Aquatic and fisheries assessment of Croagh wind farm, Drumkeeran, Co. Leitrim

Prepared by Triturus Environmental Ltd. for McCarthy Keville O' Sullivan

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Non-technical summary

- In order to collate baseline fisheries information, Triturus Environmental Ltd. were contracted by McCarthy Keville O' Sullivan to undertake both a catchment-wide electro-fishing, white-clawed crayfish and Q-sampling survey of watercourses within the footprint of the proposed Croagh wind farm development near Drumkeeran, Co. Leitrim. A total of *n*=21 sites were electro-fished across the Killanummery, Argina, Tullynascreena and Owengar rivers as well as numerous unnamed tributaries over the course of Monday 19th – Wednesday 21st August 2019. Biological water quality was analysed (via Q-sampling) at *n*=13 sites.

- A total of *n*=112 fish across five species were recorded via electro-fishing. Brown trout were the dominant species overall accounting for 92% of the total catch, followed by small numbers of Atlantic salmon, stone loach and minnow. Only one site (A7, Killanummery Stream) produced species other than brown trout and this was the only site to support Atlantic salmon at the time of survey. European eel was not recorded from any site.

- Lamprey (*Lampetra* spp.) were not recorded during the survey, with all bar one site (A7) considered generally unsuitable for the species in terms of both nursery and spawning habitat. Typically, survey sites were too high-energy to support lamprey larvae or adult spawning.

- A total of *n*=12 (57%) electro-fishing sites did not support resident fish (any species) at the time of survey. These sites were located in more upland areas and invariably featured high-energy flows exposed to regular spate conditions, often flowing over moderate to steep gradients. Upstream fish access for salmonids was difficult or blocked entirely due to such physical characteristics in several cases e.g. sites A1, A2, A3, C1, C2 etc. Some did offer some low suitability for European eel, however, despite their absence at the time of survey.

- No white-clawed crayfish were recorded via trapping or sweep netting surveys across a total of *n*=24 sites in the footprint of Croagh wind farm. However, crayfish remains were recorded in otter spraint under bridges at sites A7 on the Killanummery Stream and site D3 on the Rathgeean River. The majority of sites were considered unstainable for the species.

- The biological water quality (Q-sampling) of the majority of *n*=13 sampled sites was Q3 (poor status, moderately polluted). Only a single site (A7, Killanummery Stream) achieved good status Q4 water quality as required under the Water Framework Directive (2000/60/EC). Site C1 on the upper Owengar River achieved a water quality of Q3-4 (slightly polluted).

- Overall, the watercourses with the highest value for fish species were the lower survey reaches of the Killanummery, Argina, Tullynascreena and Owengar rivers. Over half of the survey sites were on upland, eroding watercourses and featured higher gradients and higher flows not conducive to supporting resident salmonids, European eel, lamprey or white-clawed crayfish. Peat-escapement and afforestation pressures from the upland Croagh catchment may be impacting the overall fisheries value of channels downstream.

1. Introduction

1.1 Project background

Triturus Environmental Ltd. were contracted by McCarthy Keville O' Sullivan (MKO) to conduct a fisheries assessment along numerous watercourses in the footprint of the proposed Croagh wind farm near Drumkeeran, Co. Leitrim. The watercourses in question included the Killanummery, Argina, Tullynascreen and Owengar rivers as well as several unnamed channels.

In order to gain an accurate overview of the existing and potential fisheries value of the riverine watercourses within the footprint of the proposed wind farm, a catchment-wide electro-fishing survey across *n*=21 sites was undertaken (see Figure 1.1, Table 1.1 below). Electro-fishing helped to identify the importance of the watercourses as nurseries and habitats for salmonids, lamprey and European eel (*Anguilla anguilla*), as well as other species, and helped to further inform mitigation for the wind farm development.

In addition to fish stock assessments, surveys were also carried out for white-clawed crayfish (*Austropotamobius pallipes*) across all sites (under licence). Macro-invertebrate Q-sampling was undertaken at *n*=13 sites across the wider catchment to infer water quality.

Triturus Environmental Ltd. made an application under Section 14 of the Fisheries (Consolidation) Act, 1959 as substituted by Section 4 of the Fisheries (Amendment) Act, 1962, to undertake a catchment-wide electro-fishing survey in the footprint of the proposed Croagh wind farm located near Drumkeeran, north Co. Leitrim. Permission was granted on Tuesday 17th August 2019 and the survey was undertaken over Monday 19th – Wednesday 21st August 2019. Triturus also hold a national open license to survey for white-clawed crayfish (license no. C180/2019).

1.2 Croagh catchment and fisheries asset

The Croagh wind farm development encompasses numerous small streams and rivers in north Leitrim, primarily on the Killanummery, Argina, Tullynascreen and Owengar river sub-catchments. Many of these watercourses drained upland areas. Primarily, watercourses within the wider catchment flowed over dark grey shale and minor sandstones in upland areas, with carboniferous shale and occasional limestone in more lowland areas according to Geological Survey of Ireland online data (GSI, 2019).

The Tullynascreen Stream, a tributary of the Killanummery Stream was assessed as an "*intermediate stream, may be at risk*" based on Small Streams Risk Score (SSRS) conducted by Inland Fisheries Ireland in 2016 (IFI, 2016). The Tullynascreen was also identified as having unsatisfactory (Q3, moderate status) water quality by the EPA in 2015 (EPA, 2019). The Killanummery Stream, however, achieved a high status water quality (Q4-5) in 2018 (EPA, 2019). The Owengar River achieved a Q4 good status rating in 2017 according to EPA data.

Fisheries data for the Killanummery, Argina, Tullynascreen and Owengar river sub-catchments was largely lacking. A range of fish species including Atlantic salmon (*Salmo salar*), brown trout (*Salmo trutta*), European eel, stone loach (*Barbatula barbatula*), minnow (*Phoxinus phoxinus*), *Lampetra* spp., perch (*Perca fluviatilis*), gudgeon (*Gobio gobio*), three-spined stickleback (*Gasterosteus aculeatus*), roach (*Rutilus rutilus*) and pike (*Esox lucius*) are known from the wider Bonet catchment, to which the Killanummery adjoins (IFI, 2016; Kelly et al., 2011). White-clawed crayfish (*Austropotamobius pallipes*) are also know from the lower reaches of the Killanummery Stream (IFI, 2016). Natural barriers likely preclude many non-salmonid species from the upper Killanummery. The Owengar River is known locally to support a stock of brown trout. Fisheries data was not available for the Argina and Tullynascreen channels.

