ANNEX B3.2.2

Fish Assessment

This document has been written in line with the requirements of the RAPID gate two guidance and to comply with the regulatory process pursuant to Severn Trent Water's and Affinity Water's statutory duties. The information presented relates to material or data which is still in the course of completion. Should the solution presented in this document be taken forward, Severn Trent Water and Affinity 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.

Grand Union Canal Transfer SRO

Affinity Water, Severn Trent Water, Canal & River Trust

Grand Union Canal Gate 2 Environmental Assessment

Fish Assessment

September 2022

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Grand Union Canal Gate 2 Environmental Assessment

Fish Assessment

September 2022

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1 Introduction

1.1 Background

Ofwat, the economic regulator for the water and sewerage sectors in England and Wales, has identified the potential for water companies to jointly deliver strategic water resource schemes to secure long-term water supply resilience while protecting the environment.

To support the progression of these Strategic Resource Options (SROs), the Regulatory Alliance for Progressing Infrastructure Development (RAPID) has been established, comprised of representatives from Ofwat, the Environment Agency and the Drinking Water Inspectorate. RAPID has produced guidance for progressing each SRO which is aligned to a formal gated process to ensure that at each gate:

- Companies are progressing strategic water resource solutions that have been allocated funding at PR19 or have subsequently joined the programme.
- Costs incurred in doing so are efficient.
- Solutions merit continued investigation and development during the period 2020 to 2025.

The timelines for the assessment gates are shown in Figure 1.1 below; the Grand Union Canal (GUC) SRO is on the standard gate timeline and is currently at Gate 2.

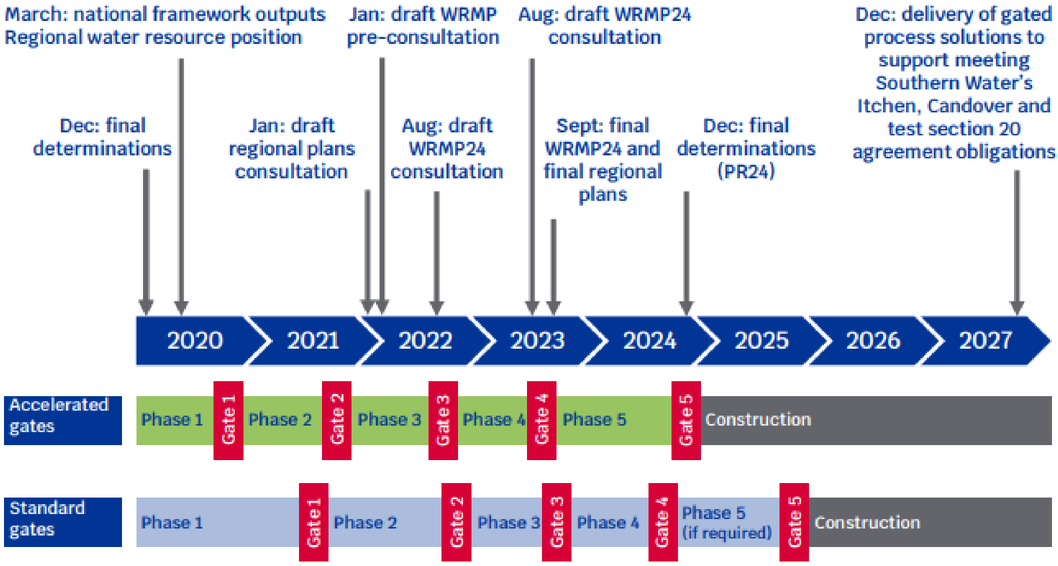

Figure 1.1: Gated process for potential strategic regional water resource solution[1]

[1] Source: Regulators' Alliance for Progressing Infrastructure Development, Forward programme 2021-22,March 2021, available online at https://www.ofwat.gov.uk/wp-content/uploads/2021/03/RAPID-Forward-programme-2021_22.pdf, accessed 07/03/2022.

1.2 Grand Union Canal SRO

The GUC SRO has been jointly developed in partnership between Severn Trent Water (STW), Affinity Water (AW) and the Canal and River Trust (the Trust). At the start of Gate 1 a long-list of sub-option routes were derived for the GUC SRO. The discharge options were then shortlisted to three route options by the start of Gate 2 based on the following criteria: environmental and societal impacts; operational flexibility and resilience; operational and embedded carbon; and cost. Of these, Option Route 3 was selected. Optioneering was also undertaken with regards to abstraction locations. A site at Leighton Buzzard was ultimately selected, further details on the optioneering process can be found in the Gate 2 submission.

The single solution assessed at Gate 2 includes the pipeline from Minworth to Atherstone (Route 3), the canal transfer to Leighton Buzzard and the abstraction and treatment works at this location (hereafter referred to as 'the scheme') and will be assessed in the following Gate 2 Environmental assessments:

- Natural Capital and Biodiversity Net Gain (BNG) (Annex B3.3.2)
- Environmental Appraisal Report (EAR) (Annex B3.3.5)
- Fish survey report (Annex B3.2.2)
- Habitats and protected species desk study (Annex B3.2.6)
- Habitats Regulations Assessment (HRA) (Annex B3.3.3)
- Invasive and non-native species (INNS) survey report (Annex B3.2.4)
- Sediment report (Annex B3.2.5)
- Strategic Environmental Assessment (SEA) (Annex B3.3.1)
- Waterbody connections report (Annex B3.2.1)
- Water Framework Directive Assessment (WFD) (Annex B3.3.4)

This report forms the Fish survey report. Figure 1.2 below shows the integration of the statutory assessment reports (i.e. SEA, HRA, WFD, NCA/BNG) with the RAPID gated process. This schematic is taken from the All Companies Working Group (ACWG) guidance that was released in Gate 1. While this is still largely relevant and followed, it has been somewhat superseded by the RAPID Gate 2 guidance[2], which the Gate 2 assessments have followed. In addition to the statutory assessments listed in Figure 1.2, the scheme has also carried out additional assessments, including this Fish survey report.

[2] Strategic regional water resource solutions guidance for gate two, Regulators' Alliance for Progressing Infrastructure Development, February 2022, available online at https://www.ofwat.gov.uk/wp-content/uploads/2022/02/Strategic-regional-water-resource-solutions-guidance-for-gate-two_Feb_2022.pdf, accessed 09/02/2022.

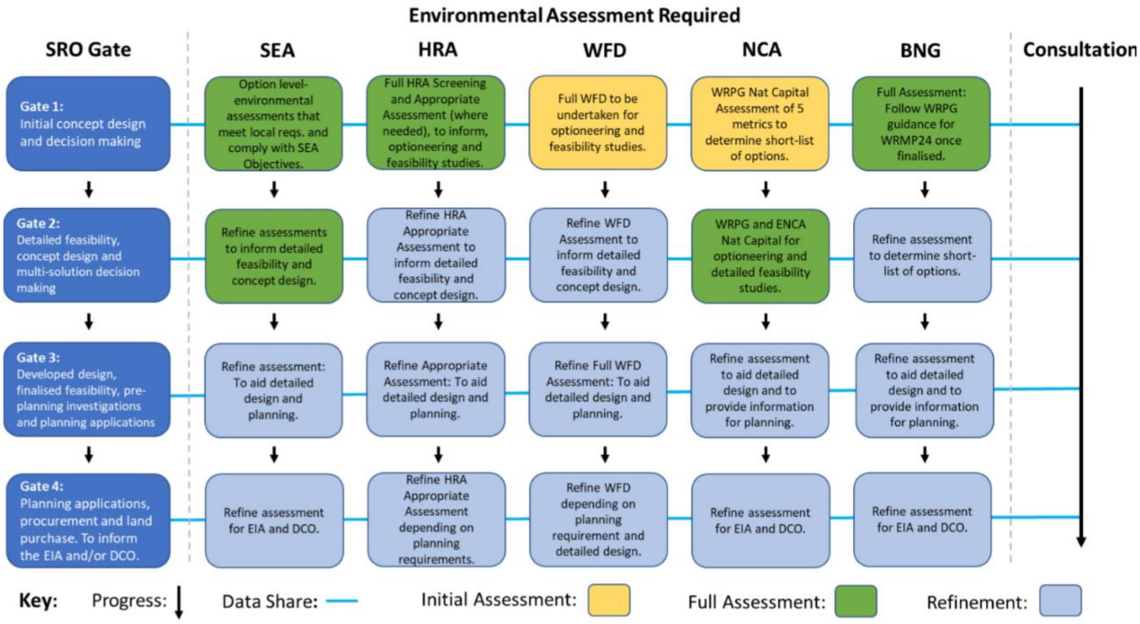

Figure 1.2: Environmental Assessment Integration with SRO Gates[3]

1.3 Scheme description

The scheme is shown below in Figure 1.3 and described in detail in Annex A1, Engineering CDR (WSP, 2022). It will comprise a transfer rising main from Minworth Wastewater Treatment Works (WwTW) to the Coventry Canal at the top of Atherstone lock flight. Once outside the Minworth site, and past the M42 and HS2 corridors, the rising main will pass through agricultural land until reaching the outskirts of Atherstone, a small market town within North Warwickshire. The rising main will discharge to the canal side at Coleshill Road, via a new discharge structure sized to avoid deleterious flow velocities and shears.

Transferred water will then progress along the Coventry Canal by gravity into the Oxford Canal at Hawkesbury Lock. Flows will need to bypass the Hawkesbury lock via a low lift pumping station.

The Oxford Canal will then convey the water to the Grand Union Canal at Braunston. The majority of the flow along the Oxford Canal will be by gravity, however a pumping station will be required to bypass the locks at Hillmorton.

At Braunston a bypass pumping station will be required to lift flows from near Braunston Marina to the top lock just before Braunston Tunnel. From Braunston to the abstraction and treatment site at Leighton Buzzard, four additional lock bypass pumping stations will be required south of Milton Keynes at Fenny Stratford, Stoke Hammond, Three Locks and Leighton. The Grand Union Canal section will also require eight gravity bypasses around “downflow” locks at the Wilton Marine Lock Flight, Stoke Bruerne Lock Flight and Cosgrove Lock.

Flow will be abstracted from the Grand Union Canal just south of the A4146 bridge, after the River Ouzel. The site currently proposed at Gate 2 for the treatment works is on relatively flat land slightly raised from the river and canal, although further investigation will be carried out at Gate 2/3 to determine the precise location. Flow will therefore need to cross the River Ouzel

[3] All Companies Working Group, WRMP environmental assessment guidance and applicability with SROs, Mott MacDonald, October 2020

within a new, short pipeline and be pumped into an operational raw water storage reservoir before gravitating into the first stage of treatment. Additional interstage pumping in the treatment works will be required with final high lift pumps transferring potable treated water to a new clean water holding tank at the existing Chaul End Water Supply Reservoir (WSR).

During the option selection process, it was determined this option would have the least overall cost, lowest environmental impact and greatest opportunity for net gain and public benefit. The slightly higher operational cost when compared to Route 1, due to longer transfer from Minworth to Atherstone, can be partially offset by energy recovery from the break tank to outfall.

