; 50 Ml/d, 75 Ml/d, 100 Ml/d and 150 Ml/d. Both flow and temperature data were modelled using a deterministic spreadsheet model to represent the impact of the treated effluent discharge on the in-channel water temperature downstream of the outfall after the discharged water has been fully mixed with the in-channel water.

The introduction of a new treated effluent discharge because of a Teddington DRA scheme will result in temperature change downstream of a proposed DRA outfall. The extent of temperature effects has been modelled by HRW for the 75 Ml/d discharge scenarios under, 700 Ml/d, 400 Ml/d and 300 Ml/d river flow scenarios. Discharge effects for each of these scenarios are outlined within the Annex B.2.1. Physical Environment Assessment Report[2] and the key findings from this report are:

[55] Steve Sheridan (2022). EA. As per comms. It should be noted that a design for a new proposed fish pass suitable for shad is underway.

- Under a 75 Ml/d Teddington DRA at 700 Ml/d river flow 1.0% of the channel is affected by a temperature increase of at least 2°C.
- Under a 75 Ml/d Teddington DRA at 400 Ml/d river flow 2.8% of the channel is affected by a temperature increase of at least 2°C.
- Under a 75 Ml/d Teddington DRA at 300 Ml/d river flow, 0.8% of the channel is affected by a temperature increase of at least 2°C
- Under a 100 Ml/d Teddington DRA at 400 Ml/d river flow, 3.6% of the channel is affected by a temperature increase of at least 2°C.
- Under a 100 Ml/d Teddington DRA at 300 Ml/d river flow, 1.3% of the channel is affected by a temperature increase of at least 2°C.
- Under a 150 Ml/d Teddington DRA at 400 Ml/d river flow, 5.8% of the channel is affected by a temperature increase of at least 2°C.
- With respect to WFD, it is anticipated that 'High' WFD status[56] (20°C) will always be achieved with peak river temperatures at scheme in operation times estimated at 19.9°C.

Temperature uplift and plume associated with the Teddington DRA outfall may influence the movement of salmonid fish at certain times of the year within this reach of the River Thames. Temperatures of 19.73˚C as predicted under the 75 Ml/d discharge scenario are likely to exceed the preferable temperature ranges for sea trout and Atlantic salmon and as such, these species may be excluded from the area associated with the Teddington DRA plume. The Environment Agency has advised that a discharge plume of 2°C or more temperature uplift cannot occupy more than 25% of the cross-sectional area of the river for more than 2% of the time. As such, migratory passage of salmonid fish will not be impeded by the Teddington DRA scheme, though access through the area within the thermal plume by salmonid may be restricted at certain times of the year.

5.5.3 Estuarine Thames Tideway

There is no evidence to suggest that the Teddington DRA scheme would impact upon this reach. This is due to negligible changes in wetted habitat, water level and suspended sediment concentrations, along with no impacts in relation to temperature and flow regime.

5.6 EUROPEAN SMELT

5.6.1 Overview

Smelt are known to spawn within tidal river within tidal freshwater reaches and there are no known records to suggest that smelt spawned above Teddington Weir prior to its construction 1810[24]. Smelt are known to spawn in the Thames Tideway in Reach D between Battersea Park and Putney Bridge and there are no known records to suggest that smelt fry or juveniles move above Teddington Weir as part of their migration. As such, there is no evidence to suggest that the Teddington DRA scheme would impact upon European smelt or their migration within the Thames Tideway.

5.7 OLFACTORY

5.7.1 Overview

As described within Section 3.7.1, an initial screening assessment has been undertaken to identify potential new or increased pressures to the study areas[32]. This assessment is intended as a guide for future investigations in relation to olfactory cues and triggers associated with fish migration and movements (see Section 6 of the Annex B.2.2. Water Quality Assessment Report[29]). As the olfactory suite of determinands for monitoring was updated at Gate 2, the data and subsequent analysis will be made available for Gate 3.

5.7.2 Freshwater River Thames

Reach C – Thames Water Walton Intake to Teddington Weir

[56] WFD Temperature for salmonid waters as per 2015 WFD Directions for England & Wales.