Table 1.1 Location of *n*=21 electro-fishing survey sites and *n*=3 fisheries appraisal sites within the footprint of the proposed Croagh wind farm, Drumkeeran, Co. Leitrim. (*sites D1, D2 & D3 are Q-sampling sites only)

Site no.	Watercourse & location	X (ITM)	Y (ITM)
Electro-fishing Sites			
A1	Killanummery Stream, Corratimore Glebe	586302	824682
A2	Unnamed stream, Garvagh Glebe	584829	823916
A3	Unnamed stream, Garvagh Glebe	584180	824297
A4	Killanummery Stream, Garvagh Glebe	583719	825138
A5	Killanummery Stream, Corglancey	582125	825961
A6	Killanummery Stream, Carrigeen	580246	827162
A7	Killanummery Stream, Killanummery	580137	828203
A8	Tullynascreen Stream, Garvagh Glebe	583602	823481
A9	Tullynascreen Stream, Garvagh Glebe	583315	823880
A10	Tullynascreen Stream, Tullynascreen	582071	824790
B1	Argina River, Garvagh Glebe	585122	822889
B2	Unnamed stream, Carrowmore	584586	822633
B3	Unnamed stream, Carrowmore	585047	822443

Site no.	Watercourse & location	X (ITM)	Y (ITM)
Electro-fishing Sites			
B4	Argina River, Carrowmore	585546	821996
B5	Argina River, Carrownadargny	585949	821229
B6	Unnamed stream, Boleymaguire	586634	821263
B7	Unnamed stream, Boleymaguire	586884	821086
B8	Argina River, Boleymaguire	586350	820949
C1	Owengar River, Knocknacosta	587611	823438
C2	Unnamed stream, Knocknacosta	587599	823415
C3	Owengar River, Camalt	589159	823317
Fisheries Appraisal Sites			
D1	Greaghnafarna River, Greaghnafarna	579776	825143
D2	Unnamed stream, Rathrower	578416	825170
D3	Rathgeean River, Drumee	576787	825036

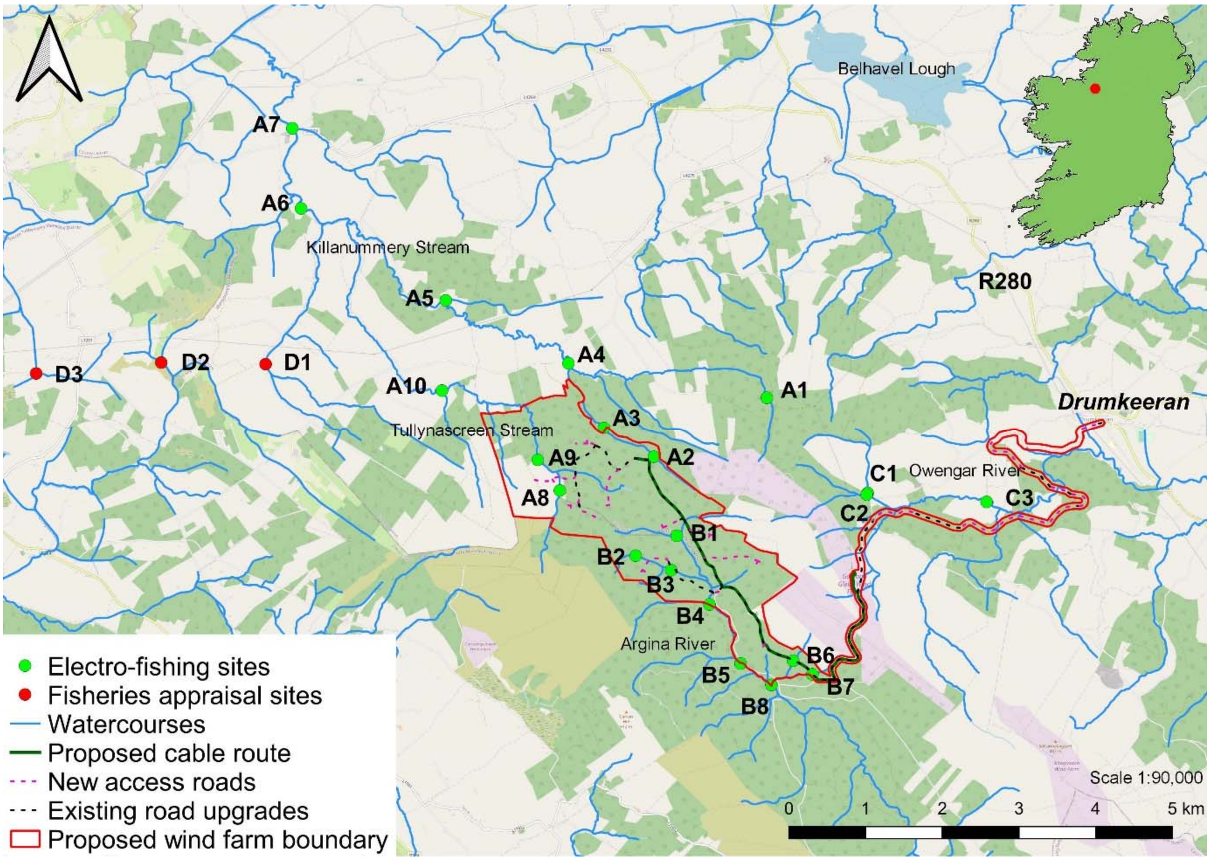

Figure 1.1 Location of the *n*=21 electro-fishing survey sites & *n*=3 fisheries appraisal sites surveyed in August 2019 in the footprint of the proposed Croagh wind farm, Drumkeeran, Co. Leitrim

Table 1.2 Location of *n*=13 Q-sampling sites within the footprint of the proposed Croagh wind farm, Drumkeeran, Co. Leitrim.

Site no.	Watercourse & location	X (ITM)	Y (ITM)
A1	Killanummery Stream, Corratimore Glebe	586302	824682
A2	Unnamed stream, Garvagh Glebe	584829	823916
A4	Killanummery Stream, Garvagh Glebe	583719	825138
A7	Killanummery Stream, Killanummery	580137	828203
A8	Tullynascreen Stream, Garvagh Glebe	583602	823481
B1	Argina River, Garvagh Glebe	585122	822889
B3	Unnamed stream, Carrowmore	585047	822443

Site no.	Watercourse & location	X (ITM)	Y (ITM)
B8	Argina River, Boleymaguire	586350	820949
C1	Owengar River, Knocknacosta	587611	823438
C3	Owengar River, Camalt	589159	823317
D1	Greaghnafarna River, Greaghnafarna	579776	825143
D2	Unnamed stream, Rathrower	578416	825170
D3	Rathgeean River, Drumee	576787	825036