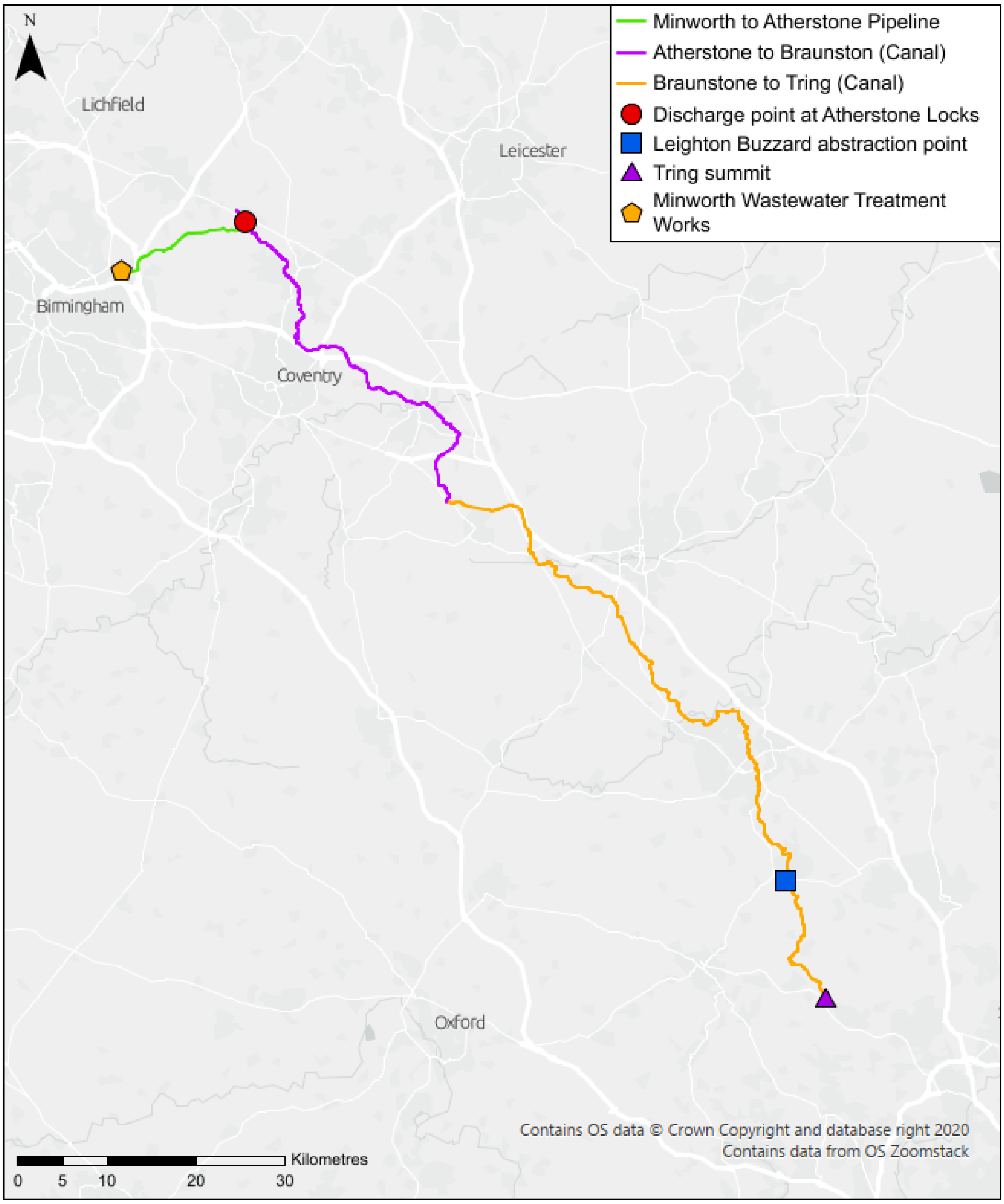

Figure 1.3: Map of the proposed scheme location.

1.4 Purpose of this report

This Annex supports the EAR that accompanies the Gate 2 submission to the RAPID for the Severn Trent to Affinity Transfer via the GUC SRO. The scheme looks to transfer water from Minworth Wastewater Treatment Works (WwTW) in the Midlands, to Affinity Water in the southeast using the existing canal network. This Annex presents the findings of the fish assessment applied to the preferred transfer route option.

This report aims to inform the fish biodiversity baseline within the scheme. A summary of the scheme description is presented Section 1.3. The fisheries relevant legislation, as well as the national planning policy are summarized in Section 2.

Section 3 presents the survey methodologies used for baseline data gathering, fish environmental DNA (eDNA) sampling, and the electro-fishing field survey methodology.

Fish data are presented in Section 4 and includes the results of a desk study investigation and the results of both the eDNA surveys and electrofishing survey results.

The impact appraisal is detailed in Section 5 and the associated suggested mitigation measures are outline in Section 6.

The report is summarised in Section 7.

1.5 Assumptions and limitations

The following assumptions have been used within the assessment:

- The design assumptions stated in the WSP Gate 2 Position Paper - Route Selection technical note can be applied to the Gate 2 Environmental Assessments, including assumption that >50mm depth change requires towpath raising is valid.
- The assessment is based on a ‘worst-case’ 100% utilisation of the SRO
- Tring represents the SE limit of influence of the SRO.
- The volume of water passing NW (after discharging from pipeline) due to the locks opening at Atherstone is deemed to be of minimal change.
- The risk of fish and INNS travelling NW of Atherstone is not increased due to the scheme.

2 Planning policy and legislation

2.1 Legislation

The construction and operational activities for the proposed works must comply with European and UK nature conservation legislation, including INNS legislation detailed in the INNS report (Annex B3.2.4), and with national and local biodiversity policies. Legislation relevant to fish fauna relevant to the scheme comprises:

- Salmon and Freshwater Fisheries Act 1975 (as amended):
  - It is an offence to knowingly take, kill or injure any salmonid or freshwater fish, disturb any spawning fish (includes any spawning fish, fish about to spawn, fish that have recently spawned or fish that have not yet recovered from spawning) or immature fish (unless specified, 'fish' refers to salmon (*Salmo salar*), trout (*Salmo trutta*), eel *(Anguilla anguilla*)*,* lampreys (*Petromyzontidae*), smelt (*Osmerus eperlanus*), shad (*Alosa spp.*), freshwater fish or any specified fish in any waters) or to disturb any spawn, spawning fish or spawning habitat.
  - It is an offence to pollute a watercourse with the result of poisoning or causing injury to fish, spawning habitat, spawn or food sources. It is also unlawful to disturb the food resource of freshwater fish.
  - In waters frequented by salmon or migratory brown trout (*Salmo trutta*), it is an offence to impact the efficiency of fish passage either directly, through creating barriers to movement, or indirectly, through any act whereby salmon or trout may be scared, deterred or in any way prevented from freely passing up and downstream at all periods of the year.
  - Where a new culvert, channel, sluice or any other such device is installed, the responsible person must ensure that a screen is installed which either prevents salmon or migratory trout from entering the outfall or prevents the ingress of farmed fish. Any screen placed, or by-wash provided, must ensure that salmon or migratory trout are not injured or damaged by it and the placing of a screen must not prevent the flow of water being prejudicially diminished or otherwise injured.
  - The river lamprey (*Lampetra fluviatilis*) is also protected under this Act.
- The Eels Regulations (England and Wales) 2009:
  - A person must not damage, interfere with, obstruct, or do anything that impedes the passage of eels in an efficient state. The Environment Agency must be notified where any construction or alteration of obstructions are likely to affect the passage of eels around, over or through a structure.
  - If a screen is required, it must be constructed and located, so far as reasonably practicable, so that eels are not injured or damaged by it. *A. anguilla* is critically endangered under the IUCN Red List of Threatened Species (IUCN, 2020).
- The Conservation of Habitats and Species Regulations 2017 (as amended).
  - European bullhead (*Cottus gobio*) are listed as an Annex II species of the EU Habitats Directive, now consolidated under The Conservation of Habitats and Species Regulations 2017 (as amended).

2.2 National planning policy

- Historically, European eel, brown trout and river lamprey were listed as UK Biodiversity Action Plan (BAP) species and are now listed as a species of 'principal importance for the conservation of biodiversity in England' under Section 41 of the Natural Environment and Rural Communities (NERC) Act 2006

3 Methodology

3.1 Background

The purpose of the fish surveys is to understand the current fish community, species diversity, population age structure within the GUC and a representative sub-set of the connected waterbodies. This understanding will determine the feasibility of the scheme and influence the optioneering and design.

It is important to have high-quality quantitative baseline fish data prior to the scheme commencing to be able to assess potential impacts and identify mitigation measures. This data serves to inform the baseline prior to the scheme works and will allow for comparisons with post-construction monitoring data. To do this, existing data from previous surveys were gathered, to give information about fish population over the area of the scheme. Where knowledge gaps existed around known waterbody connections to the GUC, sites were selected for electrofishing field surveys.

The electrofishing results were complemented by environmental DNA (eDNA) metabarcoding techniques looking at whole fish communities, allowing for a wider coverage of sites, including sites inaccessible to standard electrofishing methods. This technique estimates fish community diversity at sampling locations by sequencing collected DNA in water samples. By this method, species of fish that were not captured during the quantitative electrofishing survey still get recorded.

Fish are wild animals and can move freely within the watercourse; they are not uniformly distributed throughout the length of a watercourse, and at different ages, they will have specific habitat preferences. A good example of this is when fish have migrated out of the area for spawning or are in deep inaccessible pools. In these cases, they will either be missed or under-represented in the survey data. The advantage of using eDNA to support the physical survey data is that fish DNA will be present in the water, and even if a species is missed by other methods, fresh eDNA will still be flowing downstream from upstream sources. This also reduces the need to carry out an extensive survey programme throughout the catchment. As a result, we can have confidence in our understanding of the fish community prior to the scheme commencing, and this will assist us in determining what mitigation and compensation measures may be necessary. However, eDNA results are limited in providing information on population size, individuals health and population age structure.

3.2 Study area

The study area for the fish investigation includes the canals which will be used to transfer water from Minworth to the Leighton Buzzard abstraction point. The increase in water volume in the canal may result in an increase in water flow into the connected waterbodies and therefore these are also included in the study area. These connections were identified in the Waterbody Connections Report (Annex B3.2.1) and include:

- Artificial canals:
  - Coventry Canal
  - Oxford Canal
  - Grand Union Canal
- Connected river waterbodies:
  - River Anker
  - River Leam/Withy Brook

- River (Warwickshire) Avon
- River Nene
- River Tove
- Upper Ouse/Great Ouse
- River Ouzel

- Reservoirs
  - Tringford Reservoir
  - Marsworth Reservoir
  - Startops End Reservoir

3.3 Desk study

Records of fish surveys within the zone of influence of the scheme were gathered using the Environment Agency Ecology & Fish Data Explorer online tool[4]. Recent records - from the last ten years (2012 to 2021) - were gathered to ensure the data was up to date and of relevance to the scheme. Records of these surveys were then assessed in light of the scheme and used to provide a baseline and wider knowledge of fish populations within the scheme area.

3.4 Field surveys

The fish survey programme includes surveys at selected waterbody connections with the canal system (at locations where connectivity with the other waterbodies is relevant for the purposes of this Gate 2 assessment, although it is noted that additional connections may be identified as relevant at later Gate stages). Field surveys for this study comprise eDNA sampling in the canal and connected waterbodies, and electrofishing surveys in the connected water bodies. A.1 in Appendix A and Table 3.1 shows sample locations for fish eDNA surveys.

A.2 in Appendix A and Table 3.2 show the survey locations for electrofishing surveys. These sites were chosen taking in consideration access and health and safety considerations as well as being representative of the wider river habitats. A site walkover was undertaken prior to the electrofishing surveys to confirm site suitability.

Table 3.1: Fish eDNA Survey sites

Grid references for continued monitoring locations redacted

Location	Site no.	Site description	NGR	Survey date
A: Polesworth*	1*	Coventry Canal near River Anker connection*	[redacted]	06/04/2022
A. Polesworth*	2*	River Anker near Coventry Canal connection*	[redacted]	06/04/2022
B. Rugby	3	Oxford Canal near River (Warwickshire) Avon crossing	[redacted]	05/04/2022
B. Rugby	4	River (Warwickshire) Avon near Oxford Canal crossing	[redacted]	05/04/2022
C. Nr. Northampton	5	GUC near Northampton Arm intersection	[redacted]	08/11/2021
D. Nr. Stoke Bruerne	6	GUC near River Tove crossing	[redacted]	05/04/2022
D. Nr. Stoke Bruerne	7	River Tove near GUC crossing	[redacted]	05/04/2022
E. Leighton Buzzard	8	GUC near River Ouzel connection	[redacted]	08/11/2021

[4] EA Ecology & Fish Data Explorer, available online at <https://environment.data.gov.uk/ecology.explorer>, [accessed July 2022].

Grid references for continued monitoring locations redacted

Location	Site no.	Site description	NGR	Survey date
E. Leighton Buzzard	9	River Ouzel near GUC connection	[redacted]	08/11/2021
F. Tring	10	GUC at Tring		09/11/2021
F. Tring	11	Startops End Reservoir		09/11/2021
F. Tring	12	Tringford Reservoir		09/11/2021
F. Tring	13	Marsworth Reservoir		09/11/2021

Table 3.2: Electrofishing field survey sites

Ref	Site	NGR Upstream	NGR Downstream	Date surveyed	Fishing Method
1	River Anker at Bridge Street	[redacted]		27/06/22	Boat, 100m survey reach
2	River Tove at Mill Farm			28/06/22	Wading, 90m survey reach
3	River Ouzel at Monarchs Way			28/06/22	Boat, 45m survey reach

3.5 Fish eDNA methodology

3.5.1 eDNA technique

DNA (eDNA) methodology[5] for waterbodies has been developed by the Environment Agency in collaboration with Nature Metrics. Surveys were undertaken following Nature Metrics protocols (both for still and running waterbodies) and samples were analysed in Nature Metrics' laboratories.