Within the Teddington DRA 1 in 5 year (A82) model scenario 26 chemical determinands within the olfaction suite were identified as exceeding the LOD in the freshwater River Thames under reference conditions. Of these 26 determinands, 14 were analysed against the EQS for reference conditions and the A82 and 1 in 20 year (M96) flow Teddington DRA 75 Ml/d scenario (See Table 5.4 within the Annex B.2.2. Water Quality Assessment Report[29]). Against reference conditions dissolved copper, cypermethrin, permethrin, pirimicarb and dissolved zinc remained above the standard under both the A82 and M96 Teddington DRA-75 scenarios. Dissolved chromium (III) exhibits a decrease in concentrations to below the standard under both the A82 and M96 Teddington DRA-75 scenarios. There are two additional pressures under both the A82 and M96 Teddington DRA-75 scenarios, with cypermethrin and pirimicarb concentrations increasing to above the standard.

The known impacts on olfaction from these chemicals have been described in Section 4.7.2.

Olfactory cue dilution

In addition to olfactory inhibition resulting from chemical inhibitors, impacts to the river volume may infer some impact to olfactory homing responses in all migratory species during marine to freshwater migration. Olfactory homing cues vary dependent upon species, though in general migratory species respond to imprinted natal stream chemistry and conspecific olfactory cues. At the Teddington DRA outfall, river flow would be augmented by addition of 300 Ml/d to support abstraction upstream, in some scenarios this represents a 17% increase in river flow downstream of the outfall, which may be interpreted as a 17% reduction in olfactory cue concentration.

The impacts to natal homing migrations resulting from alterations to water odour properties are well understood for salmonids. Several studies demonstrate that salmonids exhibit a stronger homing response to undiluted natal stream waters when compared to dilute natal stream waters[35]. A stronger homing response is likely to result in a decrease in migration time, and therefore a dilution of olfactory cues is likely to result in an increased migration time. Consequently dilute olfactory cues would decrease energy available for reproduction and potentially reduce fitness. Impacts to European eel and lamprey are not as well understood, however it is assumed for the purposes of this report that the impact of olfactory cue dilution will be in line with those recorded for salmonids.

Though olfactory cues play an important role in the migration of anadromous and catadromous fish species, so too do visual, social and geomagnetic cues. To what extent olfaction is guiding the migration of salmonids has been shown to be dependent upon distance from the homing stream[36]. Tributaries known to support brown trout populations within 12 km of the lower Thames include the rivers Wey, Bourne, Colne, and Mole[52]. However, given the size of the catchment and location of the outfall in the lower River Thames it may be assumed that impacts to olfactory cue resulting from dilution are likely to be minor. However, impacts to the olfactory homing cues for migratory species resulting from the Mogden water recycling scheme cannot be determined with certainty from the information available.

5.7.3 Estuarine Thames Tideway

Within the Annex B.2.2. Water Quality Assessment Report it is noted that ‘there would be olfactory inhibitors dispersal changes in the estuarine Thames Tideway as consequence of a Teddington DRA scheme associating with less discharge of final effluent from Mogden STW. The advanced treatment unit from the Teddington DRA scheme would not return liquid process wastes to Mogden STW for mixing into the final effluent stream. As a consequence the concentration of olfactory inhibitors in the Mogden STW final effluent would remain as per reference conditions. However, as the discharge flow rate would reduce in line with the transfer rate of the Teddington DRA scheme (150 Ml/d, 100 Ml/d, 75 Ml/d or 50 Ml/d, or 25% of those values during plant maintenance periods) the total load discharged in Mogden STW final effluent would reduce. Bespoke modelling of the changes in the Thames Tideway from discharge concentrations changing at Teddington Weir and flow rates reducing at Mogden STW have not been undertaken at Gate 2.’

5.8 SUMMARY OF FISH ASSESSMENT OF TEDDINGTON DRA SCHEME

From the results it is evident that the potential changes in flow are not considered to be of a magnitude to affect the fish communities within the freshwater River Thames or estuarine Thames Tideway, though they may result in temporary changes to species distribution. Additionally the potential changes in flows are not likely to result in impacts to migratory species associated with the Thames Tideway.