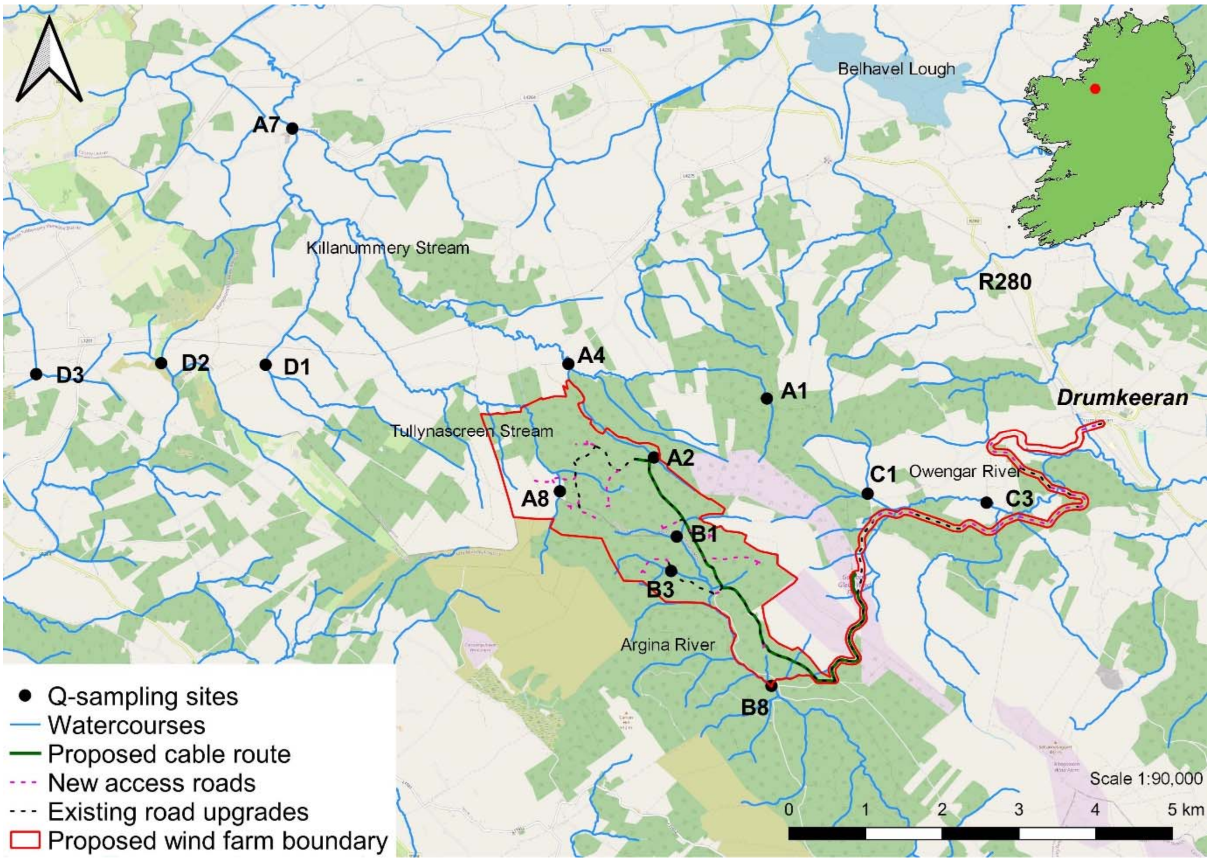

Figure 1.2 Location of the *n*=13 Q-sampling sites surveyed in August 2019 in the footprint of the proposed Croagh wind farm, Drumkeeran, Co. Leitrim

2. Methodology

2.1 Desktop review

A desktop review of the available fisheries-related data for the Killanummery, Argina and Owengar river sub-catchments was undertaken. These included consultations with Inland Fisheries Ireland, local landowners and anglers. Data records held by the National Biodiversity data Centre (NBDC) and National Parks & Wildlife Service (NPWS) were also reviewed.

2.2 Fish stock assessment (electro-fishing)

A-state-of-the-art single anode Smith-Root LR24 backpack (12V DC input; 300V, 100W DC output) was used to electro-fish sites along the Killanummery, Argina, Tullynascreen and Owengar rivers as well as several unnamed tributaries over the course of Monday 19th – Thursday 22nd August 2019, under the conditions of a Department of Communications, Climate Action & Environment (DCCAE) license. Both river and holding tank water temperature was monitored continually throughout the survey to ensure temperatures of 20°C were not exceeded, thus minimising stress to the captured fish due to low dissolved oxygen levels. A portable battery-powered aerator was also used to further reduce stress to any captured fish contained in the holding tank.

Salmonids, European eel and other captured fish species were transferred to a holding container with oxygenated fresh river water following capture. All captured fish were anaesthetised using 0.5ml/l clove oil solution (emulsified in ethanol at a ratio of 1:9), measured to the nearest millimetre and released in-situ following a suitable recovery period.

As three primary species groups were targeted during the survey, i.e. salmonids, lamprey, and eel/cyprinids, the electro-fishing settings were tailored for each species. By undertaking electro-fishing using the rapid electro-fishing technique (see methodology below), the broad characterisation of the fish community at each sampling reach could be determined as a longer representative length of channel can be surveyed. Electro-fishing methodology followed accepted European standards (CEN, 2003) and is outlined below.

The catchment-wide electro-fishing (CWEF) survey was undertaken across *n*=21 sites (see Table 1.1, Figure 1.1). Length frequency graphs and species composition graphs for all species with numbers captured are illustrated in the Results section.

Salmonids, European eel & cyprinids

For salmonid species and European eel, as well as other incidental cyprinid species such as three-spined stickleback (*Gasterosteus aculeatus*) and minnow (*Phoxinus phoxinus*), electro-fishing was carried out in an upstream direction for a 10-minute CPUE, an increasingly common standard approach for wadable streams (Matson et al., 2018). A total of approx. 100-150m channel length was surveyed at each site, where feasible, in order to gain a better representation of fish stock assemblages.

Relative conductivity of the water at each site was checked in-situ with a conductivity meter and the electro-fishing backpack was energised with the appropriate voltage and frequency to provide enough draw to attract salmonids and European eel to the anode without harm. For the low to moderate conductivity waters of the Croagh upland sites (most draining uplands and blanket bog) a voltage of 250-300V, frequency of 40-45Hz and pulse duration of 3.5ms was utilised to draw fish to the anode without causing physical damage.

Lamprey species

Electro-fishing for lamprey ammocoetes was conducted using targeted box quadrat-based electro-fishing (as per Harvey & Cowx, 2003) in objectively suitable areas of sand/silt, where encountered. As lamprey take longer to emerge from silts and require a more persistent approach, they were targeted at a lower frequency (30Hz) setting which also allowed detection of European eel, if present. Settings for lamprey followed those recommended and used by Harvey & Cowx (2003), APEM (2004) and Niven & McAuley (2013). Using this approach, the anode was placed under the water's surface, approx. 10–15 cm above the sediment, to prevent immobilising lamprey ammocoetes within the sediment. The anode was energised with 100V of pulsed DC for 15-20 seconds and then turned off for approximately five seconds to allow ammocoetes to emerge from their burrows. The anode was switched on and off in this way for approximately two minutes. Immobilised ammocoetes were collected by a second operator using a fine-mesh hand net as they emerged.

Lamprey species would be identified to species level where possible if captured, with the assistance of a hand lens, through external pigmentation patterns and trunk myomere counts as described by Potter & Osborne (1975) and Gardiner (2003).

2.3 Fisheries habitat assessment

Salmonids

Fisheries habitat quality for salmonids was assessed using the Life Cycle Unit method (Kennedy, 1984; O'Connor & Kennedy, 2002) to map the *n*=24 riverine sites (*n*=21 electro-fishing sites plus *n*=3 fisheries appraisal sites) as nursery, spawning and holding water, by assigning quality scores to each type of habitat. Those habitats with poor quality substrata, shallow depth and a poorly defined river profile receive a higher score. Higher scores in the Life Cycle Unit method of fisheries quantification are representative of poorer value, with lower scores being more optimal despite this appearing counter-intuitive.