It should be noted that Natural England has recognised the use of eDNA as a rapid and cost-effective survey technique to establish Great Crested Newt presence or absence since 2014, although not for other species. Therefore in regard to fish, the eDNA data has been evaluated as complementary information on fish biodiversity within the scheme.

3.5.2 Sampling methodology

At each site, up to 1 litre[6] of sampled water was filtered through an encapsulated disk filter immediately upon collection using a syringe to monitor the volume of water sampled. As per the sampling instructions provided by Nature Metrics, less than 1 litre of water may be filtered if the filter becomes clogged. A preservative solution was then added to the filter units, and they were promptly sent to the specialist laboratory of Nature Metrics for analysis.

The sampling instructions provided by Nature Metrics do not include a protocol for canals; however, assuming that water may be poorly mixed, canal sampling involved collection and subsequent mixing of around 20 sub-samples from the water's edge at a range of locations; these were throughout the 50m sample reach. These reaches were selected as being suitable for the both the invertebrate and fish surveys, to provide consistency across the various assessment types, and to provide as much information as possible about those selected sites.

[5] Grand Union Canal Strategic Resource Option, Sampling Methodology Report, January 2022, document reference 100105044|100105044A|P03.

[6] Volumes of water filtered varied between sites according to the turbidity of the samples.

The lake sampling protocol was followed for the three Tring reservoirs and involved the collection of around 20 sub-samples of water at approximately evenly spaced points around the perimeter, where access allowed.

For river reaches, the river sampling protocol was followed. This involved collecting five water samples from different parts of the flow within the river, throughout the 50m minimum reach. This was mixed in a bucket before being passed through the filter.

3.5.3 Sample frequency

A single round of eDNA surveys was carried out for the Gate 2 assessments, although these may be updated for the later stages of the assessment (including the EIA). At these stages, it would be advised to sample in at least two seasons (e.g. spring and autumn) to increase the probability of detecting species.

eDNA sampling can be undertaken throughout the year, though is considered to be most effective when species are more active. Activity is likely to be lowest during the winter period, therefore the optimal period is considered to be March to November inclusive, with unusually cold periods avoided where possible. Timing of sampling for the scheme (November 2021 and April 2022) is therefore within the optimal period.

3.5.4 Sample analysis

Samples were analysed by eDNA metabarcoding techniques (whole fish communities). This technique can estimate fish community diversity at sampling locations by sequencing collected DNA in water samples.

The testing procedure involves the use of the quantitative polymerase chain reaction (PCR) procedure, where DNA from each filtered sample is extracted and amplified. PCRs are performed under a negative and positive sample (mock community with a known composition). This technique uses universal primers, which can work across a range of species to amplify specific short regions of DNA. The amplified DNA is then sequenced to identify the diversity of species present.

Caution is required with the interpretation of the DNA analysis as the sampling methodology inevitably captures DNA from upstream reaches, not just that which is specific to the sampling location. However, the information collected is valuable in identifying the potential presence of fish species in the different canal pounds, as well as in nearby lakes. The half-life of eDNA is regarded as around 48 hours and may be detected from upstream locations from between a few hundred metres to a few kilometres, dependent on factors such as flow, depth, substrate, water chemistry and environmental conditions. The results were analysed in light of the habitats present in the study area. In addition, the information collected is of value for understanding the potential use of the watercourses by migratory fish species (for example, eels) and informing mitigation and compensation measures.

3.5.5 Assumptions and standard best-practice mitigation measures

As instruments will not be used to capture fish physically, an Environment Agency authorisation under Section 27A of the Salmon & Freshwater Fisheries Act, 1975, (as amended) is not required for collection of fish eDNA. These authorisations are required when using electro-fishing equipment, traps, and nets.

3.6 Electro-fishing methodology

3.6.1 Sampling methodology

Where possible, surveys were undertaken using WFD compliant fully quantitative electro-fishing, three-run catch depletion methodology. If this was not possible due to survey constraints, surveys were conducted as catch-per-unit-effort (CPUE) timed surveys. All sampling using electric fishing equipment was completed following BS EN 14011:2003, BS 6068-5.32:2003 (Water quality: Sampling of fish with electricity). Electro-fishing is the primary survey method used to assess the WFD status of fish populations throughout England and Wales.

Survey methods were in accordance with Environment Agency sampling electro-fishing depletion methods. The method used a direct current of electricity flowing between a submerged cathode and anode; stunned fish can then be easily and safely captured, details recorded, and then returned unharmed to the same waterbody.

An Environment Agency '*Authorisation to use fishing instruments other than rod & line in England*' is required prior to surveying with electro-fishing equipment. These authorisations are issued under Section 27A of the Salmon & Freshwater Fisheries Act, 1975 (as amended).

All electro-fishing surveys were led by a trained and experienced fisheries surveyor certified by the Environment Agency or the Game and Wildlife Conservation Trust (GWCT). All additional staff were provided with bespoke in-house electric fishing training to Environment Agency standards.

The equipment used was a combination of backpack and standard multiple anode PDC (Pulsed Direct Current) control box units that was bank-based or towed in a boat by staff wading upstream, with the selection of methodology undertaken on a site-by-site basis by an experienced fisheries ecologist taking into consideration individual site conditions, channel depth and width, flow rate and health and safety considerations. The process for the section of appropriate sampling methods was compliant with BS EN14962 (Water quality – Guidance on the scope and selection of fish sampling methods).

Each fully quantitative survey was approached with the aim of surveying a 100m site, and isolated using stop-nets set across the channel to prevent fish entering or exiting the fixed area, then a minimum of three passes or 'runs' were made moving in an upstream direction, to ensure depletion in numbers. A depletion is required to allow for fully quantitative absolute population metrics to be calculated using the method described by Carle and Strub (1978)[7]. Where this was not possible due to site constraints, surveys were timed using CPUE to calculate minimum estimated density, weight and biomass results.

Upon capture, fish were stored in aerated holding tanks, with the catch of each run stored separately. Processing of the catch involved species identification and measuring each fish to the fork in the caudal fin, known as fork length, to the nearest millimetre and returned alive to the water. All species were measured and recorded.

In addition to catch data, information on the water quality and habitat character was recorded on a standardised proforma. Field-based water quality parameters including temperature (ºC), pH, dissolved oxygen (DO; Mgl^{-1} and % saturation), and conductivity (μScm^{-1}) were recorded using a hand-held calibrated YSI Pro-Plus meter. This data complemented the wider water quality monitoring undertaken for this study which collects more detailed and frequent water quality data. Habitat characteristics recorded include water depth, site length, river wetted width,

[7] Carle, F. L. and Strub, M. R. (1978). A new method for estimating population size from removal data. Biometrics, 34, 621-830.

turbidity, macrophyte cover (%), flow type (pool, riffle, run, glide), substrate composition, cover for fish, shade (%).

3.6.2 Sample frequency

A single round of electrofishing surveys were carried out for the Gate 2 assessments, although these may be updated for the later stages of the assessment (including the EIA).

3.6.3 Sample analysis

All the field data were entered onto a bespoke fish population survey recording and analysis tool, which converts fish fork length to weight (g) using the Environment Agency length-weight factors used for the National Fisheries Monitoring Programme (NFMP).

- From the depletion in numbers, observed estimated population metrics were calculated using the method described by Carle and Strub (1978) to provide total estimated biomass (g/100 m^2) and density (No./100 m^2) for each species.
- From the fish numbers, estimated weights and known sampled area values for observed fish biomass (g/100 m^2) and density (No./100 m^2) were calculated for each species.
- Fish scale analysis (data forthcoming August 2022) were used to confirm age class structure, growth rates and insights into the fishery's performance. Fish lay down seasonal calcified annuli (or rings) on their scales which can then be counted, and the fish can be aged in a comparable way to ageing a tree. This information gives insights into fish growth rates – if fish are following an expected growth rate or are stunted (older than would be expected at a given size), and recruitment of juvenile fish into the population.
- Recording the current extent and population structure of invasive non-native fish is an important outcome of the surveys, which is essential to assess whether the scheme could result in their spread and what protocols might need to be implemented to manage them or even locally eradicate them. Zander (*Sander lucioperca*) is a known invasive species in the GUC, but other invasive non-native fish have also been considered.

3.6.4 Assumptions and standard best-practice mitigation measures

There is a duty to report any other non-native species which may be caught, including but not limited to:

- Wels catfish (*Silurus glanis*), channel catfish *(Ictalurus punctatus*), sunbleak (*Leucaspius delineatus*), bitterling (*Rhodeus sericeus*), topmouth gudgeon (*Pseudorasbora parva*), grass carp (*Ctenpharyngodon idella*), silver carp (*Hypophthalmichthys molitrix*), pumpkinseed (*Lepomis gibbosus*), zander and ornamental sturgeon/sterlet (*Acipenser spp*.)

The WFD Technical Advisory Group[8] has created an "alarm list" for the UK, a list of species that are not currently known to be in the UK, but if they are observed, then a rapid response to eradicate them will be initiated[9].

[8] UKTAG is a partnership of the UK environment and conservation agencies which was set up by the UK-wide WFD policy group consisting of UK government administrations. It is therefore not connected to the scheme governance.

[9] Classification of aquatic alien species according to their level of impact, WFD Technical Advisory Group (2021), available online at http://wfduk.org/sites/default/files/UKTAG%20classification%20of%20alien%20species%20working%20paper%20v8.pdf, accessed 09/03/2022.

3.7 Biosecurity protocols

Biosecurity measures were implemented to prevent the spread of diseases and INNS between survey sites. The following specific measures were taken:

- For river sites, sites were visited in an upstream-to-downstream direction.
- Multiple pond nets and net bags were taken to reduce the risks of transferring attached organisms to other sites.
- Substrate (for example, silt or sand) and plant fragments were removed from survey equipment and personal protective equipment (including waders) between visits to different survey locations, using brushes and water.
- Equipment was disinfected using Virkon® Aquatic disinfectant sites, following the manufacturers' instructions.

3.8 Sources of information

The Environment Agency's Ecology and Fish database[10] was used to collect data from regular Environment Agency electrofishing monitoring on connected watercourses only, as the Environment Agency does not routinely survey the GUC.

In addition, to identify the ecological requirements and preferred habitat of each fish species, a desk-based review of available information from international and national sources was undertaken. This information is presented within the fish surveys results. The general information sources used to support this desk study included:

- Biodiversity A-Z org. (https://biodiversitya-z.org)
- Catalogue of Life (http://www.catalogueoflife.org/)
- Convention on Biological Diversity (CBD) website (http://www.cbd.int/)
- FishBase Global Information System on Fishes (https://www.fishbase.de/home.htm)
- International Union for Conservation of Nature (IUCN) Red List of Threatened Species (http://www.iucnredlist.org)

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

4 Results

4.1 Environment Agency data

Environment Agency ecology and fish data from the last 10 years (2012 to 2021) were analysed and a total of six survey locations were identified within the study area. Table 4.1 summarises the Environment Agency fish survey information, with sample point locations shown in A.3 in Appendix A. The numbers shown in Table 4.1 for fish present are the cumulative total across the years surveyed, and specific to each site.

A total of 20 species were identified. Results indicated the bullhead and minnow (*Phoxinus phoxinus*), are the most abundant and frequent species within the study area, followed by stone loach (*Barbatula barbatula*) and to lesser extent roach (*Rutilus rutilus*).

The River Anker at Leathermill presented the highest species diversity, with 16 species in total. The most abundant species included bullhead, gudgeon (*Gobio gobio*) and minnow, followed by roach and stone and spined loach (*Cobitis taenia*). Spined loach was only found in the River Anker and River Tove.

The River Ouzel showed a similar diversity with 13 species in total, although species abundance was lower – with roach, dace and gudgeon the most abundant species overall (other species included bullhead, perch (*Perca* fluviatilis) and stone loach).

The River Leam also had 10 species recorded and was abundant in smaller species such as minnow and three-spined stickleback (*Gasterosteus aculeatus*), with other species such as gudgeon and roach recorded in smaller numbers.