The results of the water quality modelling indicate that the water quality and temperature changes within the freshwater River Thames are likely to result in changes to the freshwater fish community. Impacts to temperature are not likely to exceed the thermal tolerances of species present but may result in impacts to the behaviour of fish species particular at or close to the discharge location where temperatures are highest. The Teddington DRA is within the WFD Thames (Egham to Teddington) water body. The current WFD status of temperature within this water body is moderate which for WFD salmonid waters[54] equates to river temperature as a 98 %tile not exceeding 28°C .

For river temperature to achieve good then river temperature as a 98 %tile should not exceed 23°C. It should be noted that temperature does not form part of the WFD classification within the Thames Tideway i.e. transitional waters.

Though, these impacts are likely to be dependent upon the ambient temperature in the wider River Thames. Temperature increases below the mixing zone may result in changes to metabolic rate, gonad development, embryonic development, hatch rate and overall survival of most species to a varying degree. Species tolerant of warmer climates may show increased success compared to species indicative of colder climates, this may lead to changes to the community structure downstream of the discharge outfall. There are no predicted impacts upon temperature within the Upper Tideway and thus no predicted impacts upon the estuarine fish community.

Impacts to dissolved oxygen are not likely to effect fish communities in the freshwater River Thames or estuarine Thames Tideway, similarly ammonia is not likely to impact the freshwater and estuarine fish population. A number of WFD and EQSD priority substances have been identified as likely to exceed standards during the schemes operation, the extent to which these chemicals will impact the freshwater or estuarine fish community is not yet understood. However, several olfactory inhibitors have been highlighted including dissolved copper, cypermethrin, permethrin, pirimicarb and dissolved zinc which may impact olfaction in the estuarine Thames Tideway.

6. CURRENT KNOWLEDGE GAPS AND FUTURE INVESTIGATIONS AT GATE 3

6.1 PREVIOUSLY IDENTIFIED GAPS IN FISH UNDERSTANDING

At Gate 1 the fisheries assessment identified evidence gaps which required addressing for Gate 2. A list of these gaps in Gate 1 were:

1. Literature search on temperature thresholds / preferenda for spawning, juvenile and adult.
2. Formal EA data request for Atlantic salmon and sea trout fish trap records post-2013.
3. Flow/velocity modelling both in general terms at a reach scale and detailed velocity and flow/current modelling in the vicinity of each new intake or outfall (or where discharge or abstraction increase significantly at an existing structure).
4. A baseline for water temperature reach by month giving mean, min and max must be established.
5. One year's monitoring of Sunbury, Molesey and Teddington fish passes (e.g. camera traps) and modelling/assessment of fish pass effectiveness and efficiency under modelled increased flows. Fish pass modelling/assessment to include elver passes at each lock.
6. Reaches A to Reach C: data is required on the ratio of treated effluent to river water under baseline conditions and modelled under various scenarios. The baseline levels of key olfactory cues such as amino acids should also be investigated as part of Gate 2.
7. Reach A: formal EA data request for area fished data for juvenile seine net surveys and timed run data for boom boat surveys for existing EA fish monitoring data (this data not available online).
8. Reach A: minimum 3 years additional baseline juvenile fish monitoring data at two new sites on Desborough Cut (including one at the location of the proposed outfall) plus a continuation of the two existing EA Desborough Island sites (if these are not programmed to be undertaken by the EA).
9. Reach B: Formal EA data request for timed run data for boom boat surveys for existing EA fish monitoring data (this data not available online).
10. Reach B: Minimum 3 years additional baseline juvenile fish monitoring data at four new sites; one between Affinity Water's Walton intake and Sunbury Weir, one at Sunbury Weir, one at the location of the proposed new outfall above Sunbury Weir and one downstream in the reach down to Thames Water Walton intake.
11. Reach B: Flow and velocity modelling at Sunbury weir pool and an assessment of potential habitat change.
12. Reach C: Formal EA data request for timed run data for boom boat surveys for existing EA fish monitoring data (this data not available online).
13. Reach C: Minimum 3 years additional baseline juvenile fish monitoring data at four new sites:
    - One between Thames Water's Walton and Hampton intakes.
    - One at Molesey back weir pool
    - One at Molesey main weir pool
    - One between Sunbury Lock and Thames Water's Surbiton intake
14. Reach C: Flow and velocity modelling at both Molesey weir pools and an assessment of potential habitat change.
15. Reach C: Flow and velocity modelling at both Molesey weir pools and an assessment of potential habitat change.
16. Reach D: Repeat of 2021 Thames Water smelt ichthyoplankton and spawning habitat surveys to enhance understanding of spawning locations and relationship with salinity and temperature.
17. Reach D to Reach F: Sediment survey to identify other potential spawning habitat similar to that present between Putney – mouth of River Wandle.
18. Reach G: Minimum 3 years additional baseline juvenile fish monitoring data at two new sites; one in the vicinity of the proposed new outfall at Enfield Island and one in the in the reach downstream to the Chingford Supply Channel intake (Reach G/H boundary).

