MWP

Lamprey Assessment Report

Shannon Navigation Dredging, Limerick City

June 2023

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Appendices

Appendix 1 – Survey Site Characteristics

Appendix 2 – Fish Lengths and Statistics

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MWP, Engineering and Environmental Consultants
Address: Reen Point, Blennerville, Tralee, Co. Kerry, V92 X2TK
www.mwp.ie

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1. Introduction

Waterways Ireland is seeking to carry out maintenance dredging upstream and downstream of Sarsfield Lock, Limerick City, in order to maintain a navigable channel and thereby reduce the associated safety concerns for pleasure and commercial boats. Figure 1 gives the location of the proposed dredge sites. The upstream extent of the study area at Site 1 is part of the lower reach of the Abbey River. A weir occurs at the lower end of the Abbey River. This weir extends from northwest of Site 1 to the northern end of the island at Sarsfield Lock, adjacent to Site 4.

MWP have been commissioned by Waterways Ireland to prepare a Natura Impact Assessment as part of the Appropriate Assessment process in order to identify and assess aspects of the proposed activity that could potentially impact on the relevant Natura 2000 sites, particularly the Lower River Shannon SAC (Site code 002165), in view of the conservation objectives of those sites. Sea lamprey (*Petromyzon marinus*) [1095], brook lamprey (*Lampetra planeri*) [1096] and river lamprey (*Lampetra fluviatilis)* [1099] are conservation interests of the Lower River Shannon SAC.

It is considered that the primary potential ecological impacts of the proposed dredging are direct impacts on the habitats of lampreys and lamprey injury/mortality. This report assesses the importance of the study area for lampreys based on a desk study and field surveys. Surveys were extended upstream to assess the relative importance of juvenile lamprey habitats in areas outside the zone of influence of the proposed development.

Data collation methodology and some background information on the ecologists undertaking the assessment is provided in Section 2. General information on lampreys is provided in Section 3.1. The distribution and range of lampreys in the lower River Shannon catchment (wider study area) is presented in Section 3.2. Lamprey information specific to the proposed dredge areas is provided in Section 3.3. Information on lampreys in the wider study area is provided in Section 3.4. Information on other fish recorded is presented in Section 3.5.

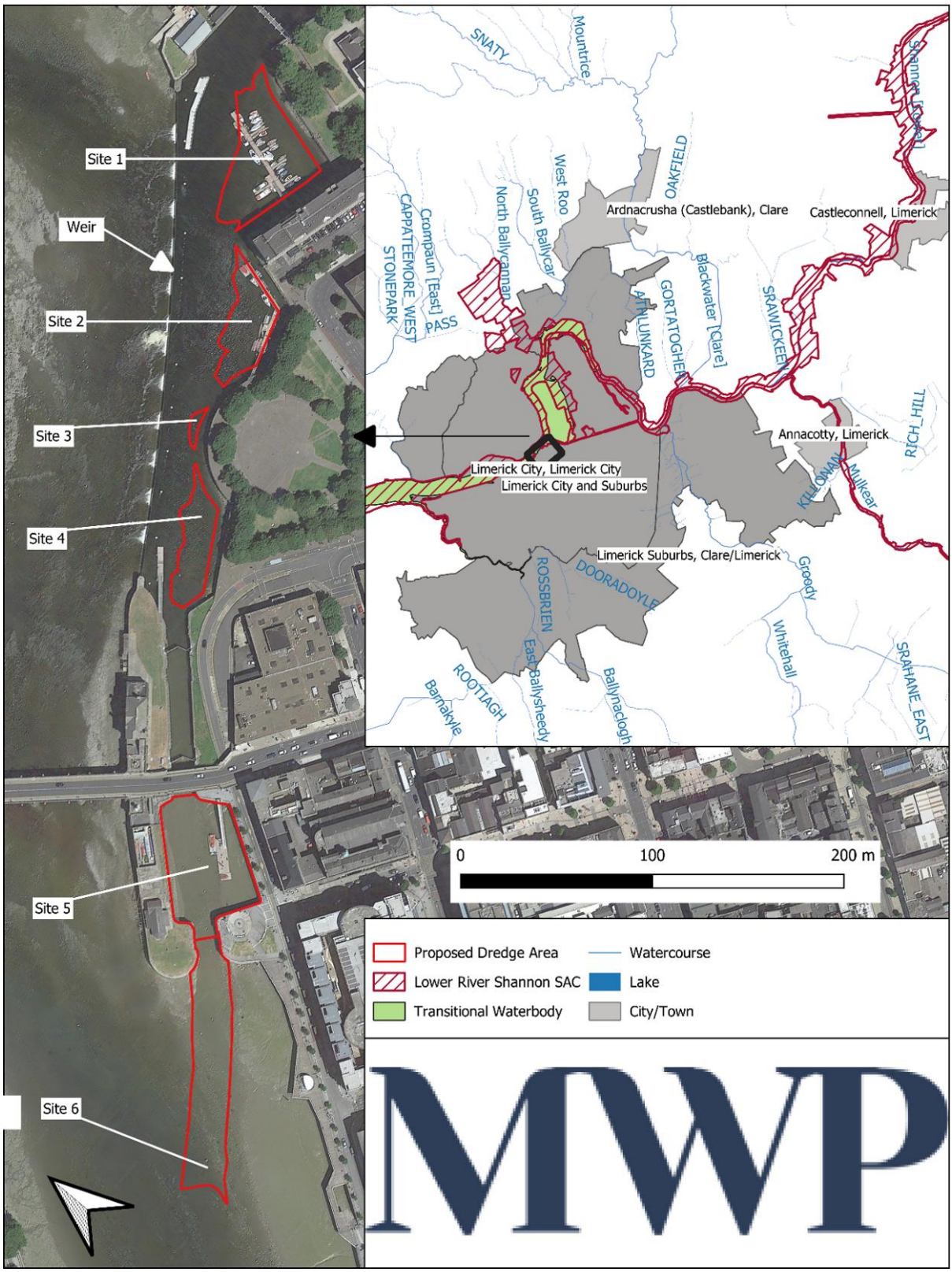

Figure 1 Location of the proposed dredge sites

2. Methodology

2.1 Desk study

A desktop study was carried out which comprised collation of data from publicly available online sources including:

- https://www.epa.ie/; and
- https://www.npws.ie/

A review of published literature was undertaken to collate data on lampreys that may occur in the receiving environment. Information on lampreys was sourced from '*Ecology of the River, Brook and Sea Lamprey*' (Maitland 2003) and '*The Status of EU Protected Habitats and Species in Ireland. Volume 3: Species Assessments'* (NPWS 2019).

GIS shapefiles were downloaded from the websites of the National Parks and Wildlife Service (NPWS) and Environmental Protection Agency (EPA). Maps of the proposed dredge areas provided by Waterways Ireland were transferred to a GIS platform to allow information on the natural environment to be analysed and to assist in field surveys. Online aerial mapping (Google satellite) was used to delineate the wetted area (area under water) of the river within the study area during low tide.

A marine sediment characterisation report for the proposed dredge site (Aquafact 2018) was reviewed.

2.2 Field surveys

Field surveys involved:

- characterisation of lamprey habitats by habitat assessment; and
- collation of data on lamprey occurrence and populations by agitation sampling and electrical fishing.

Table 1 lists the surveys carried out. All surveys were timed to coincide with low tide using online tide predictions. Surveys were also timed according to weather, preferably with clear skies, by consulting a weather forecast[1]. The primary determination of timing was tide times.

Juvenile and spawning habitats for lampreys were recorded with reference to Maitland (2003). A bathyscope was used to aid underwater visibility. An underwater camera was used to take photographs of the study area, sampling methods and fish captured. In relation to referencing riverbanks, RHS refers to right hand side and LHS

[1] https://www.met.ie/

refers to left hand side, when looking downstream. Feature locations were recorded using a Garmin etrex 10 hand-held GPS unit and an excel spreadsheet on a smartphone.

Table 1 Lamprey survey locations and types at the proposed dredge site and wider study area

Location	Survey type	Approach	Date
Within the proposed dredge area and immediate surrounds	• Habitat survey: record of river substrates • Juvenile lamprey presence/absence by agitation sampling	Bankside walkover	28th September 2018
Main channel of the River Shannon from proposed dredge area to Thomond Weir	• Habitat and agitation sampling survey: record of river substrates	Bankside walkover + kayak	17th March 2021
Mulkear River at Annacotty	• Adult sea lamprey survey	Bankside visual, bankside + instream walkover	17th June 2021
Abbey River	• Habitat survey	Boat	29th September 2021
Within the proposed dredge area and immediate surrounds	• Lamprey population survey: electrical fishing and agitation sampling	Boat	29th + 30th September 2021
Within the proposed dredge area and immediate surrounds	• Lamprey population survey: electrical fishing and agitation sampling	Boat and bankside	19th October 2021
Within the proposed dredge area and immediate surrounds	• Lamprey population survey: electrical fishing and agitation sampling	Boat	19th October 2021
Within the proposed dredge areas at Site 1 – Site 4	• Lamprey population survey: dredge sampling (five replicate samples at each subsite site)	Kayak	1st June 2023

2.2.1 Habitat assessment

The fluvial habitats of the proposed dredge site and other parts of the River Shannon as far as Thomond Bridge were defined in terms of juvenile lamprey habitats with reference to '*Ecology of the River, Brook and Sea Lamprey*' by Maitland (2003). Substrates were visually assessed and an assessment of suitability to juvenile lampreys was made based on substrate and flow type. This surveying was undertaken by walking along the banks and kayaking. A bathyscope and polaroid sunglasses were used to aid underwater visibility. Lamprey habitat suitability was categorised according to the following:

- Suboptimal (mostly clay substrate)
- Suboptimal (interstitial pockets between hard substrates)
- Optimal (silt/clay substrate)

Unsuitable (predominantly hard substrates).

2.2.2 Lamprey occurrence and populations

The aim of these surveys was to ascertain the importance of the proposed dredge sites for juvenile lampreys. A small number of locations were also examined upstream. This data was collected by electrical fishing, agitation sampling and dredge sampling. Lampreys were identified on site.

2.2.2.1 Electrical fishing

An electric fishing survey was carried out at Site 1 to Site 6 under authorisation from the Department of Communication, Energy and Natural Resources under Section 14 of the Fisheries Act (1980). See **Figure 2,** Plate 2 - Plate 4 for locations. Several sub-sites were surveyed at each site, mostly inside the dredge area boundary. Subsites were labelled with the Site No. prefix and a letter, e.g. the first subsite at Site 1 is referred to as subsite 1a. Grid reference locations of subsites are listed in **Appendix 1**.

The purpose of the electrical fishing surveys was to assess lamprey populations present at various locations within the proposed dredge sites and immediate environs. Habitats that were representative of dredge areas as well as river margins, areas deemed potentially affected by the proposed works were surveyed. Sites were surveyed following the methodology outlined in '*Monitoring the River, Brook and Sea Lamprey, Lampetra fluviatilis, L. planeri and Petromyzon marinus*' (Harvey and Cowx 2003). A range of substrate compositions and water depths (taken at low tide) were surveyed. Captured fish were collected using dip nets and placed in a container of river water. Following completion of fishing at each subsite, the dimensions and physical habitat characteristics of each sub-site were recorded as per **Table 2**.