Table 2.1 Life Cycle Unit scoring system for salmonid nursery, spawning and holding habitat value (as per Kennedy, 1984 & O'Connor & Kennedy, 2002)

Habitat quality	Habitat score	Overall score
Poor	4	12
Moderate	3	9-11
Good	2	6-8
Excellent	1	3-5

Lamprey species

An outline of the evaluation of the lamprey importance of the *n*=24[1] sites surveyed in the footprint of Croagh wind farm is provided below, and follows the novel Lamprey Habitat Quality Index (LHQI) scoring system as devised by the authors of this report (manuscript in preparation).

In the absence of a universally accepted lamprey-specific scoring system for overall habitat quality, the LHQI loosely follows the same rationale as the Life Cycle Unit score for salmonids above (Kennedy, 1984; O'Connor & Kennedy, 2002). Those habitats with a lack of soft, largely organic sediment areas for ammocoete burrowing, shallow sediment depth (<10cm) or compacted sediment nature receive a higher score. Higher scores in our improvised method of lamprey fisheries quantification are thus of poorer value (in a similar fashion to the salmonid Life Cycle Unit Index), with lower scores being more optimal despite this appearing counter intuitive. Larval lamprey habitat quality as well as the suitability of adult spawning habitat is assessed based on the information provided in Maitland (2003) and other relevant literature. Unlike the salmonid Life Cycle Unit index, holding habitat for adult lamprey is not assessed owing to their different migratory and life history strategies, and that surveys such as this one routinely only sample larval lamprey.

Incidentally, the LHQI scoring system provides additional information compared to the habitat classification based on the observations of Applegate (1950) and Slade et al. (2003), which deals specifically with larval (sea) lamprey settlement habitat. Under this scheme, habitat is classified into three different types: preferred (Type 1), acceptable (Type 2), and not acceptable for larvae (Type 3) (Slade et al. 2003). Type 1 habitat is characterized by soft substrate materials usually consisting of a mixture of sand and fine organic matter, often with some cover over the top such as detritus or twigs in areas of deposition. Type 2 habitat is characterized by substrates consisting of shifting sand with little if any organic matter and may also contain some gravel and cobble (lamprey may be present but at much lower densities than Type 1). Type 3 habitat consists of materials too hard for larvae to burrow

[1] Note that while electro-fishing was conducted at *n*=21 sites, a fisheries appraisal was conducted for three additional sites (D1, D2 & D3) and thus the LHQI was applied here making up *n*=24 sites.

including bedrock and overly-compacted sediment. This classification can also be broadly applied to other lamprey species ammocoetes.

Table 2.2 Lamprey Habitat Quality Index (LHQI) scoring system for lamprey spawning and settlement habitat value (Macklin et al., 2018), adapted from Kennedy (1984)

Habitat quality	Habitat score	Overall score
Poor	4	8
Moderate	3	6 - 7
Good	2	3 - 5
Excellent	1	2

General fisheries habitat

A broad appraisal / overview of the upstream and downstream habitat at each site was also undertaken to evaluate the wider contribution to salmonid and lamprey spawning and general fisheries habitat. River habitat surveys and fisheries assessments were also carried out utilising elements of the approaches in the River Habitat Survey Methodology (Environment Agency, 2003) and Fishery Assessment Methodology (O'Grady, 2006) to broadly characterise the river sites (i.e. channel profiles, substrata etc.).

2.4 White-clawed crayfish survey

An appraisal of white-clawed crayfish (*Austropotamobius pallipes*) habitat across the *n*=24 riverine sites was undertaken based on trapping, sweep netting and walkover surveys in addition to physical channel attributes. Furthermore, a desktop review of known distributions of crayfish within the wider Croagh catchment was also undertaken.

Crayfish survey (trapping)

The crayfish survey was undertaken under the National Parks and Wildlife (NPWS) under license no. C133/2019, as prescribed by Sections 9, 23 and 34 of the Wildlife Act (1976-2012) to capture and release them to their site of capture under condition no. 7 of the license (see Appendix II). As per Inland Fisheries Ireland recommendations (and as with other surveys conducted e.g. electro-fishing), the crayfish license sampling started at the uppermost site on each river sub-catchment in the study area to minimise the risk of transfer of crayfish plague or invasive species in an upstream direction.

A team of six no. 51 x 20cm, 19mm mesh polypropylene "Trappy" crayfish traps, ballasted with extra rock to prevent excessive movement, were used at each site. Traps were fished in two trains of three and positioned in suitable marginal areas overnight before being retrieved the following morning. Traps were wetted for approx. 12 hours at each site.

Since trapping has been shown to select for larger individuals and possibly introduce a sex-bias (Gallagher, 2006), a subset of the traps (50%) were wrapped with 10mm green garden mesh. Mesh-modified traps have been found to be far more effective at retaining juveniles and therefore result in a higher CPUE (O'Connor et al., 2008). Traps were inspected using the check-clean-dry approach between sites in addition to disinfection with Virkon. New traps were used during the survey that had not been used in other catchments. All traps were baited with 100g of tuna-flavoured cat food placed in fixed proprietary bait cages within each trap. Oily food such as tuna-based products offer greater attractant properties to crayfish because of the oil-scent dispersion (pers. obs.).

Crayfish survey (sweep netting)

Sweep netting (following Reynolds et al., 2010) was utilised at each canal site to detect both adult and juvenile crayfish and assess habitat quality. Biosecurity pond nets were used for all sweep netting and invertebrate sampling. Sweep netting involves sampling of both in-channel macrophytes, in addition to checking typical boulder and cobble refugia. This process involves the lifting of littoral boulders (single boulder considered a single refuge) while the net is swept underneath to trap any crayfish positioned underneath.

Crayfish survey (riparian walkover survey)

Further to physical survey methods, riparian walkover surveys were undertaken to examine any spraint from mustelids (i.e. otters & mink) feeding along riparian corridors, when other sampling techniques (i.e. trapping, sweep netting) returned a zero result. Given that mustelids hunt large areas of river, they can detect cryptic prey, present at low densities, which are not easily attainable via conventional survey methodologies. Whilst not quantitative, riparian walkover/spraint surveys are useful for clarifying the presence of absence of crayfish at a particular site (notably in the wider catchment given the large known territories of male otter in particular ~ 20km).

2.5 Q-sampling (macro-invertebrates)

In order to determine biological water quality across the wider Croagh catchment, the aquatic baseline survey included Q-sampling at *n*=13 sites (see Table 1.2, Figure 1.2). Macro-invertebrate samples were converted to Q-ratings as per Toner et al. (2005) and assigned to WFD status classes (see Table 2.1 below). All riverine samples were taken with a standard kick sampling hand net (250mm width, 500µm mesh size) from areas of riffle/glide utilising a two-minute sample, as per Environmental Protection Authority (EPA) methodology. Large cobble was also washed at each site where present and samples were elutriated and fixed in 70% ethanol for subsequent laboratory identification. Any rare invertebrate species were identified from the NPWS Red List publications for beetles, stoneflies, mayflies and other relevant taxa.