The site on the Upper Great Ouse showed a diversity of species – 14 in total – including a large number of roach and chub, and the presence of a roach *x* chub hybrid.

The results from the River Nene suggest better water quality and/or a faster flow, as a number of brown trout and dace were recorded. Also notable was the record of a roach *x* common bream hybrid.

The protected European eel was only captured in one of the Environment Agency’s fish surveys within the adjacent waterbodies of the canal system, suggesting that European eel is not widely distributed in the study area. No invasive species were identified in the Environment Agency fish surveys in any of the rivers within the survey area.

The rivers in the survey area are generally dominated by a community of cyprinid species, with bullhead also present in all connected rivers in high numbers. The presence of bullhead and gudgeon suggest the presence of clean water and gravel substrate, as well as a moderate flow velocity. The presence of other abundant and widely distributed species suggests the presence of a diversity of habitat types.

Grid references for continued monitoring locations redacted

Table 4.1: EA Fish surveys and composition

River and reference point		River Anker - Leathermill	River Tove - Cappenham Bridge	River Ouzel at Monarchs Way - Leighton Buzzard	River Leam – Manor Farm, Kites Hardwicke	Upper Ouse/Great Ouse – Manor Farm Cosgrove	River Nene Duston Branch - Nether Heyford
Site ID		273	4550	4694	8986	4383	6041
NGR		[redacted]					
Years surveyed		2012, 2021	2015, 2016, 2019	2013, 2016, 2019	2016	2013, 2016	2018
Species	Nine-spined stickleback (*Pungitius pungitius*)	10 to 99	-	-	-	-	-
	Three-spined stickleback (*Gasterosteus aciuleatus*)	78	17	10 to 99	59	-	Present
	Brook lamprey (*Lampetra planeri*)	-	1	-	-	-	-
	Bleak (*Alburnus alburnus*)	1	-	-	-	11	-
	Brown/sea trout (*Salmo trutta*)	-	-	-	-	1	18
	Bullhead (*Cottus gobio*)	1670	258	70	14	4	Present
	Barbel (*Barbus barbus*)	-	-	-	-	21	
	Chub (*Squalius cephalus*)	151	11	23	1	60	21
	Common bream (*Abramis brama*)	1	-	6	-	1	-
	Dace (*Leuciscus leuciscus*)	138	116	356	9	94	53
	European eel (*Anguilla anguilla*)	-	-	-	1	-	-
	Gudgeon (*Gobio gobio*)	300	4	240	12	31	22
	Minnow (*Phoxinus phoxinus*)	1871	303	7	520	19	Present
	Perch (*Perca fluviatilis*)	258	2	34	-	42	-
	Pike (*Esox lucius*)	11	11	13	1	19	-
	Roach (*Rutilus rutilus*)	431	1	291	13	126	31
	Roach x chub hybrid (*Rutilus rutilus* x *Squalius cephalus*)	-	-	-	-	2	-

River and reference point		River Anker - Leathermill	River Tove - Cappenham Bridge	River Ouzel at Monarchs Way - Leighton Buzzard	River Leam – Manor Farm, Kites Hardwicke	Upper Ouse/Great Ouse – Manor Farm Cosgrove	River Nene Duston Branch - Nether Heyford
	Roach x common bream (*Rutilus rutilus* x *Abramis brama*)	-	-	-	-	-	2
	Rudd (*Scardinius erythrophthalmus*)	1	-	1	-	-	2
	Stone loach (*Barbatula barbatula*)	2652	89	23	-	1	Present
	Spined loach (*Cobitis taenia*)	531	9	-	-	-	-
	Tench (*Tinca tinca*)	1	-	1	-	-	-

Source: Environment Agency, 2022.

4.2 Environmental DNA data

The eDNA results are useful in inferring the presence of other species in the study area that were not recorded through the regular Environment Agency monitoring. These may be sporadic species or species that are present but in lower numbers and not recorded during electrofishing monitoring.

A number of strictly marine fish taxa were detected from the sampling: European pilchard (*Sardina pilchardus*), anchovy species (*Engarulidae* sp.), Atlantic mackerel (*Scomber scombrus*), Dover sole (*Solea solea*), silverside species (Atherinidae sp.), European seabass (*Dicentrarchus labrax*), and painted goby (*Potamtoschistus pictus*). Of these marine species, many are common food fish and therefore are likely to have been detected as wastewater contaminants or through use of fishmeal as angling bait; alternatively these records may be the result of contamination to samples. As these marine records are not viable records of freshwater species, they are therefore not considered further in this assessment or included in Table 4.2 below.

A number of taxa could also not be identified to species level – while dace were able to be identified, in some cases identification of eDNA was only discernible to the genus *Leuciscus*, which does not exclude the non-native Orfe/ Ide (*Leuciscus idus*), sometimes released into rivers and canals from ornamental ponds[11]. Without further species-level evidence *of L. idus* for this assessment, records of *Leuciscus* are assumed to be the native dace. Similarly, records of carp species (Cyprinidae family) could not always be assessed to species level – for this assessment these are assumed to be native as a large number of native fish are within the family Cyprinidae, although it is acknowledged that a number of potential invasive species of concern are from this family of fishes. The results of the eDNA fish analysis are presented in Table 4.2 shows the proportion of the eDNA sequencing output allocated to the different taxa (species) within each sample (site). Each number per sample represents the proportion of DNA for each species for that sample, rather than the number of individual fish.

The abundance of taxa cannot be directly inferred from the proportion of total sequence for each species as while the proportion of sequence for each species is a consequence of abundance, it is also impacted by biomass, activity, surface area, condition, distance from the physical sample, primer bias, and species-specific variation in the genome.

The most common detected taxa were Cypriniformes (found in 100% of the sites surveyed), followed by Percidae (62%) and Salmonidae (54%). The eDNA results identified six additional species in the area of the scheme when compared with the EA monitoring results. There was an average species richness of 7, which ranged from 3 at River (Warwickshire) Avon to 13 at GUC near River Tove Crossing. The most commonly detected species were roach, perch, pike and brown/sea trout.

An average of 8.7 different species were identified per site within the canal system, with Site 3 (Oxford Canal) presenting the lowest fish biodiversity, and Site 6 (GUC) the highest. Pike (*Esox lucius*), perch and roach were the most commonly detected species, and the presence of fish such as common bream indicate that the canal has a fish community associated with a slow to stagnant flow of water and a silt substrate[12]. Silver bream were also identified within the canal system; in Britain this is a species restricted to slow-flowing lowland rivers and canals in the midlands and southeast of England[13].

The protected species which were detected in the sequencing are as follows (see Table 4.2):

- Bullhead
- Atlantic salmon (*Salmo salar*)
- Brown/sea trout
- Brook/river lamprey (species resolution not possible - *Lampetra planeri/fluviatilis*)

The eDNA data suggest the detection of brown trout in the GUC, although this is not a typical species that would be expected to be present in this type of habitat. However, brown trout are found in some canal systems[14] and therefore due to the high sequence readings of brown trout, it may be that trout survive in some areas of the GUC. However, these sequences could also be from close connections to rivers, fisheries, or other forms of contamination (such as wastewater or angling bait).

The presence of Atlantic salmon was recorded at Tringford Reservoir. Due to connections between waterbodies, the record may represent transfer of water involving wild salmon DNA; due to the migratory lifecycle of salmon it would not be expected that these two findings represent live fish in this waterbody. However, although salmon are native wild fish, the explanation of these eDNA readings through contamination due to food and wastewater is also possible.

Three invasive and non-native species[15] were also identified across the sample sites: zander, carp, and wels catfish.

Of note is the presence of these non-native and invasive species, including the presence of zander within the Coventry Canal and the GUC, which the Canal and River Trust is working to eliminate. Other reports of zander distribution also note presence in the Oxford canal[16]; therefore, zander can be assumed to be present throughout the northern area of the surveyed canal system and south to the River Ouzel connection. Zander are also known to be present in a number of river catchments in the Midlands including the Great Ouse, Nene and Severn[17], thereby presence in waterbodies connecting to the canal system would not be unlikely. The Canal and River Trust is also actively working to prevent further spread of zander southwards along the GUC, as well as preventing escape into adjacent waterbodies with the medium-term ambition of eradication from the southern GUC. It has been suggested

[11] Maitland, P.S. and Campbell, R.N. (1992) *Freshwater Fishes*. Harper Collins Publishers.

[12] Aarts, B. and Nienhuis, P.H. (2003) Fish zonations and guilds as the basis for assessment of ecological integrity of large rivers. *Hydrobiologia.* 500, 157-178.

[13] Maitland, P.S. and Campbell, R.N. (1992) *Freshwater Fishes*. Harper Collins Publishers.

[14] Canal and River Trust, 24 December 2020. *Brown trout.* [online] Available at < Brown trout | Types of fish | Canal & River Trust (canalrivertrust.org.uk)>. [Accessed 20 July 2022.]

[15] WFD UK TAG, 2019. *Classification of aquatic alien species according to their level of impact.* [pdf] WFD UK TAG. Available at: < UKTAG classification of alien species working paper v8.pdf (wfduk.org)> [Accessed 20 July 2022.]

[16] Canal and River Trust, 23 September 2021. *Zander.* [online] Available at < Zander | Invasive and non-native fish | Canal & River Trust (canalrivertrust.org.uk)>. [Accessed 26 August 2022.]

[17] Davies, C. *et al.* (2004) *Freshwater fishes in Britain: the species and their distribution.* Harley Books.

Grid references for continued monitoring locations redacted

that the introduction of zander can have a detrimental impact on native fish populations in the shallow, narrow turbid canal network, and that the impact in this type of habitat may be greater than in other watercourses. On canals, species likely most impacted by the presence of zander are gudgeon and roach[18], the latter being of significant interest to angling customers and the commercial viability of fishing rights owned by the Trust.

Wels catfish are known to be present as an angling species in Marsworth reservoir[19] and therefore the detection of this species at Marsworth reservoir reflects this presence. The lack of the detection of wels catfish at other sites did not provide any current evidence that the species is present elsewhere in the study area, however records of the species in the canal system have been reported in the past around the Milton Keynes area from the GUC[20]. It is unclear whether these reports suggest the successful reproduction of wels catfish within the canal system.

Table 4.2: Fish eDNA survey results

Site ID		**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**	**Site 8**	**Site 9**	**Site 10**	**Site 11**
River and reference point		Coventry Canal near River Anker connection	River Anker near Coventry Canal connection	Oxford Canal near River (Warwickshire) Avon crossing	River (Warwickshire) Avon near Oxford Canal crossing	GUC near Northampton Arm intersection	GUC near River Tove crossing	River Tove near GUC crossing	GUC near River Ouzel connection	River Ouzel near GUC connection	GUC at Tring	Startops End Reservoir
NGR		[redacted]										
Date surveyed		06/04/22	06/04/22	05/04/22	05/04/22	08/11/2021	05/04/22	05/04/22	08/11/2021	08/11/2021	09/11/2021	09/11/2021
Species	Common bream (*Abramis brama*)	10.91	-	8.22	-	6.86	31.99	-	14.80	-	-	-
	Bleak (*Alburnus alburnus*)	-	-	-	-	16.73	-	-	-	-	4.74	3.36
	Silver Bream (*Blicca bjoerkna*)	0.70		0.32			2.42					
	Barbel (*Barbus barbus*)	-	-	-	-	-	-	-	-	-	-	-
	Carp* (*Cyprinus carpio*)	-	-	-	-	-	-	-	0.52	-	0.28	5.46
	Gudgeon (*Gobio gobio*)	-	1.22	-	-	-	-	-	1.95	-	4.25	-
	Dace (*Leuciscus leuciscus*)	-	-	-	-	-	-	6.06	-	-	-	-
	Dace species (*Leuciscus sp*)**	0.22	-	-	-	-	0.32	-	-	-	-	-
	Minnow (*Phoxinus phoxinus*)	-	18.56	-	33.08	-	0.30	44.05	-	-	-	-
	Roach (*Rutilus rutilus*)	14.22	30.06	62.07	-	2.74	15.98	8.81	44.82	3.82	11.54	-
	Rudd (*Scardinius erythrophthalmus*)	-	-	-	-	2.51	-	-	-	-	-	-
	Chub (*Squalius cephalus*)	-	1.45	-	10.92	-	0.17	-	-	-	-	-
	Tench (*Tinca tinca*)	-	-	-	-	-	-	-	-	-	-	-
	Carp species (Cyprinidae species)**	-	-	-	-	0.16	-	-	2.06	-	-	-
	Stone loach (*Barbatula barbatula*)	-	9.57	-	-	-	-	-	-	-	-	-
	Pike (*Esox lucius*)	40.73	13.51	17.05	-	2.96	1.06	-	5.83	-	-	-
	Three-spined stickleback (*Gasterosteus aculeatus*)	-	-	-	56.01	-	0.67	-	-	3.05	0.33	4.50
	Nine-spined stickleback (*Pungitius pungitius*)	-	-	-	-	-	0.45	-	-	-	-	-
	Ruffe (*Gymnocephalus cernua*)	6.57	-	5.99	-	-	0.69	-	1.45	-	-	-
	Perch (*Perca fluviatilis*)	17.37	-	-	-	-	39.17	-	16.25	8.62	25.99	17.69
	Zander* (*Sander lucioperca*)	0.63	-	-	-	-	1.49	-	1.60	-	-	-
	Atlantic salmon (*Salmo salar*)	-	-	-	-	-	-	-	-	-	-	-
	Brown/sea trout (*Salmo trutta0*	-	-	-	-	66.34	-	-	10.72	84.51	52.43	65.90
	Bullhead (*Cottus gobio*)	8.65	25.64	-	-	-	5.29	35.21	-	-	-	-
	Brook/river lamprey (*Lampetra planeri/fluviatilis*)**	-	-	6.35	-	-	-	5.88	-	-	-	-

[19] Canal and River Trust, 24 December 2020. *Catfish (Wels).* [online] Available at < Catfish (Wels) | Invasive and non-native fish | Canal & River Trust (canalrivertrust.org.uk)>. [Accessed 20 July 2022.]