Table 2 Surveys carried out for lampreys and their habitats at the proposed dredge site and wider study area

General characteristics	Substrate[2]	Flow feature
Mean depth (m)	Boulder (%)	Riffle[3] (%)
Maximum depth (m)	Cobble (%)	Glide[4] (%)
Shade (%)	Coarse gravel (%)	Pool[5] (%)
Detritus cover (%)	Fine gravel (%)	
Instream veg (%)	Sand (%)	
Slope°	Silt (%)	
	Clay (%)	

[2] Particle size ranges: boulder > 256 mm; cobble = 64-256 mm; coarse gravel = 17 – 64 mm; fine gravel = 3 – 16 mm; sand < 2 mm; silt < 0.06 mm; clay < 0.06)
[3] Described in EA (2003) as shallow, fast-flowing, water with a distinctly disturbed surface over unconsolidated gravel-pebble, or cobble, substrate
[4] Laminar flow where water movement did not produce a disturbed surface
[5] Little/no observable flow

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Plate 2 Site 1 at Custom House Quay (left) and Site 2 (right)



Plate 2 Site 3 (background) and Site 4 (foreground) on left. Site 5 at Sarsfield Lock (right)



Plate 4 Site 6: upstream (left) and downstream (right) extent



Figure 2 Location of the electrical fishing and agitation sampling sites and extent of the study area in Limerick

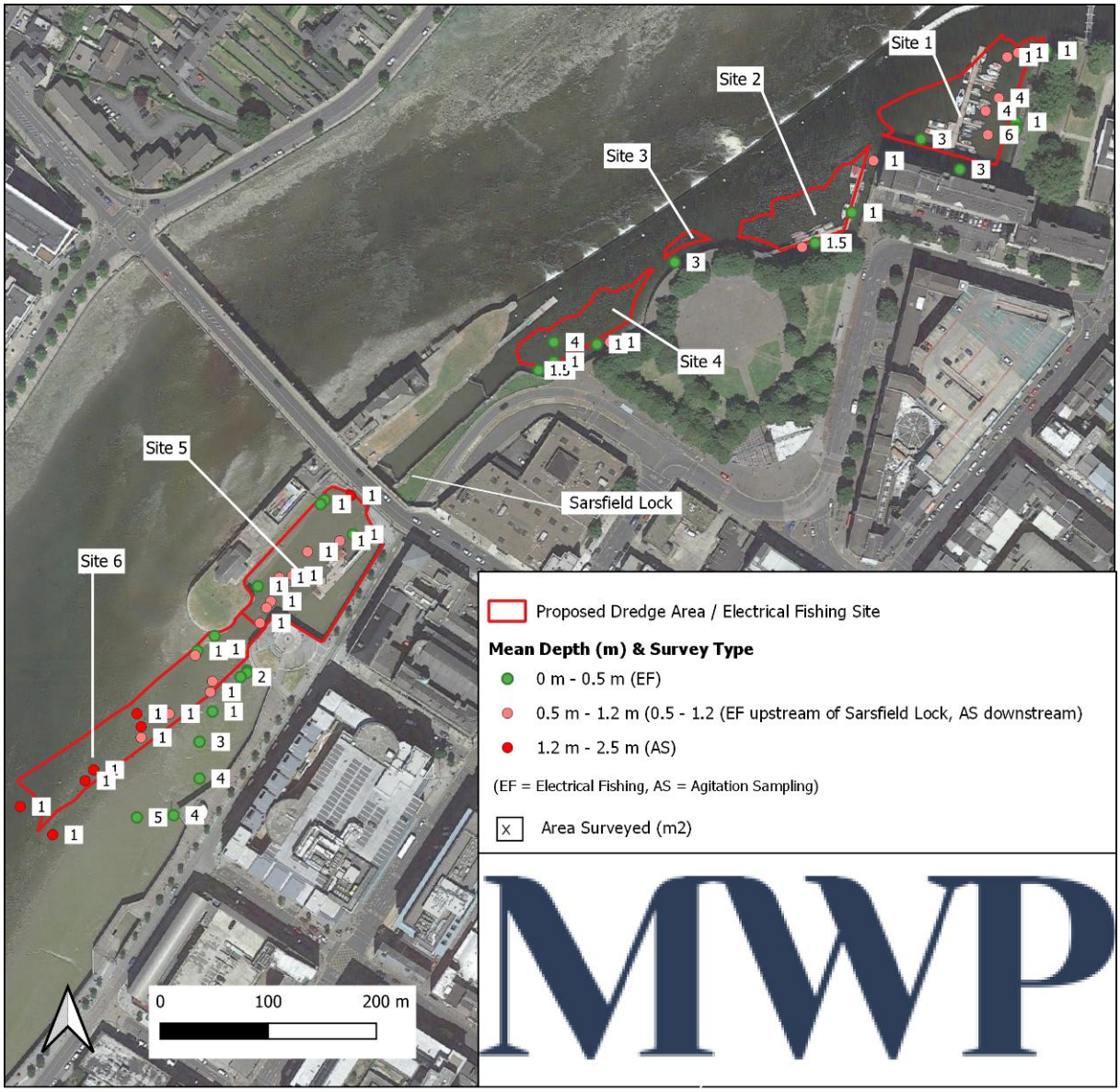

Figure 3 Fish survey types, areas surveyed and water depths at and in the environs of proposed dredge sites

2.2.2.2 Agitation sampling

Agitation sampling involves use of a dip net, where the net is rapidly swept over a disturbed area of fine substrate, and dislodged lampreys were captured. Where clay substrate dominated, a sample of the clay was extracted, spread over a white tray for examination and lampreys sought. Areas sampled were recorded using a meter stick. An extension net measuring up to 2.5 m long was deployed during agitation sampling.

A presence – absence survey for juvenile lampreys was undertaken at Site 1, Site 2 and Site 6 September 2018 by agitation sampling. Agitation sampling was also used at:

- a reach of the River Shannon west of King' Island in March 2021 where numbers and species of lampreys were recorded (Sites RS1, RS2 and RS3)
- within the dredge areas where depths were greater than 1.2 – 2 m.

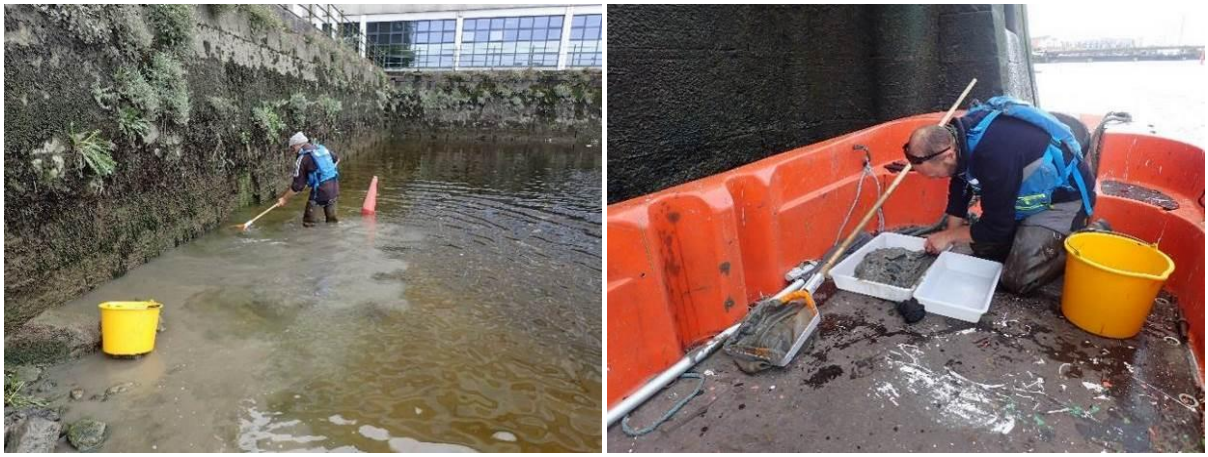

Plate 4 Agitation sampling (left) and searching for lampreys in substrate dominated by clay (right)

2.2.2.3 Dredge sampling

Dredge sampling was carried out on the 1st June 2023 at Site 1 – Site 4 at the locations listed in **Table 3** and shown in **Figure 4**. The river was accessed by kayak. Five No. dredge samples were taken at each of the survey locations. The focus of this survey was to sample deeper areas that could not be examined by the approaches outlined above. Dredge sampling was carried out using a LaMotte bottom sampling dredge tied to a rope. The locking trigger mechanism was activated, the dredge lowered onto the substrate, tension released and then pulled out of the water. For each site, the contents of the five dredge samples was placed into a white-bottomed tray and examined for lampreys. The contents of the tray were then emptied into a dip net and passed through the river to release clay as a precaution that small lampreys could be detected. Any other fish captured were also recorded.



Plate 5 Dredge sampler and white tray used to sample at depth



Plate 6 Examination of dredge samples.

Table 3 Dredge sampling locations

Code	X	Y
1a	557711	657473
1b	557683	657451
1c	557672	657448
1d	557663	657443
2a	557639	657415
2b	557630	657401
2c	557611	657397
2d	557595	657388
3a	557570	657384
3b	557559	657380
4a	557541	657361
4b	557527	657353
4c	557516	657343
4d	557508	657342
4e	557494	657332

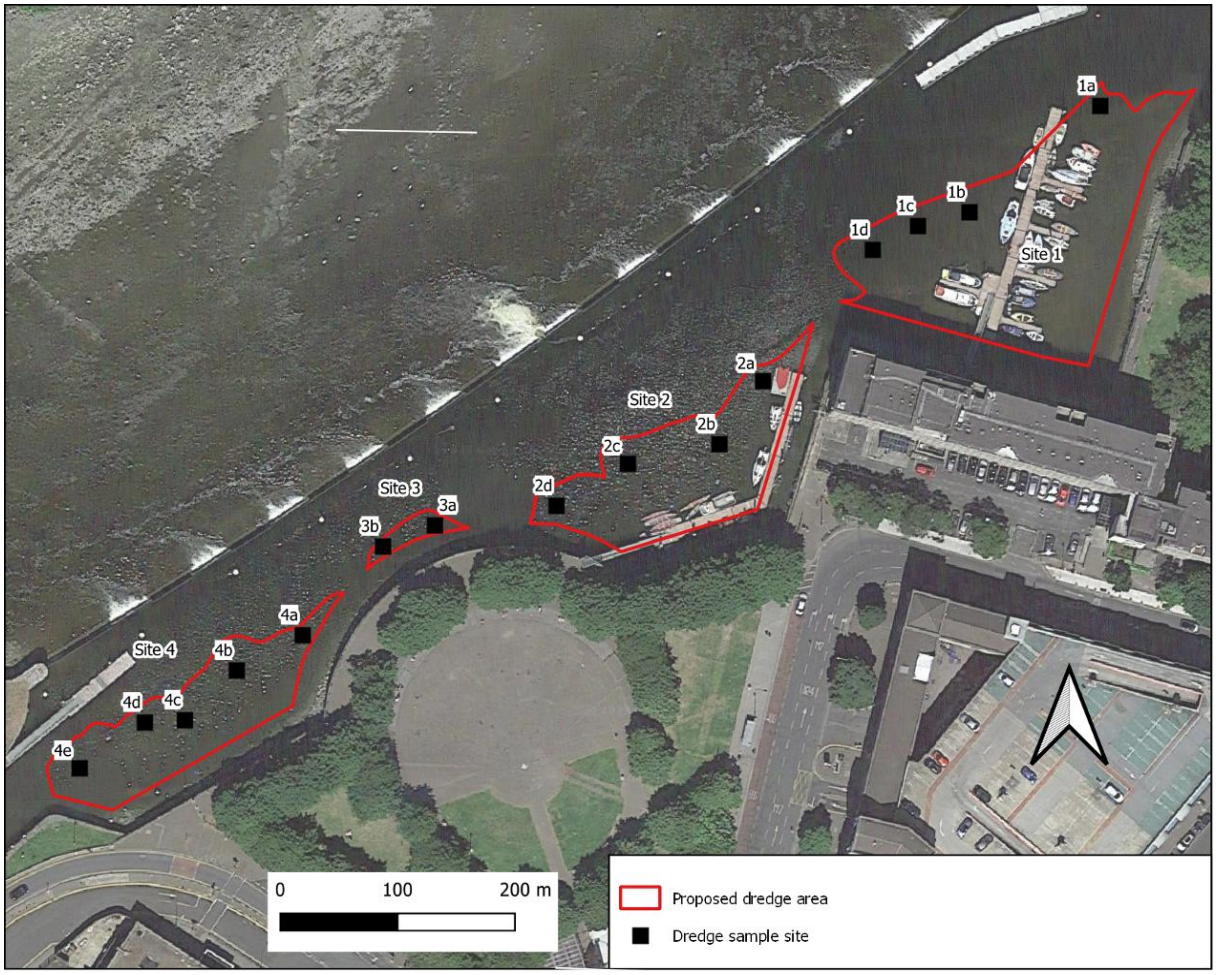

Figure 4 Dredge sampling locations

2.2.2.4 Lamprey identification

On completion of the surveys, fish were anaesthetised at intervals using a solution of clove oil, identified, and measured to the nearest mm using a measuring board. Lampreys were examined on the riverbank or in the boat for identification, with the assistance of a headband magnifier and using '*A field key for sea, river and brook lamprey' by* Gardiner (2003). Subsequent to this, lampreys and other captured fish were allowed to recover in a container of river water and then released and spread evenly over the sampling area. All lampreys and other fish were released alive; no damage or mortality was recorded.

2.2.3 Biosecurity

In cognisance of the risk of spread of non-native invasive alien species, the Inland Fisheries Ireland (IFI) document '*Biosecurity Protocol for Field Survey Work'* (IFI 2010) was followed at all stages of field work. All equipment (including waders etc.) was disinfected with spray bleach disinfectant after use, washed, dried out and put in storage.

2.2.4 Survey limitations

The River Shannon is a regulated channel at Limerick. Flows are controlled by the ESB using structures installed for the Shannon hydroelectric scheme at Parteen Weir and Ardnacrusha generating station.

Depending on background water levels, there can be a significant flow in the reach of the River Shannon in Limerick City, due to a large quantity of water being passed through Ardnacrusha generating station. This can influence water levels and therefore affected water levels, flows and visibility of the substrates within the study area.

Electrical fishing could be effectively performed to a depth of ca. 1.2 m above the weir at the lower end of the Abbey River. The effective depth downstream of the weir was variable, dependent on suspended solids concentrations, but was generally in the order of 50 cm. Agitation sampling was used where depths greater than 1.2 m were encountered. It is considered that efficiency of sampling by agitation was probably reduced with greater depths.