Table 2.1 Reference categories for EPA Q Ratings (Q1 to Q5)

Q Value	WFD Status	Pollution Status	Condition
Q5 or Q4-5	High Status	Unpolluted	Satisfactory
Q4	Good Status	Unpolluted	Satisfactory
Q3-4	Moderate Status	Slightly polluted	Unsatisfactory
Q3 or Q2-3	Poor	Moderately polluted	Unsatisfactory
Q2, Q1-2 or Q1	Bad	Seriously polluted	Unsatisfactory

2.6 Biosecurity protocol

A strict biosecurity protocol was employed during the survey including the Check-Clean-Dry approach as well as the thorough drying (UV exposure) and disinfection of all equipment before and after use with Virkon®, to prevent the transfer of pathogens and/ or invasive species between survey areas. Electro-fishing surveys were undertaken across watercourses in a downstream order to minimise the mobilisation of pathogens and invasive propagules up river catchments. Any aquatic invasive species or pathogens recorded within or adjoining the survey area were geo-referenced and records forwarded to IFI (as part of their typical license conditions).

3. Site descriptions

A brief site summary outlining both instream and adjoining habitats as well as physical characteristics is provided below. Scientific names are provided at first mention only. Habitat codes are given according to Fossitt (2000).

3.1 Site A1 – Killanummery Stream, Corratimore Glebe

Site A1 on the Killanummery Stream represented an upland eroding watercourse (FW1; Fossit, 2000) flowing through an extensive area of upland blanket bog (PB2). The stream was situated in a small valley and was deeply cut into a peat-based U-shaped channel. Averaging 0.2-0.3m deep and just 0.5m wide, the site featured 40% boulder, 20% cobble, 10% coarse gravel with 30% silt substrata. Harder substrata were heavily bedded in peat. The stream had a sinuous natural form with relatively high shading due to its deeply cut profile. Glide habitat predominated (60%) with 30% riffle and localised pools. Instream macrophyte and bryophyte growth was limited to occasional water earwort (*Scapania undulata*) on instream boulders.

The site was bordered by immature lodgepole pine (*Pinus contorta*) plantation (WS2) on north bank with an upland blanket bog riparian buffer of 30-50m grading into mixed age sitka spruce WD4 plantation. Species such as ling (*Calluna vulgaris*) and bilberry (*Vaccinium myrtillus*) were common with a dense moss layer dominated by *Polytrichum* spp. and *Sphagnum* spp. Soft rush (*Juncus effusus*), common polypody (*Polypodium vulgare*) and bramble (*Rubus fructicosus* agg.) were also common.

Plate 3.1 Representative image of site A1, a small upland, high-energy stream situated in upland blanket bog

3.2 Site A2 – Unnamed stream, Garvagh Glebe

Located along a forestry access, site A2 was a small upland eroding watercourse (FW1) flowing in an upland afforested area which supported mature Sitka spruce (*Picea sitchensis*) (WD4) on both banks, with frequent willow (*Salix* spp.) borders. The channel was U-shaped and 0.5-1m wide with a 1m bank height. It was fast flowing and of high energy, flowing over a relatively steep gradient. The stream depth averaged 0.2-0.4m. The channel cascaded over bedrock (10%) with 30% boulder, 20% cobble and 30% coarse gravels. The substrata were compacted and bedded given the high flows. The stream profile was dominated by glide habitat (50%) with 20% riffle and localised pool. The stream changed into a V-shaped valley downstream of the road crossing. Peat deposits were also present.

In addition to sitka spruce, the site was bordered by scrub composed of bracken (*Pteridium aquilinum*) buttercups (*Ranunculus* spp.), bent grasses (*Agrostis* spp.), willow, bramble and rushes (*Juncus* spp.). Instream growth was limited to water earwort on top of instream boulders. The high shading from steep vegetated banks (many undercut) reduced the capacity of the stream to support macrophytes, in addition to its high energy nature.

Plate 3.2 Representative image of site A2, a small, heavily shaded upland, high-energy stream situated in sitka spruce plantations

3.3 Site A3 – Unnamed stream, Garvagh Glebe

Located some 350m downstream from site A2, site A3 was a small upland eroding watercourse (FW1) flowing in an upland afforested area. Peat dominated the substrata (60%) although some limited boulder (10%), cobble (20%) and coarse gravels (10%) were also present in faster flowing areas downstream of the road crossing culvert. Given the high gradient, riffle habitat dominated (40%), with equal proportions of pool and glide. Situated in a natural V-shaped valley, the channel was cut into peat soils forming a sinuous pattern through upland blanket bog. This habitat supported common species such as bilberry, tormentil (*Potentilla erecta*), heath bedstraw (*Galium saxatile*), devil's bit scabious (*Succisa pratensis*), common bent (*Agrostis capillaris*), purple moor grass (*Molinia caerulea*), common knapweed (*Centaurea nigra*) and wild angelica (*Angelica sylvestris*). Mosses such as *Sphagnum* spp., *Polytrichum* spp. and big shaggy-moss (*Rhytidiadelphus triquetrus*) were common on the wet sloping banks adjoining the stream.

There were no instream macrophytes due to the high peat staining and high energy nature of the site although water earwort was present locally on boulders. Some limited marsh horsetail (*Equisetum palustre*) grew on the channel margins. The liverwort overleaf pellia (*Pellia epiphylla*) grew on muddy areas of bank and mossy hummocks supported common liverwort (*Marchantia polymorpha*). A small concrete weir (0.5m fall) with no fish pass was located immediately downstream of the road crossing which hindered fish access upstream.

Plate 3.3 Representative image of site A3 (facing downstream) a small, upland, high-energy stream flowing through upland blanket bog

3.4 Site A4 – Killanummery Stream, Garvagh Glebe

The Killanummery Stream at site A4 was located approx. 1km downstream from site A3. The stream was a small upland eroding watercourse (FW1). The channel was cascading in nature, 2.5-3m wide, 0.2m deep on average and dominated by equal proportions of riffle and glide habitat with localised deeper pool near the bridge (>1.5m deep). The stream flowed over a moderate gradient through a semi-natural V-shaped valley populated by mature treelines of ash, willow, hawthorn (*Crataegus monogyna*) and sycamore (*Acer psuedoplatanus*) adjoined by poor-quality wet grassland (GS4) and semi-improved pasture (GA1) dominated by *Juncus* spp. rushes. The invasive shrub snowberry (*Symphoricarpos albus*) was abundant along riparian corridors. Given the high energy, the substrata were composed primarily of boulder (50%) with cobble (30%) and low fractions of coarse gravels and sand. There was no soft sediment present and the localised sand deposits were bound in peat.

Instream macrophyte and bryophyte growth was sparse given the high energy of the channel and high riparian shading, although some yellow fringe moss (*Racomitrium aciculare*) grew on top of instream boulders alongside water earwort.

Plate 3.4 Representative image of site A4 (facing upstream to road bridge), a medium, cascading high-energy stream

3.5 Site A5 – Killanummery Stream, Corglancey

The Killanummery River at site A5 was an upland eroding channel (FW1) with peat-stained water. The channel width and water width were both 4-5m, with average depths ranging from 0.2m to 0.6m. The channel retained a semi-natural profile with 40% riffle, 40% glide and 20% pool habitats flowing through boulder cascade reaches. The bank height was variable between 1.0m and 2.0m but graded into a V-shaped valley downstream. The substrata were dominated by boulder (20%) and cobble (40%) with smaller quantities of coarse, medium and fine gravel (40% combined). Small areas of sand were present covering 5% by surface area of the substrata between larger substrata.