19. Reach G: Fish habitat assessment of the section of Enfield Island Loop between the weirs at TQ 37224 98280 and TQ 37678 97806.
20. Reach G: Literature review to establish spawning and nursery habitat thresholds (depth, flow etc) for key species such as chub, dace and roach.
21. Reach G: Baseline water depth by month for 2010-19 in the section between the weirs at TQ 37224 98280 and TQ 37678 97806 as well as the downstream Lee Diversion Channel plus modelled change as a result of London effluent reuse schemes by month for the same areas.
22. Reach G: Fish passability assessments of the weirs at TQ 37224 98280 and TQ 37678 97806.

6.2 KNOWLEDGE GAPS IDENTIFIED DURING GATE 2

In the Enfield Island Loop of the Lee Diversion Channel the major flow changes from flow augmentation from a Beckton water recycling scheme are for a ~100m length of heavily modified channel. There may be an additional zone of influence for the downstream ~500m of the Enfield Island Loop, but the flow regime in that reach is determined by operation of the intake to the King George V Reservoir, which may abstract no water, or abstract all of the flow, including all of the augmented flow from a Beckton water recycling scheme. As such, the flow changes need to be considered in relation to the fish habitat present within Enfield Island Loop of the Lee Diversion Channel and the swimming speeds of freshwater and migratory fish such as European eel.

The EA Ecology & Fish Data Explorer indicates that Sea lamprey (recorded as Petromyzontidae SP.) and potentially river lamprey (recorded as Lampetra sp.) have been captured within the Upper Lee catchment and freshwater River Thames. These records are subject to ongoing discussion as juvenile lamprey amoecetes are notoriously difficult to identify and recent developments in eDNA would be able to confirm their presence.

Discussions with the Environment Agency have indicated that the recent findings of the juvenile twaite shad within the Middle and Lower Thames Tideway mean that shad species should be considered further within the SRO fish monitoring programme. As such, twaite shad eDNA was added to the last two months of the Gate 2 surveys and consideration for twaite shad should form part of future London Effluent Reuse monitoring.

6.3 FUTURE INVESTIGATIONS AT GATE 3

As the engineering design and operational triggers of the London Effluent Reuse schemes are progressed in Gate 3, further specificity can be added to the fish Gate 2 assessments.

Olfaction in the freshwater River Thames will be further assessed for Mogden water recycling schemes and Teddington DRA Schemes as additional data becomes available. These data will need to be considered further in relation to migratory fish species and any potential disturbance of olfactory cues for migratory fish.

As engineering design progresses, Gate 2 tools can be re-used to assess variants in outfall velocities or discharge angle for discharge in the 3D Telemac model of the River Thames. A 2D hydrodynamic model of the Enfield Island Loop locally between Rifle Weir and the Lee Diversion Channel may assist with detailed design of a Beckton water recycling outfall and support the sustainable fish swimming speeds of freshwater fish movements within the channel and to European eel migration.

Records of sea lamprey and river lamprey are inconclusive within both the River Thames and River Lee catchments. Future investigations via eDNA of Lampetra sp. and Petromyzon sp. should be carried out within the Thames and Lee catchments and existing European smelt eDNA fish monitoring expanded to include twaite shad.

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