[20] Canal and River Trust, pers. Comm. (August 2022).

Grid references for continued monitoring locations redacted

Site ID		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
	Wels catfish* (*Silurus glanis*)	-	-	-	-	-	-	-	-	-	-	-

Continuation Site ID		Site 12	Site 13
River and reference point		Tringford Reservoir	Marsworth Reservoir
NGR		[redacted]	
Date surveyed		09/11/2021	09/11/2021
	Common bream (*Abramis brama*)	-	31.93
	Bleak (*Alburnus alburnus*)	-	-
	Silver Bream (*Blicca bjoerkna*)		-
	Barbel (*Barbus barbus*)	-	-
	Carp* (*Cyprinus carpio*)	12.02	2.69
	Gudgeon (*Gobio gobio*)	-	-
	Dace (*Leuciscus leuciscus*)	-	-
	Dace species (*Leuciscus sp*)**	-	-
	Minnow (*Phoxinus phoxinus*)	-	-
	Roach (*Rutilus rutilus*)	-	3.14
	Rudd (*Scardinius erythrophthalmus*)	-	-
	Chub (*Squalius cephalus*)	-	-
	Tench (*Tinca tinca*)	-	0.75
Species	Carp species (Cyprinidae species)**	-	0.44
	Stone loach (*Barbatula barbatula*)	-	-
	Pike (*Esox lucius*)	-	10.10
	Three-spined stickleback (*Gasterosteus aculeatus*)	5.54	-
	Nine-spined stickleback (*Pungitius pungitius*)	-	-
	Ruffe (*Gymnocephalus cernua*)	-	-
	Perch (*Perca fluviatilis*)	4.97	34.83
	Zander* (*Sander lucioperca*)	-	-
	Atlantic salmon (*Salmo salar*)	0.88	-
	Brown/sea trout (*Salmo trutta*)	71.39	10.10
	Bullhead (*Cottus gobio*)	-	2.56
	Brook/river lamprey (*Lampetra planeri/fluviatilis*)**	-	-
	Wels catfish* (*Silurus glanis*)	-	0.45

* Invasive and/or non-native species.

** Identification not possible to species level.

Source: Nature Metrics 2022

4.3 Electrofishing data

Three electrofishing surveys were undertaken in rivers at or near connections to the Grand Union Canal in areas of possible influence from the scheme design.. The results from the three sites are shown below in Table 4.3, Table 4.4 and Table 4.5.

The River Anker at Bridge Street survey was conducted as a 100m single run survey due to the density of macrophytes causing a low catch efficiency and therefore fish density, weight and biomass were calculated as minimum estimate. As this did not involve a catch-depletion, it is likely that some fish species (especially smaller species) are under-represented. The survey results (Table 4.3) show a fish community dominated in number by roach, whereas chub and pike constitute the predominant biomass. This type of community is a typical coarse fish community of a lowland river, with some characteristics of an upland river, with likely a moderate flow and water temperature[21]. The scale data shows that roach were mostly 0+ fish, with no adults beyond 1+ years. No non-native fish species were recorded in the survey.

Table 4.3. Fish survey results from River Anker at Bridge Street, 27/06/22.

Species	Abundance (number caught)	Age in years*	Observed Density (no./min)	Estimated weight (g)	Observed Biomass (g/min)
Three-spined stickleback (*Gasterosteus aculeatus*)	1	-	0.02	0.49	0.01
Roach (*Rutilus rutilus*)	35	0+ (12) 1+ (4)	0.81	394.03	9.16
Chub (*Squalius* cephalus)	1	-	0.02	2008.16	46.70
Bleak (*Alburnus alburnus*)	5	-	0.12	30.67	0.71
Perch (*Perca fluviatilis*)	3	-	0.07	656.65	15.27
Pike (*Esox lucius*)	3	0+ (1) 3+ (1) 4+ (1)	0.07	1713.10	39.84
Total	48	-	1.12	4812.12	111.91

Source: FiverRivers, 2022.

*Scale data was calculated from available samples; the estimated age in years of the fish is displayed here with the number of individuals recorded, as the age of some scales was indeterminable.

The survey of the River Ouzel at Monarchs Way was conducted as a 45m single run survey due to survey constraints (deep pools, vegetation and concrete structures) and therefore density, weight and biomass were calculated as minimum estimate. As this did not involve a catch-depletion, it is likely that some fish species (especially smaller species) are under-represented. Table 4.4 shows the results from the survey, showing a more limited fish community composed of chub, roach and bullhead. The presence of these species suggests a typical lowland stream community with a moderate flow. The scale data shows that the roach population is comprised on mostly 1+ year-old fish, with few 0+ and 2+ individuals. No non-native fish species were detected during the survey.

[21] Aarts, B. and Nienhuis, P.H. (2003) Fish zonations and guilds as the basis for assessment of ecological integrity of large rivers. *Hydrobiologia.* 500, 157-178.

Table 4.4. Fish survey results from River Ouzel at Monarchs Way, 28/06/22.

Species	Abundance (number caught)	Age in years*	Observed Density (no./min)	Estimated weight (g)	Observed Biomass (g/min)
Bullhead (*Cottus gobio*)	1	-	0.07	7.25	0.52
Roach (*Rutilus rutilus*)	32	0+ (1) 1+ (16) 2+ (1)	2.29	606.40	43.31
Chub (*Squalius cephalus*)	4	0+ (2) 1+ (1) 2+ (1)	0.29	202.58	14.47
Total	37	-	2.64	816.23	58.30

Source: FiverRivers, 2022.

*Scale data was calculated from available samples; the estimated age in years of the fish is displayed here with the number of individuals recorded, as the age of some scales was indeterminable.

The survey of the River Tove at Mill Farm was conducted as a 90m three-run catch-depletion survey, and therefore an estimated biomass could be calculated using the Carle and Strub method. This allowed estimation of the total density and biomass of fish at the site, also accounting for fish that likely evaded capture. The results (Table 4.5.) show a community dominated in biomass by chub and pike, with a large number of minnow present – this suggests a lowland community typical of a moderate flow. The scale data shows low numbers of juvenile (0+) fish. No non-native species were detected during the survey.

Table 4.5. Fish survey results from River Tove at Mill Farm, 28/06/22.

Species	Abundance (number caught)	Age in years*	Observed Density (no./100m²)	Estimated weight (g)	Observed Biomass (g/100m²)	Estimated Density (no./100m²)	Estimated Biomass (g/100m²)
Minnow (*Phoxinus phoxinus*)	43	-	9.49	10.18	2.25	10.59	2.48
Bullhead (*Cottus gobio*)	2	-	0.44	16.85	3.72	0.66	5.58
Roach (*Rutilus rutilus*)	7	-	1.54	247.26	54.55	1.76	59.49
Chub (*Squalius* cephalus)	2	-	0.44	1119.08	246.87	0.44	246.87
Dace (*Leuciscus leuciscus*)	4	0+ (2) 1+ (2)	0.88	119.54	26.37	0.88	26.37
Perch (*Perca fluviatilis*)	10	1+ (7) 2+ (2)	2.21	452.48	99.82	2.21	99.82
Pike (*Esox lucius*)	1	4+ (1)	0.22	1451.78	320.27	0.22	320.27
Total	69	-	15.22	3417.18	753.84	16.77	760.87

Source: FiverRivers, 2022.

*Scale data was calculated from available samples; the estimated age in years of the fish is displayed here with the number of individuals recorded, as the age of some scales was indeterminable.

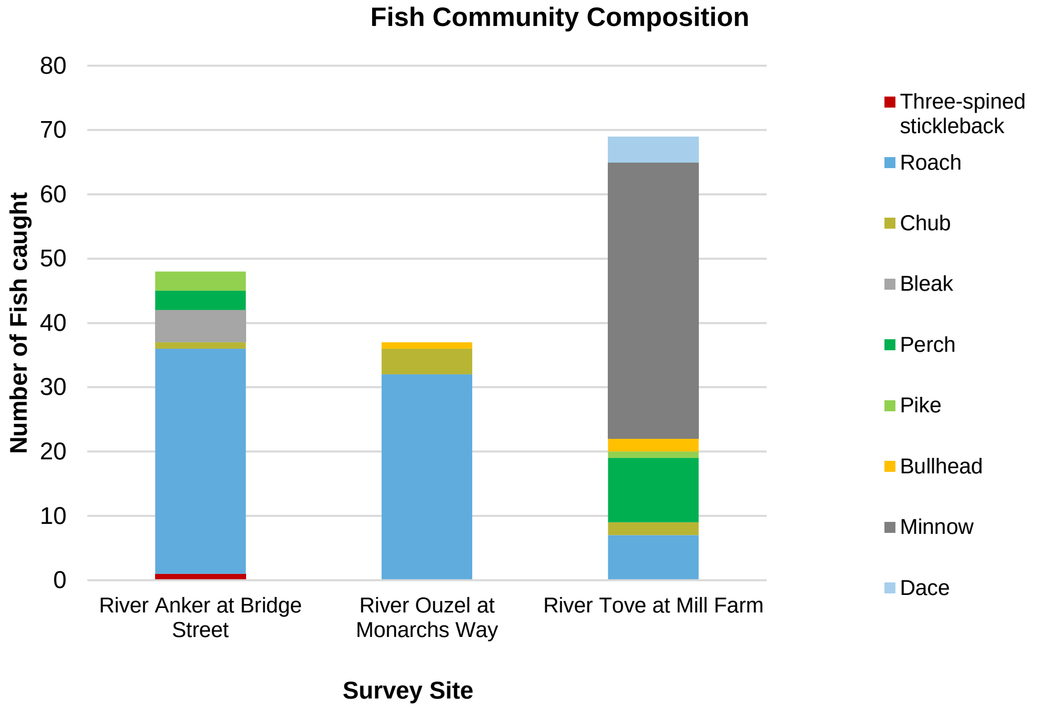

Figure 4.1. Fish abundance from the three electrofishing surveys, showing species community composition.

The fish community composition of the three surveys (shown in Figure 4.1) indicates that the community of the connected rivers surveys differs to that of the canal system. These three rivers show communities typical of a *barbel zone*[22] - dominated in number by minnow and roach, and in biomass (as shown above in Figure 4.1, Table 4.4 and Table 4.5) by lowland species typical of moderate flow such as chub, roach and pike.

4.4 Summary of fish community composition

The overall community composition of the canal system was typical of a slow-flowing or still lowland riverine habitat, as shown by the eDNA records for species such as common bream. The additional presence of species such as minnow and dace suggest the presence of areas of increased flows, indicating habitat diversity within the canal system, also indicated by the large diversity of species found.