The riparian habitat comprised semi-mature alder (*Alnus glutinosa*) and ash with bramble, bracken and gorse (*Ulex europaeus*) in the understory. These buffered a of sitka spruce (WD4) plantation for 30m on the south bank. No macrophytes were present given the heavily peat-stained water and high shading (50%) with evident riparian tunnelling. Fountain feather-moss (*Hygroamblystegium tenax*) was locally frequent on submerged boulders with yellow fringed moss on the topsides of boulders. Common water moss (*Fontanalis antipyretica*) was present very locally on large boulders instream. The liverwort water earwort was also present occasionally on the top sides of boulders.

Plate 3.5 Representative image of site A5, a medium, cascading high-energy stream

3.6 Site A6 – Killanummery Stream, Carrigeen

The Killanummery River at site A6 was a lowland spate river (FW2) with heavily peat-stained water at the time of survey. The channel width and water width were both 7-8m wide and the depth ranging between 0.2-1.2m. Bank height was variable between 1.5 and 2m and the channel was broadly U-shaped. The stream retained a semi-natural profile flowing through agricultural grassland (GA1) and the survey section featured a mix of with 30% riffle, 50% deep glide and 20% deeper pool habitats. The substrata were dominated by coarse gravel (40%) and small cobble (50%) with smaller quantities of boulder (5%). Small areas of peat and sand were present in marginal slacks covering 5% by surface area of the substrata. The gravels were, however, bedded in peat with evident heavy siltation and also moderate compaction. Softer sediment areas were also heavily compacted given the relatively high flows.

The riparian habitat comprised herbaceous scrubby margins of nettle (*Urtica dioica*), bramble, creeping thistle (*Cirsium arvense*), hedge woundwort (*Stachys sylvatica*), meadow buttercup (*Ranunculus acris*) with scattered treelines of alder, ash, willow and osier (*Salix viminalis*). Very small patches of brooklime (*Veronica beccabunga*) and water pepper (*Persicaria hydropiper*) grew on gravel shoals in the river margins. A small area of water starwort (*Callitriche* sp.) was also present in a pool slack. No moss species were recorded, likely because of the absence of more stable large cobble and boulder.

Plate 3.6 Representative image of site A6 (facing downstream) on the Killanummery Stream, an upland eroding watercourse flowing through agricultural lands

3.7 Site A7 – Killanummery Stream, Killanummery

Site A7 on the Killanummery Stream was a lowland spate river (FW2) with heavily peat-stained water at the time of survey. It was the furthest site downstream from the proposed wind farm site boundary (approx. 6.5km by water). The channel and water width were both 8-10m wide, with depths ranging from 0.2m to 0.8m. Flow rates were high. The stream channel retained a semi-natural profile with 30% riffle, 50% glide and 20% pool habitats. The bank height was variable between 1.5m and 2.5m. The substrata were dominated by bedrock (40%) and boulder (20%) with smaller quantities of cobble (20%) and coarse gravel (10%). Very small pockets of sand were present representing no more than 1% by area of the substrata. Soft sediment was absent given the spate nature of the channel and typically high flow rates.

The riparian habitat comprised herbaceous scrubby margins, mature hedgerows and treelines. The scrub (WS1) areas comprised great willowherb (*Epilobium hirstutum*), hogweed (*Heracleum sphondylium*), grey willow (*Salix cinerea*), meadow buttercup, creeping buttercup (*Ranunculus repens*), tufted vetch (*Vicia cracca*), bramble, hemp agrimony (*Eupatorium cannabinum*) with bent and cock's foot (*Dactylis glomerata*) grasses. Riparian treelines and hedgerows comprised sycamore, ash, hawthorn and blackthorn (*Prunus spinosa*). Shading was high upstream and downstream of the bridge, with a more open section adjacent to the bridge. No macrophytes were recorded present given the spate nature of the channel and peat-stained water. The moss species *Fontanalis squamosa* was present very locally on submerged boulders, with fountain feather moss characteristically present on the downstream side of boulders. *Pellia* spp. liverworts were present on the muddy margins of the channel.

Plate 3.7 Representative image of site A7 (facing downstream) on the Killanummery Stream, a high-energy spate channel with good suitability for salmonids

3.8 Site A8 – Tullynascreen Stream, Garvagh Glebe

Located on the upper Tullynascreen Stream, a Killanummery Stream tributary, site A8 was a small upland eroding, spate watercourse (FW1) flowing over a moderate to steep gradient through a steep V-shaped valley in upland blanket bog (PB2) habitat. The channel was 1.5-2m wide in a shallow U-shaped channel. Owing to high flow rates, the substrata were heavily bedded, with heavy sedimentation from peat escapement. The stream bed was dominated by cobble (60%) with 20% boulder, 10% gravels and 10% peat. The average depth was 0.2-0.3m with localised deeper plunge pools, especially on meanders. Riffles dominated (80%) with some fast glide and limited pool (20% by surface area for both).

The banks on the Tullynascreen Stream were steep and often undercut through natural erosion. Water was heavily peat-stained given the surrounding habitats. The stream was bordered by scattered sitka spruce and lodgepole pine (WD4) on the east bank with extensive sloping blanket bog with mosaics of wet heath (HH3) on the west. Afforestation was present upstream also. The riparian zone was colonised by abundant bilberry, *Polytrichum* spp. mosses, purple moor grass, tormentil, devil's bit scabious, soft rush, marsh horsetail, *Agrostis* spp. grasses and abundant ling. The channel was largely open as it flowed through the valley, with 30% shading.

Instream macrophyte and bryophyte growth was sparse given the high energy, spate nature of the channel, in addition to shading. Yellow fringe moss along with water earwort was present on top of boulders.

Plate 3.8 Representative image of site A8, a small, narrow, shallow high-energy upland watercourse flowing through upland blanket bog

3.9 Site A9 – Tullynascreen Stream, Garvagh Glebe

Located approx. 0.6km downstream from site A8, site A9 was again represented by a small upland eroding, spate watercourse (FW1) flowing over a moderate to steep gradient through a steep V-shaped valley in upland blanket bog (PB2) habitat. The channel was 1-1.8m wide in a deep U-shaped channel which retained a natural, sinuous profile. Owing to high flow rates, the substrata were heavily bedded, with heavy sedimentation from peat escapement. The stream bed was dominated by cobble (60%) with 20% boulder, 10% gravels and 10% peat. The average depth 0.2-0.3m with localised deeper plunge pools, especially on meanders. Riffles dominated (70%) with some fast glide and pools. Fisheries value was considered better compared to upstream with a greater proportion of pools.

Banks were steep and often undercut through natural erosion. Water was heavily peat-stained given the surrounding peat dominated habitats supporting coniferous plantations. The stream was bordered by scattered sitka spruce and lodgepole pine (WD4) on the east bank with extensive sloping blanket bog with mosaics of wet heath (HH3) on the west. Afforestation was present but not as extensive as upstream. The riparian zone was colonised by abundant bilberry, *Polytrichum* spp. mosses, purple moor grass, tormentil, devil's bit scabious, soft rush, marsh horsetail, *Agrostis* spp. grasses and abundant ling. The channel was largely open as it flowed through the valley, with 20-30% shading.

Instream macrophyte and bryophyte growth was sparse given the high energy, spate nature of the channel, in addition to shading. Yellow fringe moss along with water earwort was present on top of boulders.