It was not possible to maintain station within the proposed dredge area at Site 3 due to flow and therefore sampling within this area could not be undertaken. Some subsites had dense vegetation cover which made capture of lampreys difficult. It was considered that detection is such areas was not impaired to a level that affected the overall assessment, as lampreys disturbed could be seen. Where lampreys could be seen but not caught, they were recorded as unidentified juvenile lamprey. Additional time was given to electrical fishing at these locations.

2.3 Statement of authority

Surveying to inform this report was completed by Gerard Hayes and Noreen Lynch of MWP. This report was prepared by Gerard Hayes (BSc., MCIEEM).

Gerard is a Senior Aquatic Ecologist with over 13 years' experience in environmental consultancy. Gerard has a diverse ecological profile, with aquatic fauna, phase 1 habitat, mammal (including bats), bird, amphibian, macroinvertebrate, and tree survey experience. He has had numerous responsibilities including report writing (EIS, EIA, EA, AA, NIS), waste assimilation capacity assessment, and ecological monitoring. His project involvement has been primarily in the areas of wind energy development, waste-water treatment plants, roads/bridges, water supply, flood defense and hydro schemes. He is co-author and/or carried out surveys for NPWS Irish Wildlife Manual Nos. 15, 24, 26, 37, 45. This included juvenile lamprey electrical fishing surveys in the Boyne, Corrib, Moy and Suir catchments, the latter which he led. He has collated field data and prepared river water quality assessment reports for EPA biological monitoring of rivers as part of Water Framework Directive (WFD) monitoring. He has been formally trained in WFD river monitoring (Environmental Protection Agency), Stage 1 and Stage 2 Freshwater Pearl Mussel Surveying (Dr. Evelyn Moorkens), aquatic macroinvertebrate identification (Freshwater Biological Association).

Noreen has three years' experience as an ecologist working on large infrastructure projects across a range of sectors including energy, water, wastewater, roads and bridges and flooding. She has carried out a range of targeted species surveys including otter, bat, crayfish and badger and Phase 1 ecology walkovers.

3. Results

3.1 Overview of lampreys in Ireland

The lampreys (family Petromyzonidae) belong to a group known as Agnatha (jaw-less); the most primitive of all living vertebrates. They have no lower jaws, and the mouth is surrounded by a round, sucker-like disc which, in the adults, contain teeth. These suckers vary in shape, size, position and number among the species, and are an important aid to identification. Lampreys have several other characteristic features. They have no bones, all the

skeletal structures being made up of strong, flexible, cartilage. There is only one nostril, situated on top of the head, just in front of the eyes of the adults. The eyes are not functional or even visible in the young, and they develop as the individual matures from its larval state (ammocoete; pronounced am-o-seat) to its adult state. There is a row of seven gill pores behind each eye. Lampreys occur in the temperate zones of both the northern and southern hemispheres. Fossils are available from the late Silurian and Devonian periods, 450 million years ago. Three indigenous species of lamprey occur in Ireland; the non-parasitic resident brook lamprey; and the parasitic anadromous river lamprey and sea lamprey.

The lamprey spawn in fresh waters, and ammocoetes are found within the same catchments using similar microhabitats but with varying geographical distribution. Although they have much in common, there are significant ecological differences among the three species. It should be noted that almost all authors regard the River and Brook Lamprey as being very closely related, and some consider them effectively the same species. The term 'paired species' is sometimes used for these two lampreys – the description being applied to pairs of morphologically similar lampreys, one a non-parasitic species probably derived from the other, a parasitic species (Potter 1980).

Lampreys are of high ecological value and can play an important role in processing nutrients, nutrient storage, and nutrient cycling in streams (Kan 1975, Hammond 1979, Moore and Mallatt 1980). Moreover, they also constitute a food source for other animals and can act as a buffer for salmon from predators in areas where they are abundant. It is now understood that they are susceptible to the same threats facing other native freshwater fish (i.e. pollution, barriers to migration, habitat destruction, etc.).

All three species are similar in appearance and behaviour when in their ammocoete (larval) state. The sea lamprey can be readily separated from the river and brook lamprey at the ammocoete stage. Identification between the ammocoetes of River Lamprey and Brook Lamprey is difficult, except when nearing metamorphosis. The of all three species adults can easily be distinguished by a range of their traits.

Brook lamprey and river lamprey are considered by many in the same context as the brown trout / sea trout pairing, with a similar absence of genetic discriminators. Lamprey surveys in Ireland have necessarily focused on ammocoete abundances and to a lesser extent upon observations of adult spawning events. Consequently, most available data relate to 'Lampetra sp.' and cannot be assigned to one species or the other. Information can only be definitively assigned to one species or the other where adult records exist (NPWS, 2019).

Lampreys prefer a gravel-dominated substratum for spawning, and mainly silt and sand-dominated substratum for nursery habitat (Harvey & Cowx, 2003).

More detail on the ecology of the three lamprey species is provided below.

3.1.1 Sea Lamprey (*Petromyzon marinus*) [1095]

Sea lamprey migrate to sea and only return to rivers to spawn (Kurz & Costello, 1999). They build nests (redds) and spawn in rivers, usually at the downstream end of pools where there is a swift current. The sea lamprey usually spawns in late May or June when water temperatures reach at least 15°C (Maitland, 2003) and prefer sediments made up of small cobbles and pebbles for spawning. Once hatched, the larvae are known as ammocoetes and as they swim out of the nest they are washed downstream where they accumulate in areas with slower water flow e.g. backwaters, current eddies or behind big stones on the river bed. There, the ammocoetes bury themselves in stable sandy silt rich in organic matter where they remain until they become adults. After 3 to 6 years, the ammocoetes transform into adults usually between July and September. Sea lamprey and river lamprey are known to spawn in the River Shannon and in several tributaries (Kurz & Costello 1999).

The presence of obstacles to sea lamprey upstream migration will reduce access to spawning and juvenile habitats, regardless of the prevailing extent and distribution of both throughout catchments. Barriers will often result in a highly localised distribution of spawning in the lower sections of rivers, rather than a diffuse dispersion throughout the system (Gargan *et al*. 2011 and Rooney *et al*. 2015 in NPWS 2019). Barrier removal or mitigation measures to facilitate passage are considered essential in the context of conservation status of sea lamprey, especially in Irish SACs where the availability of main stem channel often falls well below the 75% criterion identified for this species.

Increases in river discharge can exacerbate the already high rate of natural egg wash-out, both from within nests and from surrounding spawning gravels. When aspects of life history such as spawning, egg survival and early larval maturation are dependent on specific flow patterns, any pronounced increase in discharge could result in decreased or complete failure of recruitment for that year (Humphries & Lake 2000; Bunn & Arthington 2002; Maitland 2003 in NPWS 2019).

Sea lampreys do not home to their natal river to spawn. In effect all of western Europe contributes to a general marine adult population, from which individuals are free to return to rivers at random across their entire range. This is probably over-simplistic – adults may have a more regionalised marine location directly related to their original natal river, i.e. Irish sea lamprey may for the most part not stray beyond Irish coastal waters and will as a consequence return to Irish rivers due to proximity and convenience (NPWS 2019).

Pollution of surface water from diffuse and point sources is a constant threat to aquatic organisms. Both adult lamprey and ammocoetes are vulnerable to the effects of pollution. The single largest pressure acting on adult sea lamprey is the presence of artificial physical barriers to upstream migrating fish. Consequently, the overall Conservation Status of the species is considered 'Bad' in view of barriers to migration and the low population levels recorded (NPWS 2019).

3.1.2 Brook Lamprey (*Lampetra planeri*) [1096]

The brook lamprey is the smallest of the three lamprey species native to Ireland and is the only one that is non-parasitic and spends all its life in freshwater (Maitland & Campbell 1992). The spawning season for brook lampreys starts when water temperatures of the river reach 10 to 11°C (Maitland 2003) and usually occurs in March or April. Ammocoetes of the three lamprey species are often found in the same locations while brook lamprey can inhabit smaller streams often occurring closer to headwaters. Brook lamprey tends to spawn at the downstream end of pools, but often in smaller rivers and in slightly shallower and slower flowing water, building a nest in sandy or gravelly sediment (Kurz & Costello 1999).

After hatching, the larvae drift or swim downstream to areas of river bed or margins with fine silt deposits. They burrow into this substrate and live as filter feeders over a period of years before transforming into young adult fish. The young adults overwinter before migrating short distances upstream to gravelled areas where they spawn. The adult fish die after spawning.

For brook lamprey in Ireland, there are extensive areas of suitable habitat and no significant pressures impacting this species. The status of brook lamprey is evaluated as being of 'Favourable' conservation status nationally (NPWS 2019).

3.1.3 River Lamprey (*Lampetra fluviatilis*) [1099]

River lamprey are an anadromous species, spending part of their life cycle in the marine environment and returning to natal watercourses to spawn. They build nests (redds) and spawn in rivers, usually at the downstream end of pools where there is a swift current. They prefer sandy or gravelly sediment for spawning

(Kurz & Costello 1999) which begins when the water temperature reaches 10 to 11°C, usually in March and April (Morris & Maitland 1987).

River lampreys often spawn in the lower reaches of rivers but can also migrate 50 miles and more upstream (Kurz & Costello 1999). For adults and juveniles there are extensive areas of suitable habitat; however the presence of barriers to migration within river systems can, depending on timing of arrival and flow conditions, undoubtedly influence their distribution.

The main threats to river lamprey are river engineering, exploitation as bait by anglers and invasive molluscs on spawning beds. The inability to distinguish between *L. fluviatilis* and *L. planeri* larvae, and the challenges associated with sampling for adult river lamprey, means that an evaluation of their actual range and population size cannot be undertaken and status is assessed as unknown (NPWS 2019).

3.2 NPWS mapped occurrence of lampreys

The distribution and range of the three lamprey species in the wider study area are illustrated in Figure 4 to Figure 6 (based on Article 17 (2013 - 2018) Assessments in NPWS 2019). Range is the total geographical area within which all significant ecological variations of the habitat or species are included and which is sufficiently large to allow the long-term survival of the habitat or species. The Range is drawn as an envelope around the distribution using a standardised procedure. Horizontal or vertical gaps in the habitat distribution of 3 or more grid squares or oblique gaps of 2 or more squares are deemed enough to justify a break in the Range. Where ecological conditions for the development of the habitat are deemed unsuitable, gaps of just 1 grid square may also be permitted.

Table 4 gives the current distribution and range of lampreys in the context of the proposed development location. The proposed development is located in the 10 km grid square R55. The River Shannon at the proposed development and most of the River Shannon within R55 is classified as a transitional water called 'Limerick Dock' (SH_060_0900). This is a 'Meso or Polyhaline, Strongly Mesotidal, Sheltered' type waterbody.

Transitional waters are those waters between the land and the sea including estuaries. The proposed development is within the Shannon Estuary - the transition from freshwater to marine conditions. Depending on the tidal influence from coastal waters, but also on the freshwater influence from upstream, transitional waters are often characterised by frequently changing salinity[6]. The proposed development is therefore located within part of the River Shannon that is prone to saline influence. Due to the size of the River Shannon and the shape of the inner estuary brackish influence on the part of river affected by the proposed development is considered to occur infrequently. When flow in the River Shannon is low however, saline intrusion into the upper zone of the transitional waterbody can be expected during spring tides, which occur twice each lunar month. Saline intrusion to the upper zone is likely more intense dry weather flow as for example during the summer of 2018[7].

[6] http://www.wiser.eu/background/transitional-waters/
[7] https://www.thetimes.co.uk/article/river-shannon-drought-in-limerick-is-ramping-up-pressure-on-irish-water-8hqsk03sl

The 10km grid square R55 is outside the current distribution of sea and river lamprey. This is probably due to the transitional waterbody classification. The 10km grid square R55 is within the current range of sea and river lamprey. These species must pass through the Shannon Estuary to reach fresh water to spawn and on their seaward outmigration.

Table 4 Proposed dredge location in the context of current distribution and range of lampreys

	Current distribution	Current range	Likely reason
Sea lamprey and river lamprey	No	Yes	The River Shannon at the proposed dredge area and most of the River Shannon within R55 is classified as a transitional water. Sea Lampreys spawn in the lower reaches of the rivers: • Mulkear (mostly downstream of Annacotty) and • Shannon These species must pass through the Shannon Estuary to reach fresh water to spawn and on their seaward outmigration
Brook lamprey	Yes	Yes	This species is the most common and occurs in most lowland watercourses, likely occurring in the Barnakyle, Rossbrien and Crompaun East Streams within R55.