Protected species[23] were identified from surveys within the canal system:

- Bullhead (*Cottus gobio*) – Habitats Directive Annex 2
- Brown trout (*Salmo trutta*) – NERC Section 41, Habitats Directive Annex 2
- Brook/river lamprey (*Lampetra planeri/fluviatilis*) - Habitats Directive Annex 2 – Oxford Canal

Invasive species were recorded within the canal system:

[22] Aarts, B. & Nienhuis, P.H. (2003) Fish zonations and guilds as the basis for assessment of ecological integrity of large rivers. *Hydrobiologia.* 500, 157-178.

[23] JNCC, 2019. *UK BAP Priority Species.* JNCC. Available at <UK BAP Priority Species | JNCC - Adviser to Government on Nature Conservation> [Accessed 20 July 2022.]

- Zander (*Sander luciperca*) - non-native to Britain and considered a Moderate Impact invasive species - recorded throughout the canal system
- Carp (*Cyprinus carpio*) - non-native and classified as a High Impact invasive species (UKTAG – provisional classification), commonly stocked in fisheries for angling purposes (Maitland and Campbell 1992) – recorded throughout the canal system

Riverine fish community compositions of the connected river water bodies were more typical of moderate flowing lowland rivers – mostly diverse coarse fish assemblages, with additional species such as brown trout at some locations (such as the River Nene).

In addition to the protected species identified within the canal system, further protected species were identified in these connecting river waterbodies. Records for the following species were noted:

- Spined loach – NERC Section 41, Habitats Directive Annex 2 - Rivers Anker and Tove
- Eel – NERC Section 41 – River Leam
- Barbel (*Barbus barbus*) - Habitats Directive Annex 4 and Annex 5 – Upper Ouse/Great Ouse
- Atlantic salmon (*Salmo salar*) – NERC Section 41, Habitats Directive Annex 2 – Tringford Reservoir (eDNA record may be from wastewater and not deemed likely to be a positive indication of wild fish in this waterbody)

5 Impact assessment

5.1 Introduction

This section presents the impact assessment of the scheme. It should be noted that at this early stage of scheme design limited information is available on mitigation, and therefore this impact assessment largely presents the unmitigated scenario. Possible mitigation measures for the identified potential effects are set out within section 6.

5.2 Water quality

The WFD Assessment report (Annex B3.3.4) has indicated that many of the potential risks to the water quality of the GUC are anticipated to be minimised through design of appropriate operational controls. These controls would include water quality treatment of effluent prior to discharge into the canal system, and would also minimise any increase in overflow spills into connecting waterbodies. Discharge standards would serve to minimise any water quality changes localised at the discharge point. Also highlighted was the risk that increase in movement of water along the canal system towards the abstraction point could cause increased mixing of water, potentially causing deterioration in areas of currently higher water quality. Fish may respond to pollution through increased activity, exploration and avoidance[24] and therefore may have some adaptation to short-term stressors in a canal environment; however, these behaviours may not be applicable to all life stages, as some life stages may be less tolerant to water quality changes.

The WFD Assessment report (Annex B3.3.4) has also indicated that an increase in flow through the canal system could confer benefits to the ecology by improving dissolved oxygen levels and temperature profiles through the canal, by reducing the risk of fish kills from algal blooms which can be a particular issue in still or slow-flowing water[25]. Improvements in oxygen levels at critical times of the year - such as the spawning season - could confer increased survival of juvenile fish[26]. Furthermore, changes in temperature or dissolved oxygen may confer changes to the fish community by benefitting species that are less tolerant of low-oxygen conditions such as brown trout[27], which are found in some canals[28] and were detected within the GUC using eDNA analysis. Conversely, sudden changes in temperature can be lethal to young fish. As limited data is available on these potential changes arising from operation of the scheme, further data would be required to understand changes in water quality and the associated effects on the fish community.

Any increase in flow through the canal system could confer an increase in turbidity due to sediment mobilisation, which might in turn have effects on individual species and ecological communities – such as reducing light levels for macrophyte growth or affecting fish egg

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[24] Jacquin, L. *et. al* (2020) *Effects of Pollution on Fish Behavior, Personality, and Cognition: Some Research Perspectives*. Front. Ecol. Evol. (8) 86.

[25] Canal and River Trust, 6 July (2020).*Blue green algae – what you need to know.* [online] Available at <Blue green algae – what you need to know | Canal & River Trust (canalrivertrust.org.uk)>. [Accessed 20 July 2022.]

[26] Environment Agency, (2004). *Science Report SC020112/SR: Flow and Level Criteria for Coarse Fish and Conservation Species.* Environment Agency. Available at <Flow and Level Criteria for Coarse Fish and Conservation Species> [Accessed 20 July 2022.]

[27] Wild Trout Trust, n.d. *Brown trout.* [online] Available at < Brown Trout | Wild Trout Trust>. [Accessed 20 July 2022.]

[28] Canal and River Trust, (2020). *Brown trout.* [online] Available at < Brown trout | Types of fish | Canal & River Trust (canalrivertrust.org.uk)>. [Accessed 20 July 2022.]

development[29]. Increased turbidity and alteration of the macrophyte community could alter the community composition of fish to favour those suited to more turbid conditions[30], and potentially increase the survival of the predatory zander - which is adapted to feeding in low-light conditions and avoids dense vegetation[31].

A further localised risk is the mobilisation of sediment in the vicinity of the discharge, causing a deterioration in water quality due to the nature of the sediment including increased turbidity – with the potential to affect water quality suitability for all fish life stages in the immediate area. Analysis of the potential for water velocity changes due to the scheme indicate that velocities should not be increased sufficiently to mobilise sediments, but additional work at Gate 3 will confirm this. Appropriate design of the discharge structure would help to mitigate these localised effects by reducing deleterious flow velocities and mobilisation of sediment.

Accidental or unpermitted discharge to the environment through operational error also presents a risk, causing a deterioration in water quality and affecting aquatic ecological communities. However, this type of risk is present in all situations of discharge to the environment and this likelihood would be reduced through best practice measures.

Consideration of hydrological modelling[32], water quality monitoring[33] and detailed assessment of sediment impacts and the interactions of these factors would help to further understand expected spatial and temporal changes in water quality and their associated effects on the fish communities, as described in the WFD Assessment (Annex B3.3.4).

5.3 Water velocity

An increase in flow between the discharge point and abstraction point is expected with the scheme in operation. This increase in canal flow velocity has the potential to alter the water chemistry - affecting water temperature and oxygen levels - and also alter habitats, affecting the associated invertebrates and macrophytes that rely on specific conditions. Any changes to these factors can in turn alter the diet and habitat available for fish species.

Such changes to passage and habitat may mean that juvenile fish survival could be decreased, and movement patterns of species change, as species seek more favourable areas of habitat. This in turn could affect the recruitment of fish and fish population structure. Flow preferences for many fish species identified as present within the canal (included in Table 5.1) may be different for different life stages. The larvae and juvenile stages of many coarse fish species prefer a velocity of <5cm/s, while adults of many species may be much more tolerant of a variety of flow velocities[34]. Factors such as high flows and low water temperatures can lead to low growth and poor survival for 0+ fish[35], reducing successful recruitment to the adult population.

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[29] US EPA, n.d. (2022) *Factsheet on water quality parameters: Turbidity.* [online] Available at < Turbidity (epa.gov)>. [Accessed 20 July 2022.]

[30] Smith, P. n.d. *Zander in the canals system*. Canal and River Trust. [pdf] Available at: <35681-zander-in-the-canal-system-by-dr-phillip-smith.pdf (canalrivertrust.org.uk)>

[31] Maitland, P.S. and Campbell, R.N. (1992) *Freshwater Fishes*. Harper Collins Publishers.

[32] Annex A2.4, Final modelling report, JBA (2022).

[33] Annex B1.6, WQ Monitoring - Gate 2 (April 22 - Oct 2022), Atkins (2022)

[34] Environment Agency, 2004. *Science Report SC020112/SR: Flow and Level Criteria for Coarse Fish and Conservation Species.* Environment Agency. Available at <Flow and Level Criteria for Coarse Fish and Conservation Species> [Accessed 20 July 2022.]

[35] EA (2003) *Factors Affecting Coarse Fish Recruitment* [pdf] Available at: Factors Affecting Coarse Fish Recruitment [Accessed 27 August 2022].

Table 5.1. Flow preferences for selected fish at different life stages.

	Flow Requirements (cm per second)			
Fish species	**Larvae**	**Juvenile**	**Spawning**	**Adult**
Common bream (*Abramis brama*)	<5cm/s	<5cm/s	<20cm/s	
Bleak (*Alburnus alburnus*)	<5cm/s	<5cm/s	<20cm/s	
Stone loach *Barbatula barbatula*)		Still		
Barbel *(Barbus barbus*)	<20cm/s	<20-100cm/s	25-49cm/s	40-100cm/s
Silver bream (*Blicca bjoerkna*)		<5cm/s	5-60cm/s	
Bullhead (Cottus gobio)				10->40cm/s
Carp (*Cyprinus carpio*)			<5cm/s	
Pike (*Esox lucius*)		Still	<5cm/s	
Three-spined stickleback				Slow
Gudegeon (*Gobio gobio*)	<20cm/s	0-40cm/s	2-80cm/s	<55cm/s
Ruffe (*Gymnocephalus cernua*)				Still
Brook lamprey (*Lampetra planeri*)	8-10cm/s		30-50cm/s	
Dace (*leuciscus leuciscus*)	<2.5	Still	20-50cm/s	0-57cm/s
Chub (*Squalius cephalus*)	<5cm/s	<5cm/s	5-75cm/s	
Perch (*Perca fluviatilis)*		Still or slow		
Minnow (*Phoxinus phoxinus*)	<2->3cm/s	<4->12cm/s	20-30cm/s	0->35cm/s
Nine-spined stickleback (*Pungitius pungitius*)				Slow - 10cm/s
Brown trout (*Salmo trutta*)	0<30cm//s	0-44cm/s	11-81cm/s	0-142cm/s
Roach (*Rutilus rutilus*)	<5cm/s	0-40cm/s	>20cm/s	
Zander (*Sander lucioperca*)			10>70cm/s	0-1cm/s
Rudd (*Scardinius erythrophthalmus*)	Still	Still	<5cm/s	

Source: EA 2004 [36].

Modelled flow velocities when the scheme is operating at the 57.5Ml/d flow level (expected for spring and autumn) indicate that most of the canal would experience velocities more than 5cm/s; this threshold would be exceeded in the high flow scenario expected to be used in summer (115Ml/d). Further analysis that included the friction/roughness of the channel showed that there would be an area of just a few centimetres along the bed and banks that would experience velocities less than 5cm/s during the summer expected flows; this would be approximately 1cm at the bed for the spring/autumn expected flows. Current flows in a high-flow scenario (without the water transfer) are reported to be less that 5cm/s across most of the channel[37].

These modelled flows suggest that the transfer could markedly alter the habitat for coarse fish species such as roach, rudd, common and silver bream, bleak and dace. These changes would be most prominent during larvae and juvenile life stages - the spring and summer. Therefore, without mitigation of effects of flow - for example through provision of juvenile habitat with ideal flow velocities - the fish community composition and abundance may change. This could be due to decreased survival of certain affected species, and increased survival of species tolerant to the conditions under the transfer - the community shifting towards that that of a moderate flow lowland river.

[36] Environment Agency, (2004). *Science Report SC020112/SR: Flow and Level Criteria for Coarse Fish and Conservation Species.* Environment Agency. Available at <Flow and Level Criteria for Coarse Fish and Conservation Species> [Accessed 20 July 2022.]

[37] Annex A2.4, Final modelling report, JBA (2022).

Constrictions at which the velocity increases more than surrounding wider areas of the canal may present a further velocity challenge for survival and movement of juvenile fish. Such changes may mean that constrictions become impassable to juvenile fish, and that marginal habitat is reduced. Fry and juveniles of many fish species rely on areas of low flow associated with high plant cover[38] and higher survival is correlated with high summer water temperature[39], factors that may be affected through increased velocity of water.

Furthermore, increased velocity through the canal system has the potential to facilitate the spread of invasive species - including plants and invertebrates, which can in turn affect fish populations through a number of ecological means, such as indirect effects on habitat or direct effects through species competition. The INNS report (Annex B3.2.4) highlights that no new hydrologically connections will be formed as a result of the scheme; however, an increase in flow may facilitate the movement of INNS downstream within the canal system towards the area of the abstraction point, therefore potentially furthering the spread of zander, carp and wels catfish.