Plate 3.9 Representative image of site A9, a small, narrow, shallow high-energy upland watercourse flowing through upland blanket bog

3.10 Site A10 – Tullynascreen Stream, Tullynascreen

Site A10 was located on the Tullynascreen Stream near the Tullynascreen Mass Rock. Here the stream was an upland eroding watercourse (FW1) flowing through a large open natural valley. The channel was U-shaped with often steep, naturally cut banks in peaty soils. The stream was high-energy both upstream and downstream of an adjoining WD4 unnamed stream confluence and dominated by fast riffle and glide with limited pool in a semi-cascading channel. The substrata were dominated by boulder and large cobble (40% overall) with lesser amounts of coarse gravels and some limited peat. The substrata were relatively mobile but their larger sizes reduced value for spawning salmonids.

Poor-quality, wet GA1 agricultural grassland (semi-improved) bordered the channel and was dominated by soft rush and thistles. Intermittent alder treelines grew along the banks with occasional hawthorn but was largely open. Some marsh thistle (*Cirsium palustre*), devil's bit scabious and bramble was also present. Less than 0.5km upstream of the site was a mature sitka spruce plantation (WD4). Macrophyte and bryophyte growth was limited to yellow fringe-moss and water earwort present on boulders. *Pellia* spp. liverworts grew on muddy, peaty banks.

Plate 3.10 Representative image of site A10 on the Tullynascreen Stream, a small, shallow high-energy upland watercourse

3.11 Site B1 – Argina River, Garvagh Glebe

Site B1 on the upper Argina River was situated in an upland eroding peat-base channel adjoining a mature sitka spruce plantation (WD4). The narrow channel retained a semi-natural, meandering profile with 10% riffle, 70% glide and 20% pool habitats. The bank height was 1.5m and water width and channel width of between 1m and 1.5m. Banks were often undercut and featured numerous plunge pools. The substrata were dominated by peat (40%) with frequent bedded cobble (20%) and also small quantities of gravel (20%). Boulders were localised (10%). Siltation levels were high given the erosion of peat in the catchment, with large areas of historical clear-fell (WS5) upstream.

The riparian habitat comprised small strips of species poor wet grassland (*Juncus* spp. dominated) with patches of willow grading into sitka spruce plantation. No macrophytes were recorded given the heavily-peat stained water and high degree of shading (60%) resulting from the deeply-cut U-shaped channel and afforestation cover. No aquatic mosses or liverworts were recorded instream.

Plate 3.11 Representative image of site B1 on the upper reaches of the Argina River, a small, very narrow, high-energy upland watercourse largely unsuitable for fish

3.12 Site B2 – Unnamed stream, Carrowmore

Site B2 was an unnamed upland eroding stream flowing through an extensive area of sitka spruce (WD4) over upland peaty soils. The channel featured steep V-shaped banks, heavily shaded by afforestation, and retained some semi-natural sinuous profile. The stream was narrow, often <1.5m in width and was invariably shallow (<0.2m). Riffle and glide dominated with localised shallow pools only in cascading areas. Large woody debris was frequent instream. The stream flowed over a moderate gradient through the plantation and featured a peat-dominated base (50%) with some localised (bedded and silted) cobble and coarse gravels in higher-energy areas.

Given the high shading from mature sitka spruce, the riparian vegetation was limited to mosses such as *Sphagnum* spp. with broad buckler fern (*Dryopteris dilatata*), hay-scented buckler-fern (*Dryopteris aemula)* common polypody (*Polypodium vulgare*) and tormentil occasional. Growth of *Russulla* spp. fungi was frequent. No macrophytes or bryophytes were recorded instream.

Plate 3.12 Representative image of site B2, a small, shallow, high-energy upland watercourse dominated by peat substrata flowing through dense sitka spruce plantations

3.13 Site B3 – Unnamed stream, Carrowmore

Located at a forestry access road crossing, site B3 was a small, narrow deeply cut V-shaped channel, <2m wide and <0.5m deep flowing through an area of mature sitka spruce and lodgepole pine (WD4). The site featured a series of cascading riffles, glides and pools with 30% riffle, 60% glide and 10% pool. Bankful height was up to 2.5m upstream of the culvert but >4m downstream, where the channel entered a steep V-shaped valley. Downstream of the pipe culvert, the channel was bordered by an extensive area of recently cleared clear-fell (WS5), which extended to the channel edge.

The stream flowed over a moderate gradient with the substrata composed mostly of bedrock (30%) with boulder (10%), cobble (20%) and coarse gravels (20%). The remainder was bare peat, especially upstream of the culvert where there was also lots of slate-like cobble. The riparian zone supported a low diversity of grass species only, with little herbaceous vegetation. Common liverwort grew on the muddy banks upstream of the culvert.

Plate 3.13 Representative image of site B3, a small, shallow, high-energy upland watercourse adjoining extensive areas of recent clear-fell.

3.14 Site B4 – Argina River, Carrowmore

The Argina River at site B4 was an upland eroding river 4-5m wide, in a moderate to high gradient channel with heavily peat-stained water at the time of survey. The channel retained a semi-natural profile in a shallow U-shaped channel set in a wider valley. The site comprised 30% riffle, 50% glide and 20% pool habitat. The bank height was 0.8m with a water width averaging 4-5m, equalling the channel width. The substrata were dominated by bedrock (30%) and boulder (30%) with smaller quantities of gravel (20%). The substrata were, however, bedded in peat that comprised 20% by surface area of the channel bed. Siltation levels were high given the erosion of peat in the catchment, with large areas of coniferous clear-fell (WS5) upstream.

The riparian habitat was dominated by upland blanket bog (PB2) with frequent willow and ling with characteristic blanket bog species such as tormentil, purple moor grass, bilberry and common haircap moss (*Polytrichum commune*) moss also present. However, this graded into semi-mature sitka plantation (WD4) to the west of the site (downstream). No macrophytes were recorded present given the higher energy of the site and heavily peat-stained water. The moss species *Fontanalis squamosa* was present very locally on boulders. As with many of the other sites in the catchment, the yellow fringe-moss was locally common on instream boulders above the waterline alongside water earwort.

Plate 3.14 Representative image of site B4 on the upper Argina River flowing through areas of afforestation and upland blanket bog

3.15 Site B5 – Argina River, Carrownadargny

Located approx. 0.8km downstream from site A4, site A5 was an upland eroding river (FW1) with a 6-7m wide channel over a moderate to high gradient with peat-stained water. The Argina River retained a semi-natural profile with 20% riffle, 50% glide and 30% pool habitats. Deeper pool habitat (>2m) was present downstream of the site. The bank height was 0.6m with a water width averaging 6-7m, equalling the channel width. The substrata were dominated by bedrock (30%) and boulder (30%) with smaller quantities of cobble (20%) and gravel 10%. Some peat substrata existed but it was not as extensive as other sites on the river (typically 10% only). Siltation levels were moderate given the erosion of peat in the catchment but, again, lower than areas upstream and downstream given the absence of adjoining clear-fell.