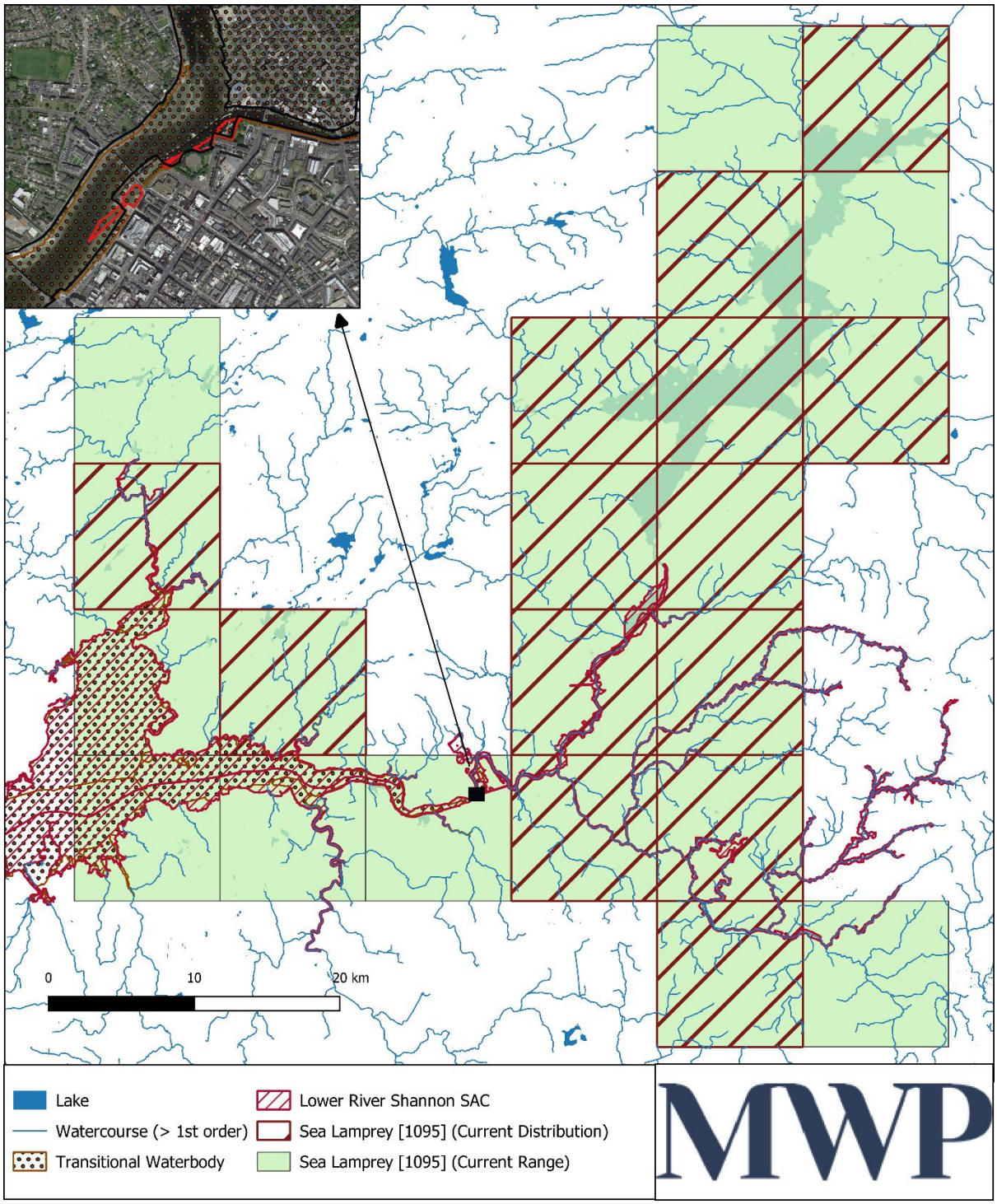

Figure 5 Sea lamprey *Petromyzon marinus* (1095) and proposed dredge locations

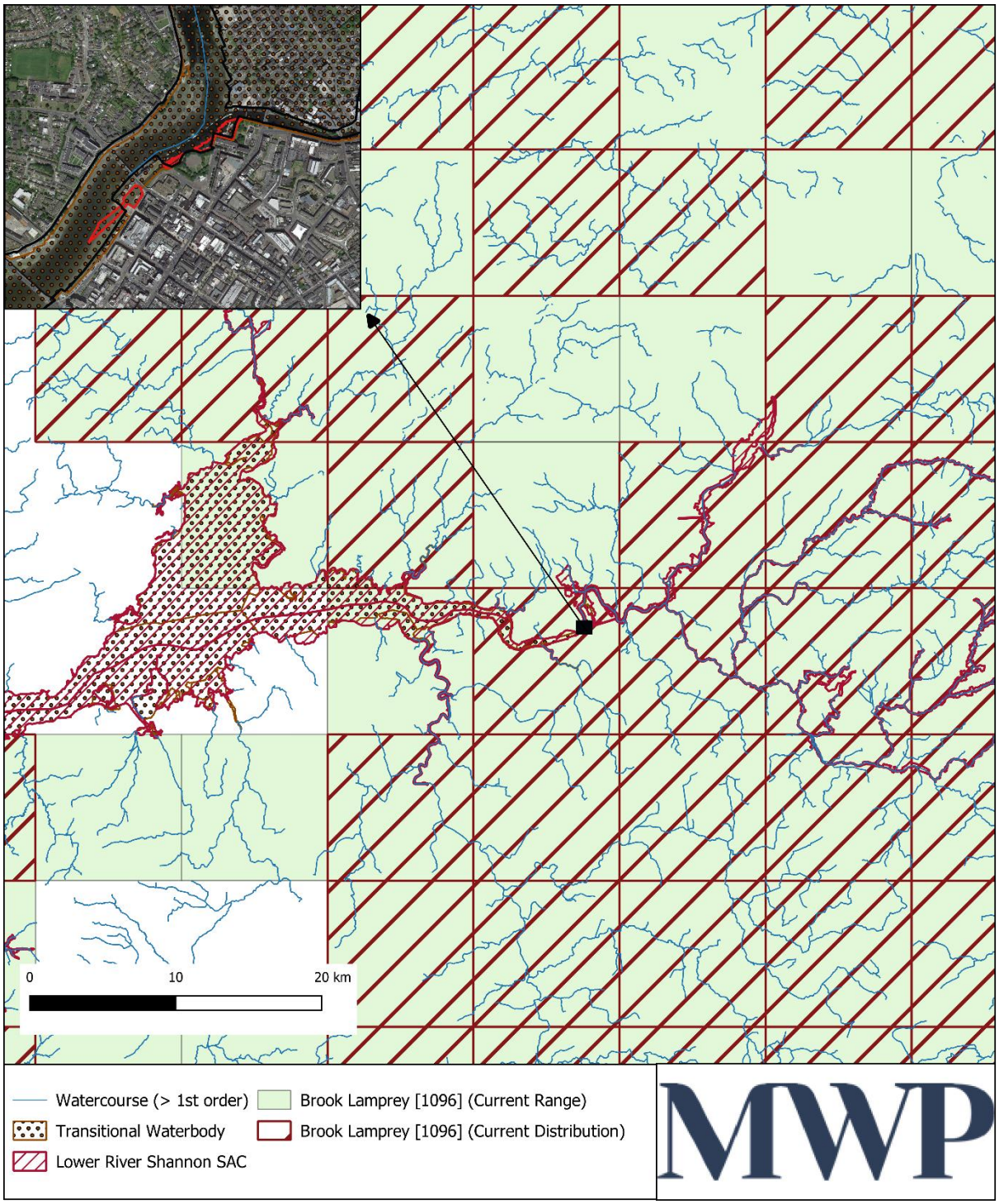

Figure 6 Brook lamprey *Lampetra planeri* (1096) and proposed dredge locations

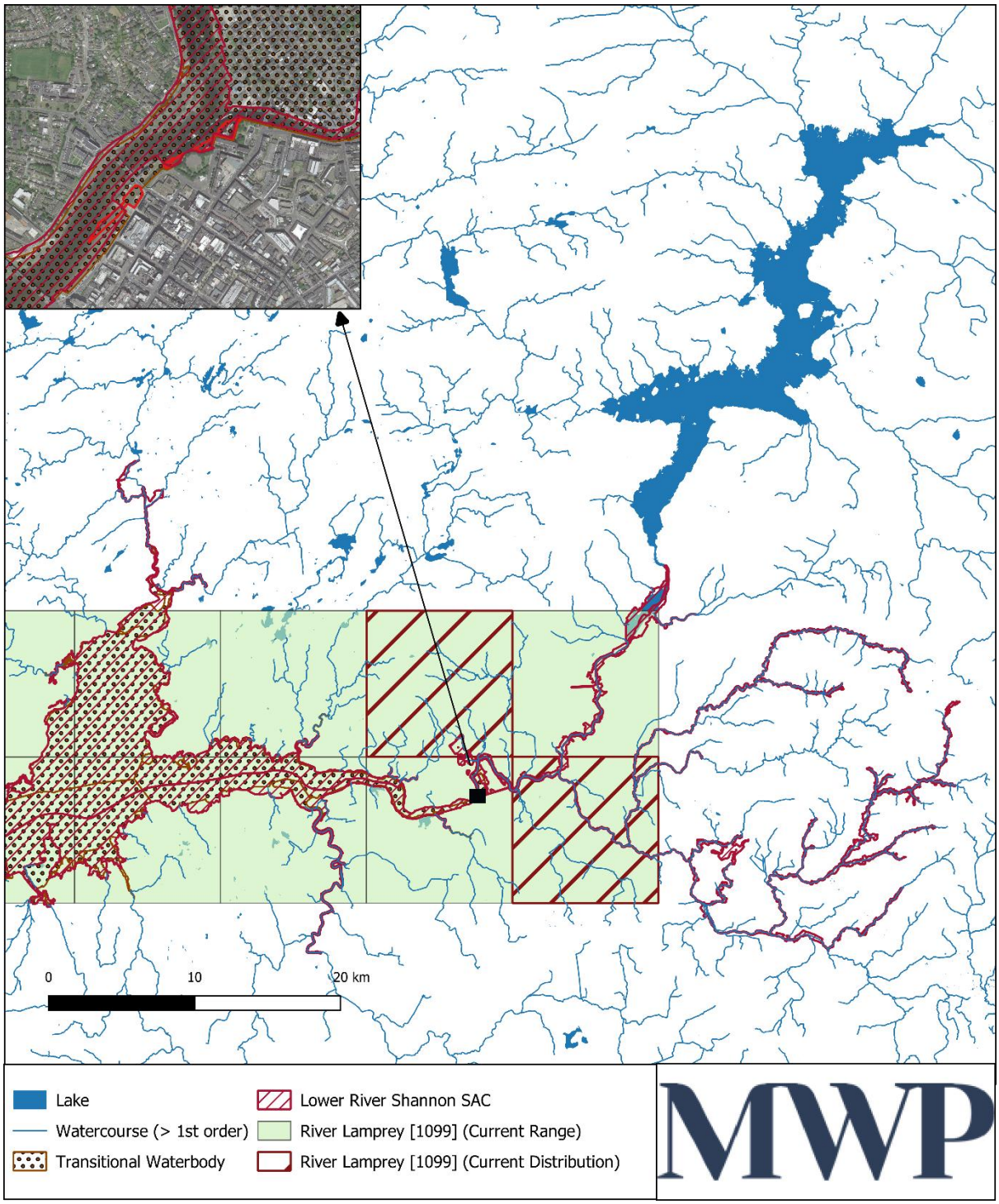

Figure 7 River lamprey *Lampetra fluviatilis* (1099) and proposed dredge locations

3.3 Proposed dredge locations

3.3.1 Habitats

Lamprey habitats in the study area are governed by a range of factors including flows and substrates, these parameters dictated by physiography, regulation of the River Shannon and the tidal regime. It was found that the most important nursery areas for lampreys were at the margins of the river in areas of relatively slow flow. A map depicting habitat suitability for juvenile lampreys at the proposed dredge sites is provided in Figure 8. A large area of optimal juvenile lamprey habitat also occurs in the lower end of the Abbey River at the marina (Site 1). The shallower substrates of proposed dredge Site 2 and Site 4 were considered optimal juvenile lamprey nursery areas.

Much of the Abbey River within the study area comprises mixed substrates of boulder (>250mm), cobble (65-250mm), gravel (2-64mm) with interstitial spaces between these hard substrates filled by finer substrates. These pockets of soft substrates are regarded as suboptimal due to the lower lamprey densities potentially sustained in these areas. Such habitat occur as narrow strips parallel to the bank of the river, and also in areas away from the thalweg (part of river conveying most flow). It is important to note that during high river flows, as is the case when water is being passed through the Ardnacrusha power station[8], flow in the Abbey River is considerable and therefore only certain areas allow deposition of fine material in significant quantities. These areas correspond to 'optimal' juvenile lamprey habitat in Figure 8.