As such changes could affect protected species, invasive species and angling opportunities. Preserving a diversity of flow and habitat types whilst preserving fish movement will be considered in future assessment of mitigation measures to be included in the scheme, and the potential cost implications of those measures. Further information regarding fish assemblages in canals featuring a higher flow velocity will aid in this type of assessment[40].

5.4 Habitat changes

Scour caused by the discharge into the canal system has the potential to have localised effects on habitat and effects on water quality. Areas of habitat in the immediate area of influence from a discharge may suffer from riparian erosion or washout of aquatic vegetation important for fish spawning and juvenile habitat. It is anticipated that suitable measures will be incorporated into the discharge structure to minimise any of these localised effects on habitat.

As discussed in Sections 5.2 and 5.3, increased turbidity within the canal system may confer changes to aquatic communities, affecting plant growth[41] - which may in turn reduce habitat availability or change habitat characteristics and food availability necessary for fish survival[42]. Analysis of the potential for water velocity changes due to the scheme indicate that velocities should not be increased sufficiently to mobilise sediments, but additional work at Gate 3 will confirm this.

Changes to the flow regime of an aquatic system may alter the sediment composition, affecting the fish communities, macrophyte growth and invertebrate species composition[43]. Many fish species of slow-flowing and stagnant waterbodies lay eggs in vegetation on the substrate, while adult fish may have a preference for areas of submerged vegetation[44], and therefore may be sensitive to such changes.

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[38] Maitland, P.S. and Campbell, R.N. (1992) *Freshwater Fishes*. Harper Collins Publishers.

[39] EA (2003) *Factors Affecting Coarse Fish Recruitment* [pdf] Available at: Factors Affecting Coarse Fish Recruitment [Accessed 27 August 2022].

[40] Annex A2.4, Final modelling report, JBA (2022).

[41] US EPA, n.d. (2022) *Factsheet on water quality parameters: Turbidity.* [online] Available at < Turbidity (epa.gov)>. [Accessed 20 July 2022.]

[42] FAO, (2000). *Fisheries Technical Paper 396.* [online] Available at < Interactions between fish and aquatic macrophytes in inland waters (fao.org)>. [Accessed 20 July 2022.]

[43] Schmutz, S. and Sendzimir, J. (2018) *Riverine Ecosystem management.* Springer Open.

[44] Environment Agency, (2004). *Science Report SC020112/SR: Flow and Level Criteria for Coarse Fish and Conservation Species.* Environment Agency. Available at <Flow and Level Criteria for Coarse Fish and Conservation Species> [Accessed 20 July 2022.]

5.5 Barriers to fish movement

With an increase in quantity of flow in the canal, there is a risk that the movement of water could affect juvenile fish - which in turn could affect the distribution of fish in the canal system, for example washing juveniles to downstream habitats. If fish passage is not possible at operational flows past specific features such as constrictions, there is a risk of a change to the species community composition. Any potential new obstacles to fish passage would need to be assessed to ensure no additional impacts to the fish community.

5.6 Impact on fish populations in connecting waterbodies

It is anticipated that as a result of the scheme, no new hydrological connections will be formed with other catchments (INNS report (Annex B3.2.4)). It is suggested that the design of the scheme should aim to not increase any likelihood of overflows from the canal system to the existing river connections (WFD Assessment report (Annex B3.3.4)) – therefore this design would help to prevent any additional effects on fish populations in connecting waterbodies. However, any potential changes to water quality or quantity could affect these populations, for example impacting populations of spined loach in the Rivers Anker and Tove through habitat changes (as spined loach prefer a sandy substrate and dense aquatic vegetation[45]) or pollution.

Such impacts as changes to sediment composition due to increased flows or deterioration in water quality could impact fish community composition and fish recruitment. Eel were not recorded in the canal system and so may not pass between these connections, however consideration of how fish may use any structures and connections should be given when assessing changes to these features under operation of the scheme. Furthermore, increased flow quantity has the potential to increase the likelihood of eggs, juveniles or adults of invasive fish species and/or invasive plants and invertebrates impacting receiving watercourses.

5.7 Specific impacts on protected fish species

Brown trout are susceptible to poor water quality and therefore may be sensitive to a deterioration in conditions due to increased mixing of pollutants or additional pollutant load. However, increased oxygenation and decreased susceptibility of the canal to algal blooms could benefit any population of trout in the canal system and therefore potential impacts on brown trout, if this species is present in the canal system, may be mixed. As trout are known to be present in connecting rivers, any water quality changes could have more impact in these watercourses than in the canal system.

Bullhead favour similar water conditions to trout, including requiring well-oxygenated water, and therefore the populations of bullhead noted in the canal (from eDNA results) may be subject to from the same mixed effects of changes to water quality.

Life stages of lamprey may rely on areas of silt as habitat, and therefore a change to sediment composition from alteration in average flow velocity has the potential to affect the survival of brook lamprey.

Barbel rely on areas of clean gravel for successful spawning[46]; therefore any increase in sediment reaching connecting rivers through overflow weirs has the potential to affect spawning success, through settlement of sediment on spawning gravels.

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[45] Natural England (1998) *The habitat and management requirements of spined loach (Cobitis taenia) (ENRR244)* [pdf] Available online at: < The habitat and management requirements of Spined loach (Cobitis taenia) - ENRR244 (naturalengland.org.uk)>

[46] Britton, R. & Pegg, J. (2011) *Ecology of European Barbel Barbus barbus: Implications for River, Fishery, and Conservation Management.* Reviews in Fisheries Science, 19(4):321-330.

Spined loach populations in the Rivers Tove and Anker would also be subject to influence from any changes to water quality from connections to existing overspill weirs. Spined loach can occupy a range of slow-flowing lotic and lentic habitats[47] and therefore may be tolerant of small changes occurring in these waterbodies; however any change in water quality has the potential to impact this species.

5.8 Specific impacts on invasive fish species

From the eDNA and survey data, the known invasive fish species within the zone of influence of the scheme are zander and carp, however it is noted that wels catfish have also been reported in the GUC.

The potential for increased turbidity may favour survival and spread of zander, which hunt effectively in low-light conditions and are suited to survival in turbid water[48]. It is unclear whether zander distribution is limited by water clarity, however it is possible other predatory species that compete for food could be negatively affected by turbidity, thereby favouring zander survival.

Carp tend to inhabit areas of slow flow with aquatic vegetation[49], and it may be that increased flow conditions confer decreased recruitment for carp due to a reduction in areas of suitable habitat.

As wels catfish is a predatory species that does not rely on vision for tracking prey, an increase in turbidity would not likely affect this species negatively; however temperature changes may have this potential, as the species is thought to benefit from warmer temperatures[50].

From the survey results, there were no invasive fish species found within the canal system that were also found in connecting waterbodies within the analysed area of the scheme, although it is acknowledged that this may be due to differing habitats found within the connecting waterbodies and limitations of the search methodology. The INNS report (Annex B3.2.4) states that no new connections to waterbodies that would spread INNS would be formed. Any increase in mixing of water between waterbodies has the potential to increase the distribution of INNS; however the design of the scheme aims to not increase rates of overflow into connecting waterbodies and therefore an increased chance of spreading INNS into connecting watercourses is not deemed likely.

However, the report does conclude that an increase in flows may facilitate the spread of INNS downstream within the canal system; therefore, this has the potential to further the distribution of zander, carp and wels catfish downstream towards the abstraction at Leighton Buzzard and the surrounding area.

5.9 Abstraction

Fish species are vulnerable to damage at intakes of abstraction points and therefore appropriate screening should be incorporated into the design of any intake structure or lock by-pass pumping station.

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[47] Maitland, P.S. and Campbell, R.N. (1992) *Freshwater Fishes*. Harper Collins Publishers.

[48] Maitland, P.S. and Campbell, R.N. (1992) *Freshwater Fishes*. Harper Collins Publishers.

[49] Environment Agency, 2004*. Science Report SC020112/SR: Flow and Level Criteria for Coarse Fish and Conservation Species.* Environment Agency. Available at <Flow and Level Criteria for Coarse Fish and Conservation Species> [Accessed 20 July 2022.]

[50] CABI, n.d. *Silurus glanis* (wels catfish). [online] Available at: <Silurus glanis (wels catfish) (cabi.org)> [Accessed 26 August 2022]

6 Mitigation measures and further studies

6.1 Suggested mitigation measures

The potential impacts described in Section 5 and the associated suggested mitigation measures for consideration are depicted in Table 6.1. The WFD Assessment Report (Annex B3.3.4) was used to inform suggested measures. As knowledge of some of the risks associated with the scheme may not yet be known in detail, mitigation measures are based on current knowledge of the scheme and fish communities as detailed in earlier sections of this report. Where knowledge gaps and uncertainties remain, further assessment and monitoring requirements have been suggested. These suggestions do not necessarily represent preferred further actions and are presented for consideration.

Table 6.1. Potential impacts of the scheme on fish populations and suggested mitigation measures.

Potential impact	Suggested mitigation measures	Suggested further monitoring/assessment
Deteriorating water quality at discharge point	Discharge standards to match water quality of receiving watercourse	Monitoring of water quality of discharge and canal system before and during operation
Increased water movement within canal causing movement of water of poorer quality and subsequent effects on fish populations	Assessment of sediment build up that may contribute to poor water quality	Monitoring required to assess levels of pollution, and modelling movement of water to assess effects on fish community composition
Increased movement of water, causing temperature changes that may be harmful to juvenile fish	Consideration of seasonal impacts of transfer flows on fish during key periods, with potential for additional treatment/mitigation for high temperatures, if required	Modelling of water temperature changes with particular emphasis on spring and summer, important for juvenile fish
Increased turbidity of water affecting habitats and species community composition	Assessment of sediment build up that may contribute to poor water quality	Modelling of sediment mobilisation and effect on water quality Baseline monitoring of existing water quality at key areas
Acute pollution events caused by accidental discharge	Best practice measures to avoid accidental discharge	Monitoring of water quality during scheme operation following a pollution event
Increased velocities altering habitats and species community composition	Provision of marginal low-flow habitat areas to protect fish recruitment	Habitat velocity modelling to assess effects on fish community composition Fish habitat walkover surveys to map key habitats for juvenile fish
Localised scour at discharge point	Design of discharge structure	Monitoring of habitat changes in immediate area of discharge
Movement of fish downstream with lack of passage upstream	Increase or protect bed/margin roughness at constrictions to decrease flow velocity Provide fish passage across impassable structures	Identification of barriers and assessment of fish passage, given modelled higher flow through the canal system

Potential impact	Suggested mitigation measures	Suggested further monitoring/assessment
Increased flow to connecting waterbodies causing deterioration in water quality	Minimise spills from overflow weirs	Monitor water quality at targeted locations where water quality concerns have been identified
Increased chance of translocation of non-native fish species into connecting waterbodies	Screens on spill weirs, minimise spills	Targeted INNS monitoring to assess possibility of transmission
Increased spread of invasive fish species within the canal system	Raising awareness of INNS, encouragement of submission of records of INNS Removal of non-native species where feasible	Further monitoring of distribution of key invasive species at targeted locations of concern. Duration of monitoring to be determined
Intake of fish at abstraction point causing mortality	Appropriate screening of intake to protect fish	Localised species monitoring near intake structure to inform appropriate design of structure

Key areas of uncertainty remain where potential impacts have been identified, therefore further assessment in the form of modelling and monitoring may be required at Gate 3 and for the EIA to identify the appropriate mitigation measures with more confidence.

Further monitoring of water quality and modelling of changes to water quality through the canal system as a result of water transfer would allow identification of measures required to maintain water quality within acceptable limits - particularly focussing on mixing of areas of pollution, sediment mobilisation and water temperature differences.

Knowledge gaps remain in the utilisation of habitats by fish populations, particularly for fry and juvenile fish, and further information regarding these habitats would allow for consideration of interactions between changes in water quantity and quality and the effect on these features and fish populations. This would also inform potential areas where habitat improvement could benefit juveniles.

Further uncertainty remains about the effects of increased water flow on connected waterbodies, the significance of these connections, and the implications this may have for invasive species and their dispersal.

There is also uncertainty about invasive fish species distribution in connected waterbodies further downstream of the discussed connections; species in connected waterbodies may move to downstream to areas of habitat suitability and therefore any interaction of these species with the scheme would not have been picked up in this assessment.