The physical characteristics of the electrical fishing sites are provided in Appendix 1 and include substrate compositions. Overall, substrate heterogeneity was greatest at Site 1. There was greater substrate diversity at the margins of the river at all sites, typically with boulders and cobbles at the bases of walls along the channel, generally grading to gravel silt and clay. The proportion of clay in the study area increases towards the greater Shannon Estuary to the south and west. Indeed, a marked increase in the proportion of clay (<0.06mm) was recorded in areas of high deposition rates downstream of the Abbey River Weir (Site 5 and Site 6), with 100% clay at most sites. This is attributed to the estuarine influence, with fine suspended solids settling out of the water column in areas of slow flow, especially at the river margins. Ammocoete density in areas of high clay content was lower than substrates dominated by sand and silt (see section 3.3.2), so the suitability of lamprey nursery habitat generally decreases to the south and west. Areas dominated by clay substrates were therefore mapped as suboptimal.

The proposed dredge sites are affected by the tide. When water levels fall to their minimum level at the end of the ebb of Spring tide, the wetted area of the river is reduced and much of the river substrate is above water level. This is a feature of the main channel of the River Shannon as far upstream as Thomond Weir and beyond, with the effect diminishing with distance upstream. The Abbey River also experiences this effect but to a lesser degree because of the weir. The Abbey River weir and Sarsfield Lock retain water at a minimum level upstream of the weir at low tide as depicted in Figure 8. Areas prone to drying out are therefore deemed unsuitable for lampreys given the intermittent absence of water.

[8] Flow in the Abbey River and River Shannon at Limerick are also governed by other inflowing rivers such as the Mulkear and Groody.

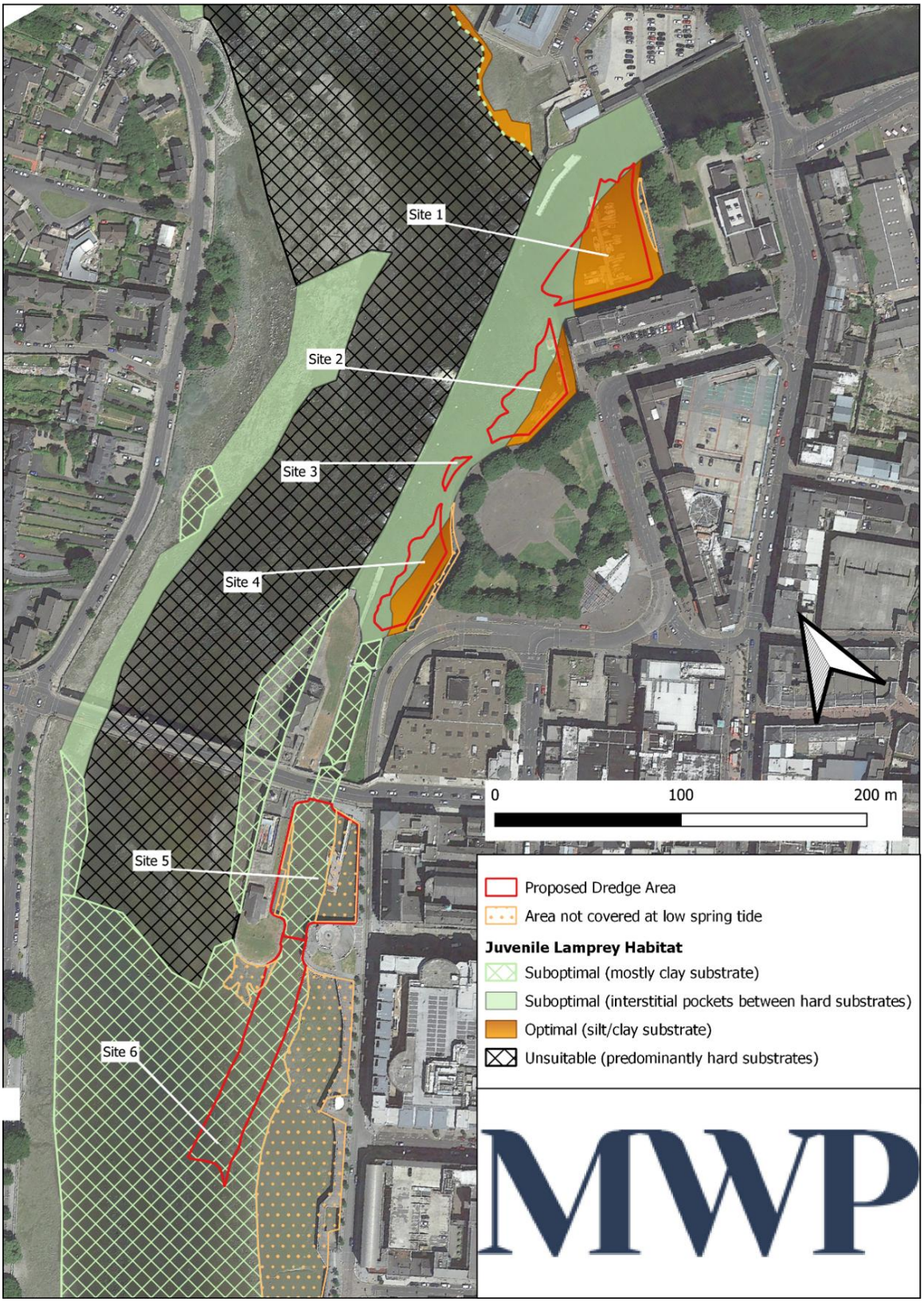

Figure 8 Habitat suitability for juvenile lampreys within the study area

There was some instream vegetation cover at Sites 1 – 4, mainly of rooted plants (*Myriophyllum* sp., Canadian pondweed *Elodea canadensis*) and algal mats. These areas, all upstream of the Abbey River Weir, were the only locations where surface detritus was detected. As noted in Maitland (2003), lamprey larvae feed by filtering fine organic particles, especially diatoms and other algae, as well as protozoans and detritus, from the surface of the silt around the mouths of the burrows. Site 1 – 4 therefore are deemed relatively better in terms of feeding opportunities for juvenile lampreys. Some of the substrates in depositing areas upstream of the Abbey River Weir were found to be anoxic within a few centimeters of the surface. This feature likely reduces habitat suitability for juvenile lampreys. No such anoxia was recorded in the main channel of the River Shannon upstream of the dredge areas (see Section 3.4.1).

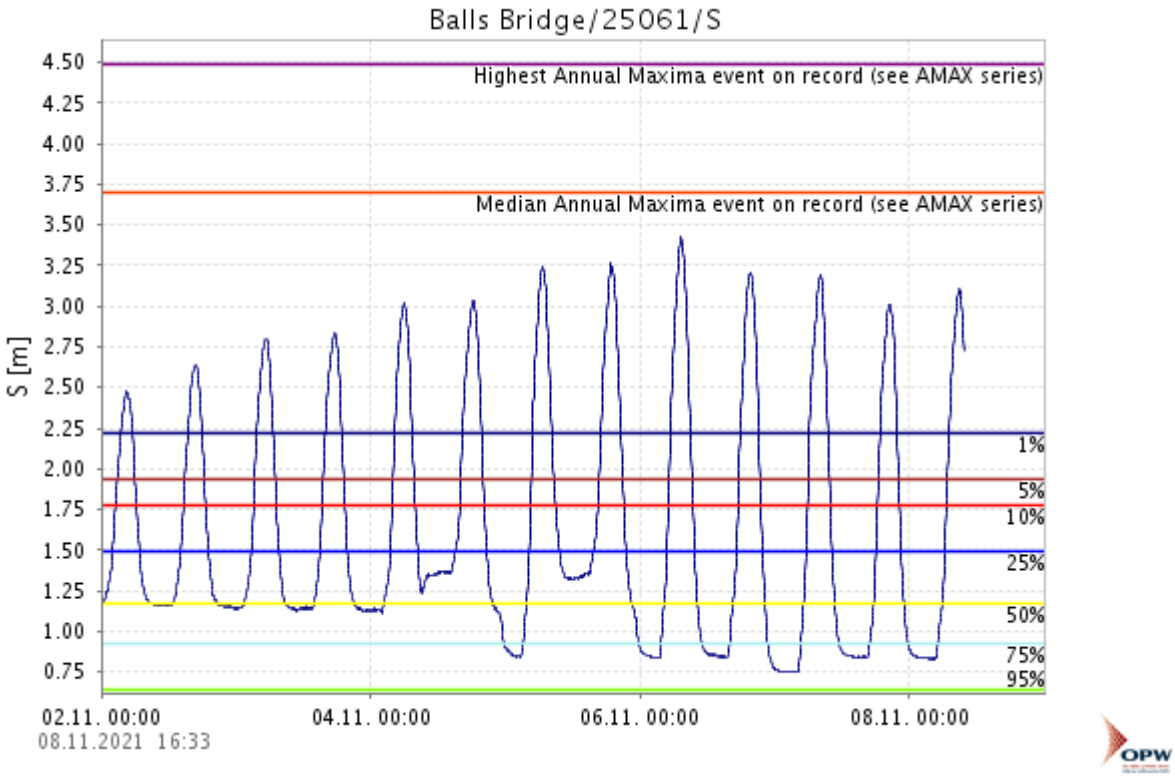

Figure 9 Hydrograph for the Abbey River, Limerick over a week period. (Source: OPW website https://waterlevel.ie/0000025061/0001/).

It is considered that the reach of the River Shannon affected by the proposed dredging is highly unlikely used by migratory lampreys for spawning owing to the influence of the tide, substrate compositions and sluggish flows. Adult lampreys select freshwater reaches for spawning but the subject waterbody is classified as transitional so is prone to saline intrusion. Lampreys will access freshwater reaches in the River Shannon and River Mulkear further upstream for spawning, in cognisance that flow in the subject reach would be insufficient to aerate gravels at high tide, and a requirement of lamprey ova deposited during spawning are well-aerated substrates. The substrates at the proposed dredge sites were found be too silted for lamprey spawning purposes. Furthermore, a large proportion of cobble/gravel substrates where they occurred, were sharp and therefore suboptimal for lamprey spawning.

It is noted that larvae of the mayfly *Ephemera danica* were recorded during agitation sampling between Thomond Weir and Thomond Bridge but not at any of the survey sites within proposed dredge areas. This could be attributed to salinity.



Plate 7 Overview of Site 1: view from eastern bank (left) and southern bank (right)



Plate 8 Gravel, sand and silt substrate near the thalweg of the Abbey River at subsite 1g (left). Clay dominated substrate at subsite 1I



Plate 9 Typical habitat in the shallows of Site 4 with a substrate sample shown in dip net



Plate 10 Substrate at subsite 4a comprised mostly clay (left). Anoxic leaf litter recorded in the substrate at subsite 4f.

3.3.2 Lamprey populations

Brook/river, river and sea lamprey were recorded during the electrical fishing surveys undertaken. Detailed results can be found in Appendix 2.

During electrical fishing within the proposed dredge areas and environs, a total of 40 ammocoetes (29 brook/river lamprey, 7 river lamprey, and 4 sea lamprey) were recorded over an area of 111m^2. This corresponds to a density of 0.36 lamprey/m^2. Where they occurred, juvenile lamprey densities were low. Length descriptive statistics for all lampreys are provided in Table 4. Table 5 gives the numbers of lampreys detected at electrical fishing subsites. Results are illustrated in Figure 10. Table 7 gives densities of lampreys by dredge site location. The lampreys recorded were from mid to older age cohorts, ranging in size from 5.5 cm to 10.1 cm. It is considered possible that a large proportion of the brook/river lampreys could be river lampreys taking given that most were <10 cm.

Lampreys were recorded only at Site 1 to Site 4. Lampreys were not recorded at any of the sites downstream of the Abbey River Weir, where the total area of ca. 29 m^2 could be fished effectively by electrical fishing and 19 m^2 sampled by agitation. It is noted that some of the subsites at Site 6 were outside the proposed dredge areas but had some surface water in small channels. This confirms that the substrates away from the wetted main channel at low tide are not suitable for juvenile lampreys.

Upstream of the Abbey River Weir – Thomond Lock, where an area of 55 m^2 was sampled, the lamprey density was 0.73 / m^2. The density of brook/river, river and sea lamprey was 0.53 m^2, 0.13 m^2 and 0.07 m^2, in that order.

The results for each site are presented below.

During dredge sampling, a total of 6 European eels were found, the only fish species recorded. All these eels were juvenile. The majority of dredge samples were found to consist of fine-grained mud. A deep area (2.5m) surveyed by dredge at Site 1a was found to comprise gravels, this attributed to fast flow.

Table 5 Length descriptive statistics for all lampreys at the proposed dredge sites and environs

		River/brook lamprey	River lamprey	Sea lamprey
Length (cm)	Minimum	5.5	6.7	6.7

	Maximum	10.1	10.2	9.2
	Average	7.9	8.5	8
N		31	7	4

Table 6 Numbers of lampreys detected at the electrical fishing subsites

Site	Subsite	Area (m^2)	River lamprey	River/brook lamprey	Sea lamprey	Total No. of lamprey	Density of lampreys (No./m^2)
Site 1	1a	1	1	1	1	**3**	3
Site 1	1b	1	1			**1**	1
Site 1	1c	1	1	2		**3**	3
Site 1	1d	1		3		**3**	3
Site 1	1e	1			1	**1**	1
Site 1	1f	1				**0**	0
Site 1	1g	1				**0**	0
Site 1	1h	4		2		**2**	0.5
Site 1	1i	4		1		**1**	0.25
Site 1	1j	6	1			**1**	0.17
Site 1	1k	3	1	1		**2**	0.67
Site 1	1l	3				**0**	0
Site 2	2a	1				**0**	0
Site 2	2b	1				**0**	0
Site 2	2c	1.5		2		**2**	1.33
Site 2	2d	1				**0**	0
Site 3	3a	3				**0**	0
Site 4	4a	16	2	4	1	**7**	0.44
Site 4	4b	1		1		**1**	1
Site 4	4c	1		2		**2**	2
Site 4	4d	1		4		**4**	4
Site 4	4e	1.5		6	1	**7**	4.67
Site 4	4f	4				**0**	0
Site 5	5a	1				**0**	0
Site 5	5b	1				**0**	0
Site 5	5c	1				**0**	0
Site 5	5d	1				**0**	0
Site 5	5e	1				**0**	0
Site 5	5f	1				**0**	0
Site 5	5g	1				**0**	0
Site 5	5h	1				**0**	0
Site 5	5i	1				**0**	0
Site 5	5j	1				**0**	0
Site 5	5k	1				**0**	0
Site 5	5l	1				**0**	0

Site	Subsite	Area (m^2)	River lamprey	River/brook lamprey	Sea lamprey	Total No. of lamprey	Density of lampreys (No./m^2)
Site 6	6a	3				**0**	0
Site 6	6b	2				**0**	0
Site 6	6c	2				**0**	0
Site 6	6d	1				**0**	0
Site 6	6e	3				**0**	0
Site 6	6f	4				**0**	0
Site 6	6g	4				**0**	0
Site 6	6h	5				**0**	0
Site 6	6v	1				**0**	0
Site 6	6i	2				**0**	0
Site 6	6w	1				**0**	0
Site 6	6j	1				**0**	0
Site 6	6k	1				**0**	0
Site 6	6l	1				**0**	0
Site 6	6m	1				**0**	0
Site 6	6n	1				**0**	0
Site 6	6o	1				**0**	0
Site 6	6p	1				**0**	0
Site 6	6q	1				**0**	0
Site 6	6r	1				**0**	0
Site 6	6s	1				**0**	0
Site 6	6t	1				**0**	0
Site 6	6u	1				**0**	0
Totals		111	7	29	4	40	

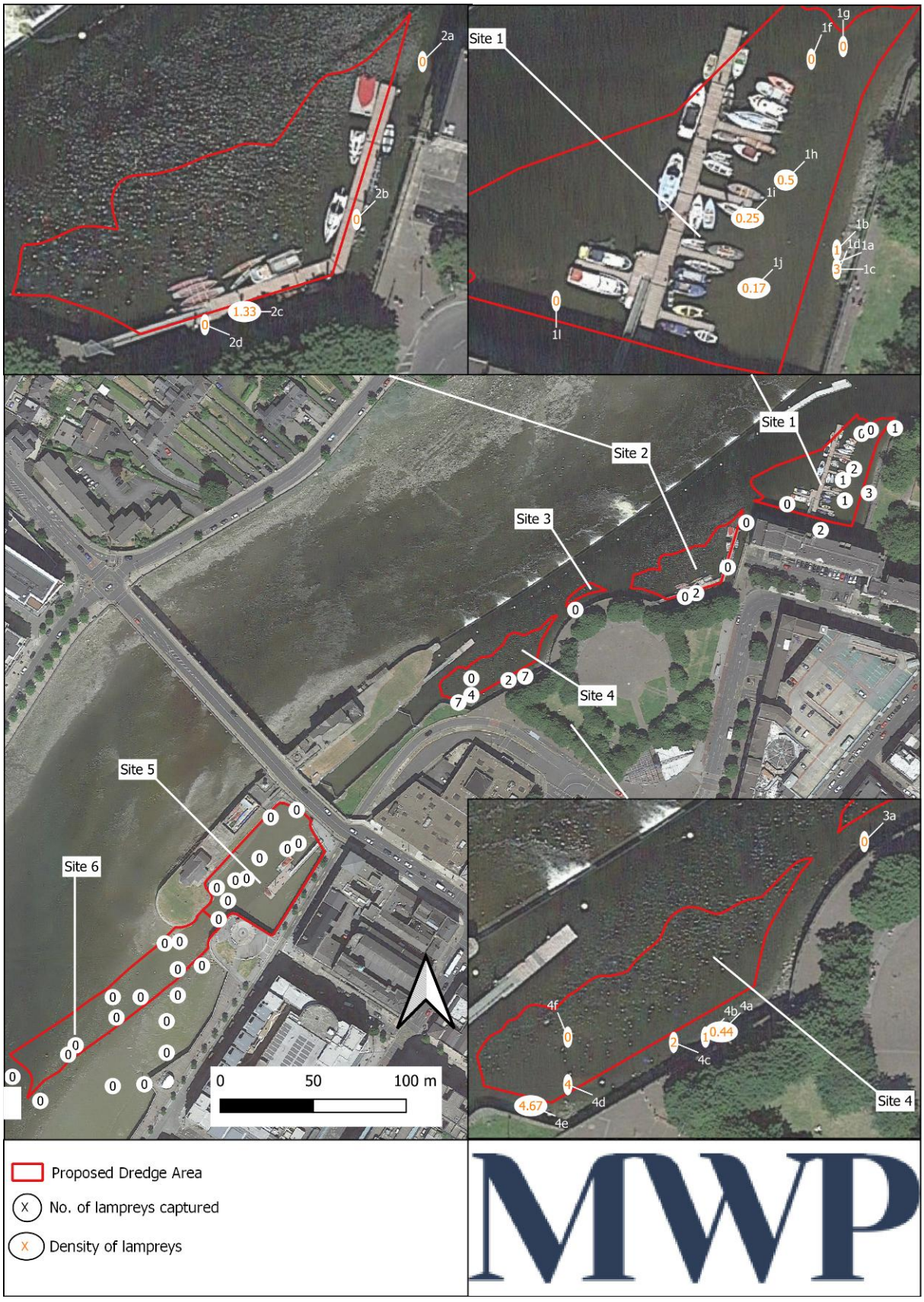

Figure 10 Numbers of lampreys and densities at the proposed dredge sites and environs

Table 7 Densities of lamprey at the proposed dredge locations and environs

Site	Area sampled (m2)		River/brook lamprey	River lamprey	Sea lamprey	Total Lampreys
Site 1	27.0	No. of lampreys	11	5	2	18
		Density (lampreys/m^2)	0.41	0.19	0.07	
Site 2	4.5	No. of lampreys	2	0	0	2
		Density (lampreys/m^2)	0.44	0	0	
Site 3	3	No. of lampreys	0	0	0	0
		Density (lampreys/m^2)	0	0	0	
Site 4	24.5	No. of lampreys	11	1	2	14
		Density (lampreys/m^2)	0.45	0.04	0.08	
Site 5	12	No. of lampreys	0	0	0	0
		Density (lampreys/m^2)	0	0	0	
Site 6	40	No. of lampreys	0	0	0	0
		Density (lampreys/m^2)	0	0	0	

3.3.2.1 Site 1

A total of 18 lampreys were recorded at Site 1 in a surveyed area of 27 m^2. Most lampreys were found along the river margins with these areas supporting greatest densities, to a maximum of 3 / m^2 (subsites 1a, 1c, 1d). These lampreys were found in substrates composed mainly of clay and silt where depths were in the 20 cm to 30 cm range. Two lampreys were recorded in an area of silt - clay substrate in an area of 4 m^2 where mean depth was ca. 70 cm (subsite 1i, density of 0.5 / m^2). Lampreys were also recorded at subsites 1j (0.17 / m^2) and 1h (0.5 / m^2). Much of the area of optimal habitat to be dredged at this location can be expected to support lampreys in densities ranging from 0.5 – 0.3 / m^2. The northern extent of this site comprised gravel dominated substrate that was strongly influenced by the thalweg of the Abbey River and where no lampreys were detected.

3.3.2.2 Site 2

A total of 2 lampreys were recorded at Site 2 in a surveyed area of 4.5 m^2. These lampreys were found in substrates composed mainly of clay and silt in depth up to 40 cm (subsite 2c). The optimal habitats in the area to be dredged at this location can be expected to support lampreys in densities ranging from 0 – 1.33 / m^2.

3.3.2.3 Site 3

No lampreys were recorded at Site 3 in a surveyed area of 3 m^2. The substrate at this location and extending out into the proposed dredge area comprised large particles. Boulder was the main substrate component at area sampled and depth increased rapidly away from the wall towards the Abbey River Weir. This site was strongly influenced by the flow of the Abbey River and deposition rates of fine particles is therefore low. It was not possible to maintain station within the proposed dredge area at Site 3. There are no optimal habitats in the area to be dredged at this location and lampreys are unlikely to occur in the area affected.

3.3.2.4 Site 4

A total of 14 lampreys were recorded at Site 4 in a surveyed area of 14 m^2. Two sites covering 5 m^2 were sampled within the proposed dredge area. At one of these (Site 4d), 4 lampreys were recorded in 1 m^2 clay substrate at a depth of 40 cm near the margin of the river. Lower densities in similar habitats at this site were recorded, e.g. subsites 4b (1 / m^2) and 4c (2 / m^2). An area of m^2 (subsite 4f) was sampled within a silt accumulation of ca. 20 m^2 within the proposed dredge area and no lampreys were recorded. This area had a mean depth of 0.5 m and as noted in Section 3.3.1, a high proportion of anoxic leaf litter recorded in the substrate.

The optimal habitats in the area to be dredged at this location can be expected to support lampreys in densities ranging from 0 – 4 / m^2.

3.3.2.5 Site 5 and Site 6

An area of 12 m^2 and 40 m^2 was sampled at Site 5 and Site 6 respectively. Lampreys were not detected at these locations. The substrates at these locations are mainly estuarine clays. It is considered that lampreys do not occur in these areas.



Plate 11 River lamprey ammocoetes (top) and sea lamprey ammocoete (below) from Site 1 (left). European eel, river/brook lamprey, river lamprey and sea lamprey in descending order captured at Site 4 (right).

3.4 Wider study area

3.4.1 Habitats

The habitats of the main channel of the River Shannon and the Abbey River in the environs of the island were assessed with regard to lamprey habitats. A map depicting juvenile lamprey habitats within these river reaches is provided in Figure 11.

3.4.1.1 River Shannon west of King's Island

The main channel of the River Shannon has a bed of mixed substrates, including bedrock. Flow speed along this reach can be considerable at low tide so only the river margins provide conditions where fine sediment can settle in quantities associated with optimal juvenile lampreys. Iinterstitial spaces filled by finer sediment occurs between hard substrates adjacent to the bank of the river, and also in some slower flowing areas away from the thalweg. These areas are characteristic where glide and pool flow features occur at low tide. Areas deemed most suitable for lamprey nursery were typically downstream of features that project into the river (willow *Salix*

sp. trees growing on the verge of the river, slipways and piers) to create backwaters that allow settlement of fine substrates including sand, silt and clay. Based on agitation sampling, the best juvenile lamprey habitats occurred in areas with a high proportion of sand and silt. An extensive area of this habitat occurs at along the RHS margin of the river upstream of Thomond Weir and the LHS margin between Thomond Weir and Thomond Bridge.

It is considered that the possibility of lampreys spawning in this reach of river cannot be completely ruled out, but the chances are very low, diminishing to the south and west towards the greater Shannon Estuary. Furthermore, the potential for lamprey spawning in the subject reach is limited by the generally coarse substrates where suitable flows occur at low tide. The upper end of the subject reach, in the environs of Thomond Weir could perhaps contain some suitable gravels for lamprey spawning, but only during neap tides, this area flooded by spring tides.



Plate 12 Optimal juvenile lamprey habitat near the right bank of the River Shannon upstream of Thomond Weir.



Plate 13 Optimal juvenile lamprey habitat near the left bank of the River Shannon downstream of Thomond Weir.



Plate 14 Optimal lamprey habitats at the lateral margins of the River Shannon between Thomond Bridge and Thomond Weir.



Plate 15 The baths on the LHS of the River Shannon between Thomond Weir and Thomond Bridge. Lamprey ammocoetes were found in sandy substrate (optimal habitat) by agitation sampling.



Plate 16 Lamprey ammocoetes found between Thomond Weir and Thomond Bridge by agitation sampling. River / Brook lamprey (top) and sea lamprey (below) on the left. Sea Lamprey ammocoete posterior end (right).