7 Conclusions and recommendations

At least 24 distinct fish species were identified as likely present in the canal and/or connected waterbodies, with a high diversity of fish species in the canal system. The eDNA survey data indicate that the canal system has a mixed coarse fish assemblage associated with slow-flowing water, comprising a number of species that rely on vegetation and slow-flowing areas for spawning and juvenile habitat. The connecting river waterbodies in general exhibit a fish community characteristic of moderate velocity flowing water, with rivers in possible areas of influence from the scheme supporting populations of species such as bullhead that requires well-oxygenated water, lamprey that may depend on areas of silt as key habitat, and spined loach.

A number of protected fish species were also recorded within the canal system - lamprey, bullhead and possibly trout, also highlighting the use of the canal system by species that prefer areas of faster flow than the main canal coarse fish assemblage.

The non-native invasive species carp and zander were found to be present in the canal system and zander were not noted in any of the connecting waterbodies, whilst wels catfish were also detected in Marsworth Reservoir. Wels catfish have also been noted in the past from the GUC.

Potential impacts of the scheme on the fish community include changes to water quality such as an increase in turbidity and change in temperature, changes to habitat availability for fish, high flows affecting fish recruitment and survival, restriction of fish passage, risk of accidental pollution events, increase in overflow spills to connecting waterbodies, increased spread of invasive fish species towards the abstraction area, and localised impacts at the intake structure.

Proposed mitigation strategies include:

- Appropriate design of discharge outlet and intake structures to protect habitat and fish communities in those areas.
- Protection of marginal habitat areas important for spawning and juvenile fish (NB: more information on habitat utilisation would benefit the assessment and mitigation of such impacts).
- Measures to protect or increase bed roughness in high-velocity constriction points.
- Appropriate allowance for fish passage.
- Prevention of pollution through discharge standards and best-practice measures.
- Minimisation of spills from overflow weirs into waterbody connections.
- Screening on overflow weirs to prevent invasive species transmission.
- Increasing public awareness of INNS and continued removal of invasive species where feasible.

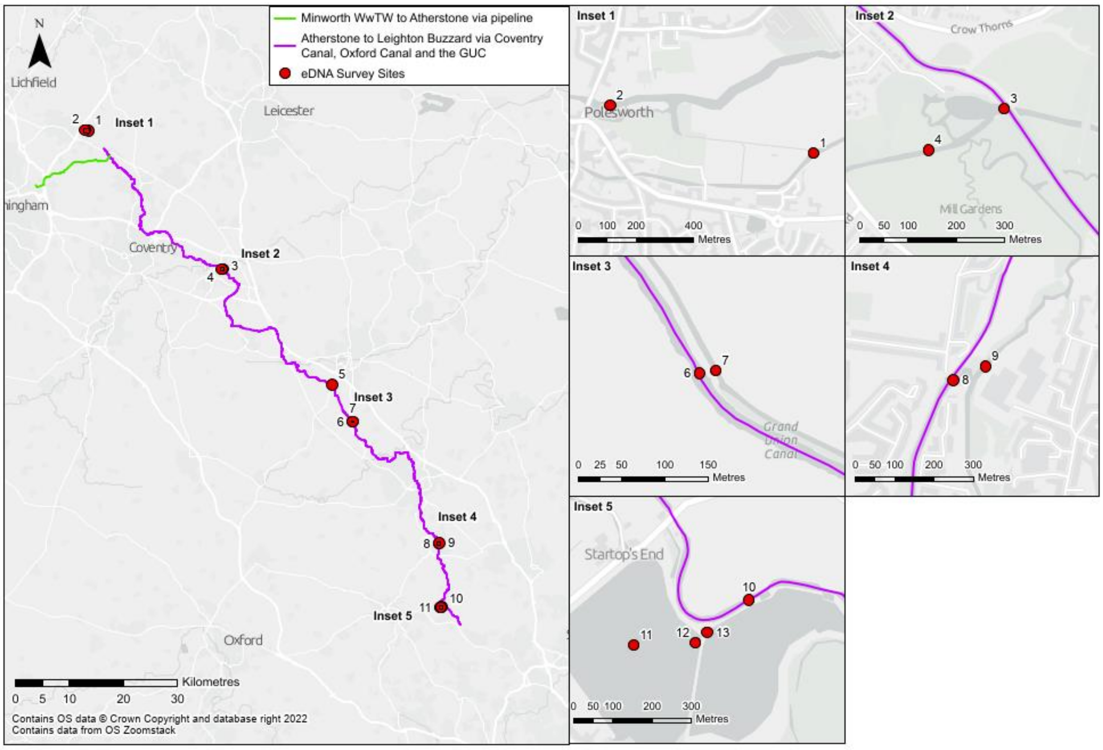
Further investigation during Gate 3 should aim to inform highlighted uncertainties, with emphasis on:

- Monitoring of water quality impacts.
- Assessment of key areas of silt and associated impacts.
- Modelling of flow velocity and associated water quality changes.
- Assessment of barriers to fish movement.
- Understanding of present habitats, likely habitat changes and the associated effects on fish communities including invasive species.

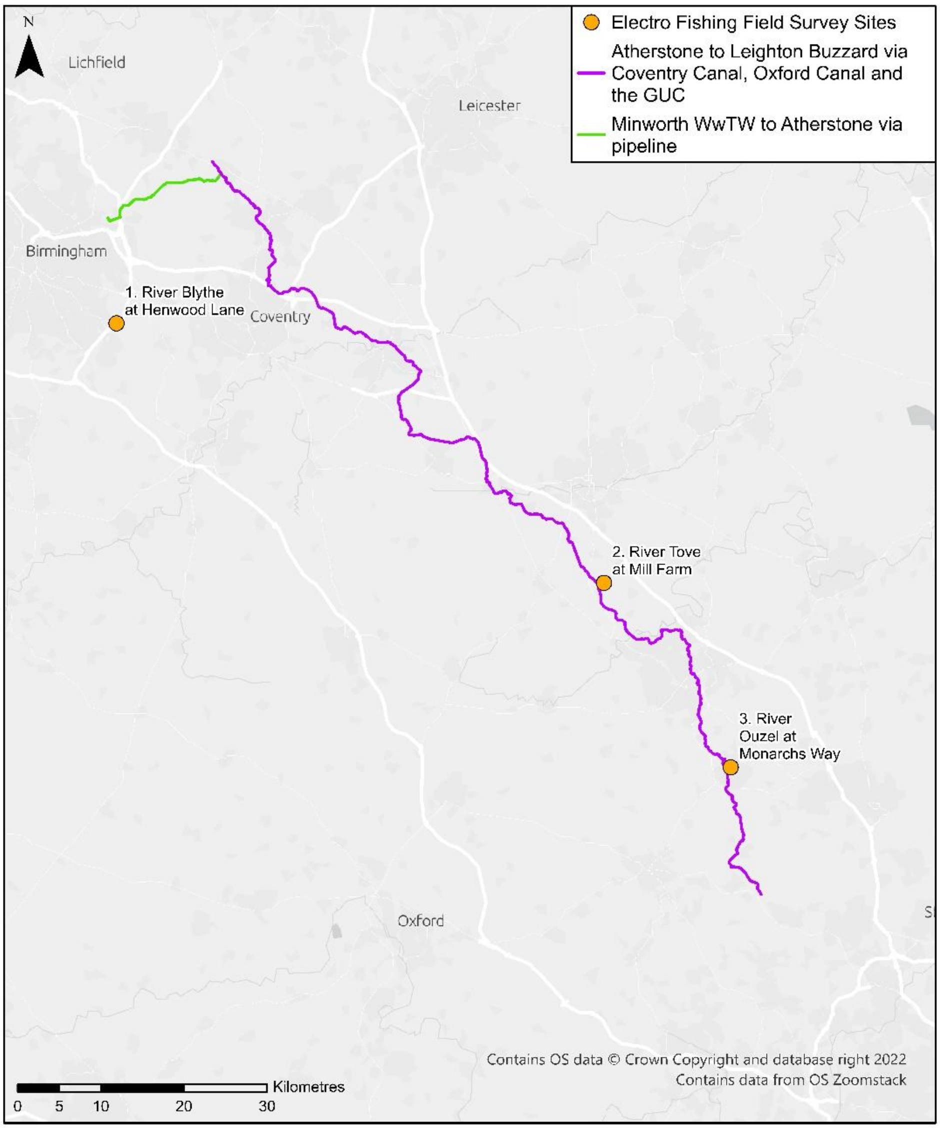
- Further understanding of the significance of waterbody connections and the impacts on fish populations through water and species transfer.

A. Appendices

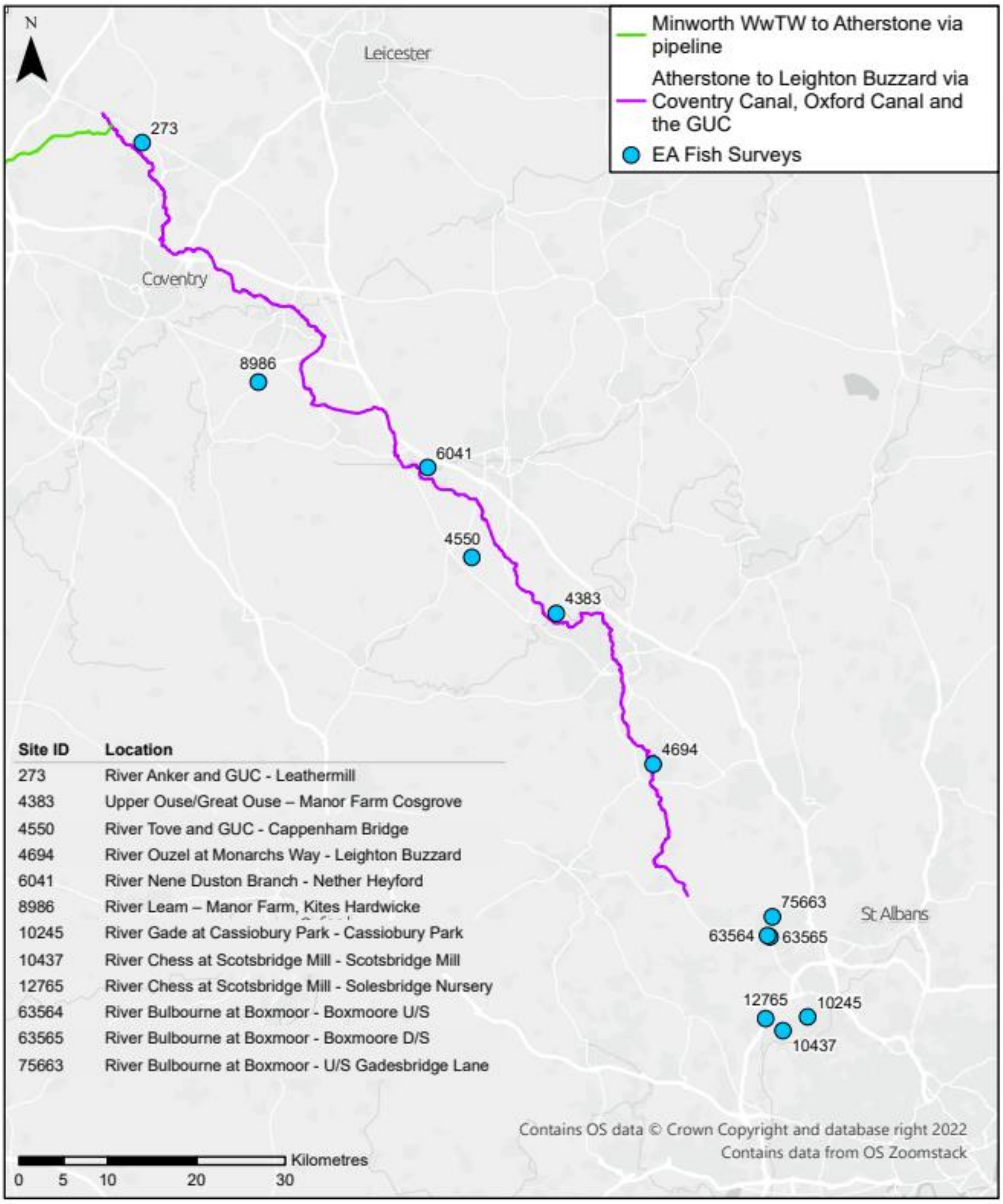
A.1 A.1: Fish eDNA survey sites.



A.2 A.2: Electrofishing field survey locations.



A.3 A.3: EA fish survey locations.



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