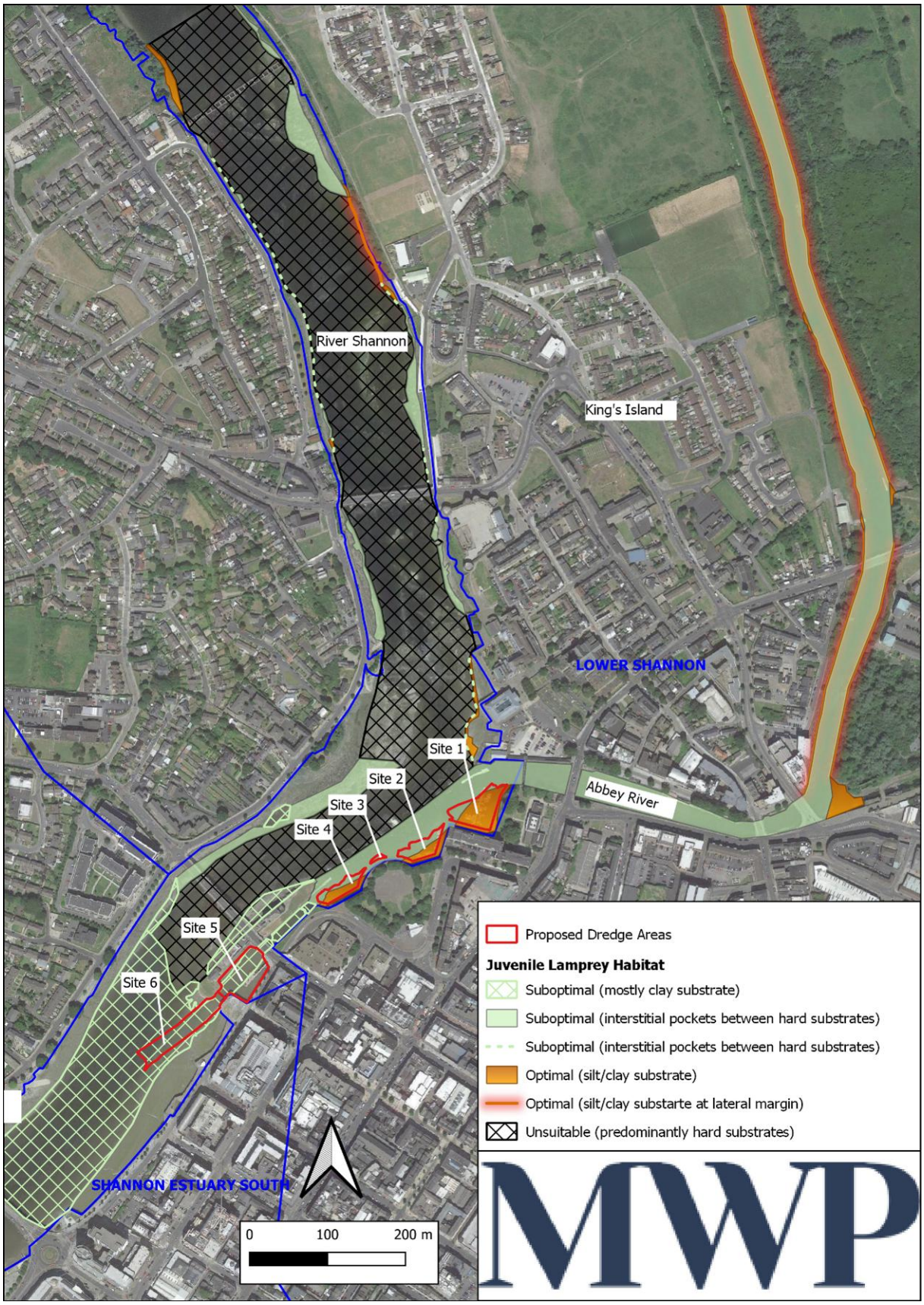

Figure 11 Habitat suitability for juvenile lampreys in the wider study area

3.4.1.2 Abbey River

Flows in the Abbey River are relatively stable and are still influenced by the tide. A large proportion of silt occurs along the side of the channel, exacerbated by the presence of instream willows. Recesses and associated backwaters in Abbey River and margins adjacent to the banks are considered important areas for supporting juvenile lampreys.

The Abbey River is not considered an important reach for lamprey spawning owing to tidal influence and the impact of weir impoundment.



Plate 17 Recesses and associated backwaters in Abbey River and (left) and margins adjacent to the banks (right) are considered important areas for supporting juvenile lampreys. These areas typically comprise soft substate that support ammocoetes.

3.4.1.3 Annacotty

Adult Sea Lampreys were recorded in the Mulkear River at Annacotty on the 17th June 2021. Lampreys are poor swimmers and cannot jump or climb (Reinhardt *et al.,* 2009), so will have significant difficulty getting past a weir that is present at Annacotty. This issue has been well documented in the media (e.g. https://www.irishexaminer.com/news/munster/arid-40255757.html), where the barrier effects of the weir have been highlighted with regard to migratory lampreys. Indeed, during the survey in June 2021, numerous sea lamprey redds were recorded at the end of the pool downstream of the weir. Some redds had clearly been dug on existing redds, therefore reducing the productivity of the 2021 sea lamprey spawning effort in this reach of the river. This competition for spawning areas is a pressure brought about by the weir, which obstructs upstream passage. This annual problem relates to both sea and river lampreys.



Plate 18 Sea lamprey redd (left) and sea lamprey (right) in the Mulkear River at Annacotty on the 17th June.



Plate 19 Lampreys have difficulty swimming over the weir (left) in the Mulkear River at Annacotty. A high density of sea lamprey redds (right) were recorded on the 17th June.



Plate 20 Cluster of Sea Lamprey redds in one area below Annacotty Weir (left). Lethargic Sea Lamprey after spawning (right) – lampreys die soon after spawning.

3.4.2 Lamprey populations

During the 2018 presence absence agitation sampling survey, lampreys were detected at Site 1 and Site 2. Lampreys were not detected at Site 6 at this time.

During the 2021 agitation sampling survey in the River Shannon between Thomond Weir, lampreys were detected at Site RS1 (N = 5, mean depth = 0.7 m), Site RS2 (N = 3, mean depth = 0.2 m) and RS3 (N = 11, mean depth = 0.7 m) in areas of 0.4 m^2, 0.3 m^2 and 0.3 m^2 respectively. The corresponding densities were 13, 10 and 37 lampreys / m^2. These lampreys were found in habitats consisting mostly of sand and silt.

3.5 Other fish

Other fish encountered during the surveys were European eel *Anguilla Anguilla,* flounder *Platichthys flesus*, goby *Gobius* sp. perch *Perca fluviatilis,* three-spined stickleback *Gasterosteus aculeatus*. Table 7 lists the length statistics of other fish recorded during the surveys.

European eel occurs less frequently than lampreys and showed preference to vegetated areas and larger substrate sizes. The European eel is subject to European Council Regulation 1100/2007 'Establishing measures for the recovery of the stock of European eel'. European eel is listed as 'Critically endangered' and is now 'Red Listed' according to 'Red List No. 5: Amphibians, Reptiles & Freshwater Fish' (King *et al*. 2011).

Flounder was found throughout Site 1 – Site 6 whereas goby was restricted to Site 5 and Site 6. Roach and three-spined stickleback were recorded at Site 4.

Table 8 Length statistics of other fish recorded during the surveys

	Perch	Roach	Goby	European eel	Flounder	Three-spined stickleback
Minimum	7	4.2	2.2	6.3	3.6	1.8
Maximum	11.5	9.4	4	27.5	15	2.5
Average	7.9	6.1	3.1	14.4	6.8	2.2
N	8	5	16	18	34	2



Plate 21 Flounder, roach, perch, lamprey and European eel recorded at Site 1h (left). European eel found during dredge sampling (right).

4. Conclusions

Lamprey habitat suitability within the proposed dredge areas decreases from Site 1 to Site 6. It is considered that the weir across the lower end of the Abbey River represents a threshold for juvenile lampreys, with the population in the Shannon and Abbey River restricted to the river reaches upstream of this structure. Lampreys that get carried downstream of the weir possibly perish due to the intermittent saline influence of the Shannon Estuary. Lampreys are considered present only at Sites 1 – 4.

The study area is within the known distribution of brook lamprey but not of migratory river and sea lampreys but these species do occur. There is no suitable spawning habitat at proposed dredge sites and environs. It is considered that the lampreys recorded at the proposed dredge sites and environs drifted downstream from

spawning areas upstream. A significant proportion of the brook/river lampreys could be river lampreys, given that this species have access difficulties on the lower reaches of the Shannon and Mulkear Rivers.

The best habitat for juvenile lampreys at the proposed dredge sites are the shallow margins where there is a high proportion of fine sediment and ample lamprey food. Some of the larger accumulations of clay/silt away from margins had a high organic content but anoxic conditions close to surface. These areas were documented by the marine sediment characterisation undertaken by Aquafact. A site surveyed by Aquafact corresponded with susbsite 4f, which was categorised as 'Grey fine grained anoxic mud with plant material present'. No lampreys were recorded at this location where 4 m^2 were examined. This type of substrate also occurs at the northwestern extent of Site 1 and Site 2. Substrates referred to as 'Dark grey/brown throughout anoxic fine grained mud' were recorded by Aquafact at Site 5 and 6. These anoxic substrates are considered unsuitable for lampreys, but lampreys may occur in low densities where these substrates occur at Sites 1 -4. Based The dredge samples taken in deeper slow flowing and deeper areas of standing water were found to consist of fine-grained mud. on the sample effort, it is considered that these deeper areas are not important for juvenile lampreys and that if lamprey occur in these areas, density is low. A deep area (2.5m) surveyed by dredge at Site 1a was found to comprise gravels, this attribute to fast flow.

Parts of the Abbey River that experience strong flows lack suitable substrates and are therefore unsuitable for ammocoetes. Flows in the Abbey River are highly dependent on ESB regulation, and also governed by fluvial conditions other rivers that feed the lower Shannon. This can have a scouring effect on substrates rendering them unsuitable for juvenile lampreys.

To conclude, the proposed dredge areas:

- do support juvenile lampreys but densities are considered low
- support sea lamprey and river lamprey, with brook lamprey likely comprising a significant fraction of lampreys
- are at the downstream limit of juvenile lamprey distribution in the River Shannon
- downstream of the Abbey Weir / Sarsfield are not considered to support lampreys.

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Appendix 1

Survey Site Characteristics

Site	Subsite	Coordinate		Mean depth	Max depth	Area m2	Boulder (%)	Cobble (%)	Coarse gravel (%)	Fine gravel (%)	Sand (%)	Silt (%)	Clay (%)	Pool %	Glide%	Instream vegetation (%)	Detritus cover (%)	Slope
		x	y															
Site 1	1a	557718	657436	0.1	0.35	1	0	20	0	10	20	25	25	100	0	10	0	30
Site 1	1b	557718	657438	0.2	0.5	1	0	50	0	5	5	20	20	100	0	10	0	30
Site 1	1c	557718	657435	0.1	0.3	1	0	0	0	0	0	50	50	100	0	10	0	5
Site 1	1d	557718	657434	0.1	0.3	1	0	0	0	0	0	50	50	100	0	10	0	5
Site 1	1e	557732	657471	0.3	0.4	1	0	30	30	10	10	10	10	100	0	5	0	10
Site 1	1f	557714	657468	0.9	1	1	0	20	70	0	10	0	0	0	100	0	0	0
Site 1	1g	557719	657470	1	1.1	1	0	0	0	50	40	10	0	50	50	0	0	0
Site 1	1h	557710	657449	0.7	0.7	4	0	0	0	0	0	40	60	100	0	10	0	0
Site 1	1i	557704	657443	0.7	0.7	4	0	0	0	0	0	40	60	100	0	0	0	0
Site 1	1j	557705	657432	0.7	1	6	0	0	0	0	0	20	80	100	0	15	10	0
Site 1	1k	557692	657416	0.45	0.8	3	0	0	0	0	0	10	90	100	0	30	0	15
Site 1	1l	557674	657430	0.5	0.6	3	0	0	0	0	0	10	90	100	0	50	0	5
Site 2	2a	557652	657420	0.8	0.8	1	0	0	0	0	0	10	90	100	0	15	0	5
Site 2	2b	557642	657396	0.5	0.5	1	0	0	0	0	0	5	95	100	0	30	0	0
Site 2	2c	557625	657382	0.2	0.4	1.5	0	0	0	0	0	20	80	100	0	60	5	15
Site 2	2d	557619	657380	0.65	0.7	1	0	0	0	0	0	10	90	100	0	100	0	0
Site 3	3a	557560	657373	0.4	0.8	3	85	0	0	0	0	0	15	100	0	30	0	40
Site 4	4a	557533	657337	0.3	0.4	16	0	0	0	0	0	5	95	100	0	50	0	5

Site	Subsite	Coordinate		Mean depth	Max depth	Area m2	Boulder (%)	Cobble (%)	Coarse gravel (%)	Fine gravel (%)	Sand (%)	Silt (%)	Clay (%)	Pool %	Glide%	Instream vegetation (%)	Detritus cover (%)	Slope
		x	y															
Site 4	4b	557530	657336	0.7	0.7	1	0	0	0	0	0	5	95	100	0	50	0	10
Site 4	4c	557524	657335	0.4	0.4	1	0	0	0	0	0	5	95	100	0	30	0	5
Site 4	4d	557504	657327	0.4	0.4	1	0	0	0	0	0	5	95	100	0	20	0	5
Site 4	4e	557497	657323	0.2	0.25	1.5	0	0	0	0	0	5	95	100	0	25	0	5
Site 4	4f	557504	657336	0.5	0.6	4	0	0	0	0	0	5	95	100	0	60	5	5
Site 5	5a	557410	657265	1.9	1.9	1	0	5	55	35	5	0	0	100	0	0	0	0
Site 5	5b	557411	657247	0.1	0.3	1	0	0	0	0	0	0	100	100	0	0	0	0
Site 5	5c	557405	657244	0.6	0.6	1	0	0	0	0	0	0	100	100	0	0	0	0
Site 5	5d	557398	657263	0.1	0.1	1	0	0	0	0	0	0	100	100	0	0	0	0
Site 5	5e	557396	657261	0.05	0.08	1	0	0	0	0	0	0	100	100	0	0	0	0
Site 5	5f	557390	657239	1	1	1	0	0	0	0	0	0	100	100	0	0	0	0
Site 5	5g	557383	657228	1	1	1	0	0	0	0	0	0	100	100	0	0	0	0
Site 5	5h	557377	657227	0.8	0.8	1	0	0	0	0	0	0	100	100	0	0	0	0
Site 5	5i	557373	657216	1.1	1.1	1	0	0	0	0	0	0	100	100	0	0	0	0
Site 5	5j	557367	657223	0.25	35	1	0	0	0	0	0	0	100	100	0	0	0	0
Site 5	5k	557371	657213	0.9	0.9	1	0	0	0	0	0	0	100	100	0	0	0	0
Site 5	5l	557368	657206	0.9	0.9	1	0	0	0	10	0	0	90	100	0	0	0	0
Site 6	6a	557362	657184	0.3	0.5	3	35	35	10	5	0	0	15	100	0	0	0	0
Site 6	6b	557362	657183	0.3	0.35	2	50	20	15	0	0	0	15	100	0	0	0	20
Site 6	6c	557359	657181	0.3	0.35	2	10	20	15	5	0	0	50	100	0	0	0	15

Site	Subsite	Coordinate		Mean depth	Max depth	Area m2	Boulder (%)	Cobble (%)	Coarse gravel (%)	Fine gravel (%)	Sand (%)	Silt (%)	Clay (%)	Pool %	Glide%	Instream vegetation (%)	Detritus cover (%)	Slope
		x	y															
Site 6	6d	557346	657165	0.2	0.25	1	15	20	20	10	0	0	35	100	0	0	0	5
Site 6	6e	557340	657151	0.3	0.25	3	10	20	20	0	0	0	50	100	0	0	0	0
Site 6	6f	557340	657134	0.15	0.2	4	0	0	0	0	0	0	100	100	0	0	0	5
Site 6	6g	557328	657117	0.25	0.25	4	0	0	0	0	0	0	100	100	0	0	0	0
Site 6	6h	557311	657116	0.05	0.01	5	0	0	0	0	0	0	100	100	0	0	0	5
Site 6	6v	557345	657174	0.7	0.7	1	0	10	0	0	0	0	90	100	0	0	0	0
Site 6	6i	557311	657084	0.05	.03	2	0	0	0	0	0	0	100	100	0	0	0	0
Site 6	6j	557347	657200	0.15	0.15	1	0	5	0	0	0	0	95	100	0	0	0	0
Site 6	6w	557346	657179	0.9	0.9	1	0	0	0	0	0	0	100	100	0	0	0	0
Site 6	6k	557347	657194	0.2	0.4	1	0	15	10	0	0	0	75	100	0	0	0	0
Site 6	6l	557339	657193	0.35	0.5	1	0	0	0	0	0	0	100	100	0	0	0	0
Site 6	6m	557338	657191	0.6	0.6	1	0	0	0	0	5	5	90	100	0	0	0	0
Site 6	6n	557326	657164	1	1	1	0	0	0	0	5	15	80	100	0	0	0	0
Site 6	6o	557311	657164	1.7	1.7	1	0	0	5	15	10	10	60	100	0	0	0	0
Site 6	6p	557313	657158	1.5	1.5	1	0	25	25	25	25	0	0	100	0	0	0	0
Site 6	6q	557313	657153	1.1	1.1	1	0	0	0	0	0	0	100	100	0	0	0	0
Site 6	6r	557291	657138	2.5	2.5	1	0	0	0	0	0	0	100	100	0	0	0	0
Site 6	6s	557287	657133	1.7	1.7	1	0	15	50	30	5	0	0	100	0	0	0	0
Site 6	6t	557257	657121	1.8	1.8	1	0	5	35	40	20	0	0	0	100	0	0	0
Site 6	6u	557272	657108	1.3	1.3	1	0	15	10	25	0	0	50	100	0	0	0	0

Appendix 2

Fish Lengths and Statistics

Table 9 Fish Lengths

Site	Subsite	species	length cm
1	1a	River lamprey	8.5
1	1a	River/brook lamprey	7.0
1	1a	Sea lamprey	6.7
1	1b	River lamprey	7.3
1	1b	Eel	8.0
1	1c	River/brook lamprey	6.2
1	1c	River/brook lamprey	10.1
1	1c	River lamprey	6.7
1	1d	River/brook lamprey	8.1
1	1d	River/brook lamprey	7.3
1	1d	River/brook lamprey	8.2
1	1d	Sea lamprey	7.5
1	1e	Eel	12.5
1	1e	Eel	10.3
1	1f	Eel	25.0
1	1g	River/brook lamprey	8.2
1	1h	Flounder	7.5
1	1h	Eel	27.5
1	1h	Roach	5.7
1	1h	River/brook lamprey	7.4
1	1h	Roach	6.5
1	1h	Perch	7.0
1	1h	River/brook lamprey	6.0
1	1h	Perch	7.8
1	1i	Flounder	7.3
1	1i	Perch	7.0
1	1i	River/brook lamprey	8.2
1	1j	River lamprey	10.2
1	1j	Flounder	13.5
1	1k	River lamprey	8.3
1	1k	Eel	6.6
1	1k	River/brook lamprey	8.7
1	1l	Eel	23.0
1	1l	Eel	12.5
1	1l	Flounder	11.3
1	1l	Flounder	7.2
4	2a	No fish	0.0
4	2b	Perch	11.5
2	2c	River/brook lamprey	5.5

Site	Subsite	species	length cm
2	2c	River/brook lamprey	7.2
4	2d	Eel	22.0
3	3a	Eel	23.0
3	3a	Eel	15.0
3	3a	Eel	18.5
3	3a	Perch	7.6
3	3a	Perch	7.0
3	3a	Perch	8.5
4	4a	River lamprey	9.3
4	4a	River lamprey	9.0
4	4a	River/brook lamprey	9.4
4	4a	Eel	9.3
4	4a	Sea lamprey	8.6
4	4a	River/brook lamprey	8.0
4	4a	Eel	7.5
4	4a	River/brook lamprey	8.3
4	4a	River/brook lamprey	7.0
4	4a	Eel	7.0
4	4b	River/brook lamprey	7.2
4	4c	River/brook lamprey	9.1
4	4c	River/brook lamprey	7.6
4	4d	River/brook lamprey	8.0
4	4d	River/brook lamprey	9.0
4	4d	River/brook lamprey	8.6
4	4d	Eel	6.3
4	4d	River/brook lamprey	7.9
4	4e	River/brook lamprey	8.0
4	4e	River/brook lamprey	9.1
4	4e	Eel	12.5
4	4e	Roach	9.4
4	4e	River/brook lamprey	6.8
4	4e	Sea lamprey	9.2
4	4e	River/brook lamprey	7.5
4	4e	River/brook lamprey	9.1
4	4e	River/brook lamprey	8.8
4	4e	River/brook lamprey	7.8
4	4f	3 spined stickleback	2.5
4	4f	3 spined stickleback	1.8
5	5b	Flounder	6.8
5	5b	Flounder	4.0
5	5b	Flounder	4.2

Site	Subsite	species	length cm
5	5c	Flounder	4.9
5	5d	Flounder	7.3
5	5e	Flounder	6.2
5	5e	Goby	2.9
5	5e	Goby	2.8
5	5e	Goby	3.1
5	5j	Goby	3.3
5	5j	Flounder	8.0
5	5j	Flounder	6.6
5	5j	Goby	3.2
4	6a	Flounder	6.5
4	6a	Flounder	6.6
4	6a	Eel	13.0
4	6a	Flounder	5.5
4	6b	Flounder	7.6
4	6b	Flounder	7.0
4	6b	Flounder	5.7
4	6c	Goby	3.6
4	6c	Flounder	15.0
4	6c	Flounder	6.6
4	6c	Flounder	4.8
4	6c	Flounder	6.5
4	6d	Perch	7.1
4	6d	Roach	4.2
4	6d	Flounder	6.6
4	6e	Flounder	6.5
4	6e	Goby	3.0
4	6f	Flounder	3.6
4	6g	Flounder	4.6
4	6g	Flounder	6.5
4	6g	Goby	4.0
4	6h	Flounder	6.5
4	6i	Roach	4.8
4	6i	Goby	3.0
4	6i	Goby	2.5
4	6i	Goby	3.2
4	6i	Goby	2.2
4	6i	Goby	3.3
4	6i	Goby	3.0
6	6j	Flounder	5.5
6	6j	Goby	3.1

Site	Subsite	species	length cm
6	6k	Flounder	7.5
6	6k	Flounder	6.5
6	6l	Flounder	4.5
6	6l	Goby	2.9
6	6l	Flounder	7.5

Table 10 Fish Statistics

Site	Subsite	Area (m^2)	River lamprey	River/brook lamprey	Sea lamprey	Total lampreys (river, brook and sea)	Density of lampreys	European eel	Flounder	Roach	Perch	3 spined stickleback	Goby
Site 1	1a	1	1	1	1	3	3						
Site 1	1b	1	1			1	1	1					
Site 1	1c	1	1	2		3	3						
Site 1	1d	1		3		3	3						
Site 1	1e	1			1	1	1						
Site 1	1f	1				0	0	2					
Site 1	1g	1				0	0	1					
Site 1	1h	4		2		2	0.5	1	1	2	2		
Site 1	1i	4		1		1	0.25		1		1		
Site 1	1j	6	1			1	0.17		1				
Site 1	1k	3	1	1		2	0.67	1					
Site 1	1l	3				0	0	2	2				
Site 2	2a	1				0	0						
Site 2	2b	1				0	0				1		
Site 2	2c	1.5		2		2	1.33						
Site 2	2d	1				0	0	1					
Site 3	3a	3				0	0	2			2		
Site 4	4a	16	2	4	1	7	0.44						

Site	Subsite	Area (m^2)	River lamprey	River/brook lamprey	Sea lamprey	Total lampreys (river, brook and sea)	Density of lampreys	European eel	Flounder	Roach	Perch	3 spined stickleback	Goby
Site 4	4b	1		1		**1**	1						
Site 4	4c	1		2		**2**	2						
Site 4	4d	1		4		**4**	4	1					
Site 4	4e	1.5		6	1	**7**	4.67	1		1			
Site 4	4f	4				**0**	0					2	
Site 5	5a	1				**0**	0						
Site 5	5b	1				**0**	0		3				
Site 5	5c	1				**0**	0		1				
Site 5	5d	1				**0**	0		1				
Site 5	5e	1				**0**	0		1				3
Site 5	5f	1				**0**	0						
Site 5	5g	1				**0**	0						
Site 5	5h	1				**0**	0						
Site 5	5i	1				**0**	0						
Site 5	5j	1				**0**	0		2				2
Site 5	5k	1				**0**	0						
Site 5	5l	1				**0**	0						
Site 6	6a	3				**0**	0	1	3				
Site 6	6b	2				**0**	0		3				
Site 6	6c	2				**0**	0		4				1
Site 6	6d	1				**0**	0		1	1	1		
Site 6	6e	3				**0**	0		1				1
Site 6	6f	4				**0**	0		1				

Site	Subsite	Area (m^2)	River lamprey	River/brook lamprey	Sea lamprey	Total lampreys (river, brook and sea)	Density of lampreys	European eel	Flounder	Roach	Perch	3 spined stickleback	Goby
Site 6	6g	4				0	0		2				1
Site 6	6h	5				0	0		1				
Site 6	6v	1				0	0						
Site 6	6i	2				0	0			1			6
Site 6	6j	1				0	0		1				1
Site 6	6w	1				0	0						
Site 6	6k	1				0	0		2				
Site 6	6l	1				0	0		2				1
Site 6	6m	1				0	0						
Site 6	6n	1				0	0						
Site 6	6o	1				0	0						
Site 6	6p	1				0	0						
Site 6	6q	1				0	0						
Site 6	6r	1				0	0						
Site 6	6s	1				0	0						
Site 6	6t	1				0	0						
Site 6	6u	1				0	0						