The riparian habitat was dominated by mature sitka spruce on both banks which were situated on a very steep V-shaped valley. Mosses such as *Sphagnum* spp. moss, *Polytrichum* spp. and big shaggy moss dominated much of the banks with broad buckler fern, hay-scented buckler-fern, common polypody, hard fern (*Blechnum spicant*), hart's tongue (*Asplenium scolopendrium*), great wood rush (*Luzula sylvatica*) and wood sorrel (*Oxalis acetosella*) common. The river was heavily shaded by forestry (50%). No macrophytes were recorded present given the very high energy of the site, heavy shading and peat-stained water. As with many of the other sites in the catchment yellow fringe-moss and water earwort were frequent on instream boulders above the water line with small areas of *Fontanalis squamosa* on submerged boulders.

Plate 3.15 Representative image of site B5 on the upper Argina River flowing through a natural, very steep V-shaped valley colonised by mature sitka spruce

3.16 Site B6 – unnamed stream, Boleymaguire

Site B6 was a small, unnamed upland eroding stream (FW1) in a high-gradient area that was situated in a narrow 0.5m wide V-shaped channel in an area of upland peat. Located at a forestry access road crossing, the bank height was 1m with a water width <0.5m in cascading riffle-pool sequences. The profile was of 30% riffle, 50% glide and 20% pool. The substrata comprised medium gravels (20%) but with frequent boulder and cobble (30% combined). However, peat made up 50% by area of the bed. Much of the substrata were bedded in a peaty base.

The riparian habitat was species poor wet grassland (GS4) dominated by soft rush and willow with foxglove (*Digitalis purpurea*), broad buckler-fern and great willowherb. These areas graded into young growth sitka spruce (several years old), some 20-30m from the stream. These stands appeared to have been replanted on historical clear-fell. More recent clear-fell was also noted upstream and downstream of the site.

Plate 3.16 Representative image of site B6, a very narrow, steep gradient, cascading upland eroding watercourse largely unsuitable for fish

3.17 Site B7 – unnamed stream, Boleymaguire

Site B7 was a small, unnamed upland eroding stream (FW1) in a high-gradient area that was situated in a narrow 2-2.5m wide V-shaped channel in an area of upland peat. Located at a forestry access road crossing, the bank height was 1m with a water width averaging 1-2m in cascading riffle-pool sequences. Deeper plunge pools associated with the road culvert and steeper gradient areas were present, sometimes >1m deep. The profile was of 50% riffle, 20% glide and 30% pool. The substrata comprised medium gravels (20%) but with frequent boulder and cobble (70% combined) and some exposed bedrock in higher energy areas. Siltation levels moderate given natural erosion of peat banks but moderate at worst. Most of the substrata were clean but nonetheless bedded given high flow rates and the spate nature of channel. The water was heavily peat-stained.

The riparian habitat was dominated by species poor wet grassland (GS4), supporting soft rush, purple moor grass, willow and tormentil with mature sitka spruce and lodgepole pine plantations mature adjoining downstream. Some natural growth of sitka spruce was present upstream. An evident area of clear-fell was located upstream on north bank. Common haircap moss grew on the banks with some bilberry and broad buckler-fern. Water earwort was limited but present on instream boulders.

Plate 3.17 Representative image of site B7, a small, steep gradient, cascading upland eroding watercourse largely unsuitable for fish

3.18 Site B8 – Argina River, Boleymaguire

Represented by an upland eroding river (FW1), site B8 on the Argina River was 6-8m wide in a moderate to high gradient channel with peat-stained water. The Argina retained a semi-natural profile with 40% riffle, 40% glide and 20% pool habitats. The bank height was 1m with a water width averaging 6-8m, equalling the channel width. The substrata comprised medium gravels (30%) but with frequent boulder and cobble (40% combined). The substrata were, however, bedded in peat that comprised 30% by area of the channel bed. Siltation levels were high given the erosion of peat in the catchment, with large areas of clear-fell located adjacent to the site (north bank) as well as upstream.

The riparian habitat was dominated by mature sitka spruce plantation (WD4, south bank) but also recent clear-fell (WS5). No macrophytes were recorded present given the high energy of the site and peat-stained water, although some marsh horsetail existed marginally near the confluence of a small unnamed stream. The moss species *Fontanalis squamosa* was present very locally on boulders common liverwort present on muddy margins. As with many of the other sites in the catchment, yellow fringe-moss was common on in-stream boulders. The liverwort water earwort was also locally frequent on exposed boulders.

Plate 3.18 Representative image of site B8 on the upper Argina River, flowing through extensive areas of afforestation and recent clear-fell

3.19 Site C1 – Owengar River, Knocknacosta

Located at a road crossing, site C1 was a high-energy upland eroding small stream (FW1) with cascading sequences flowing over siliceous rock. The meandering semi-natural channel was dominated by small boulder substrata (40%) with large cobble co-dominating (30%) substrata. The cobble was also represented by a more slate-like form which was largely unstable. Smaller amounts of bedrock (10%) with greater quantities of angular coarse and medium gravel (20%) was locally present in pockets. The channel was 0.75m wide with a water and channel width of 1.0m. Overall, the channel was shallow at 0.2m deep with the deepest areas 0.3m. The stream flowed through a steep V-shaped valley with a bankful height of 2.5-3m. The river profile was predominantly fast riffle (80%) with 10% glide and 10% pool. Above the road crossing the channel flowed over a moderate gradient before steepening considerably downstream and flowing predominantly over bedrock.

Riparian areas were composed of scattered gorse, grey willow, bramble scrub and patches of hazel (*Corylus avellana*) woodland. The channel was heavily shaded (40%) due to overhanging trees and scrub. No macrophytes were present instream given the high energy but yellow fringe-moss and water earwort were present locally attached to instream boulders. Big shaggy-moss and common liverwort grew on muddy banks.

Plate 3.19 Representative image of site C1, a small, narrow, steep gradient, cascading upland eroding watercourse largely unsuitable for fish

3.20 Site C2 – Unnamed stream, Knocknacosta

Located adjacent to site C1, site C2 on a separate unnamed stream was a high-energy upland eroding small stream (FW1) featuring cascading sequences over siliceous rock. The meandering semi-natural channel was again dominated by small boulder and unstable slate-like cobble substrata (50% overall). Site C2 supported more gravels than neighbouring site although these were typically angular and coarse. Bedrock was also present, particularly downstream of the road crossing where the gradient steepened in a scrubbed-over valley. The gravels were situated in pockets between slate cobble and localised boulder areas.

The channel was 1.75m wide with 2m-wide channel (larger than site C1). Overall, the channel was shallow with a maximum depth of 0.2m. It was situated in a steep V-shaped valley with a bankful height of 2.0m and the river profile was predominantly riffle (80%) with smaller proportions of glide and pool (10% by area of each). Riparian areas were of scattered gorse, sally willow, bracken, wild angelica and bramble scrub. Scrubby willow woodland was abundant upstream of the box culvert. Mature sitka plantations adjoined upstream but were buffered somewhat by several metres of willow-dominated habitat. This also accounted for the heavy shading of the channel due to overhanging tree limbs and scrub (>60%). No macrophytes were present instream given the high energy nature but the epiphytic yellow fringe-moss was present locally attached to instream boulders. The liverworts *Marchantia polymorpha* and great scented liverwort (*Conocephalum conicum*) were present on the culvert wall near the waterline.

Plate 3.20 Representative image of site C2, a small, shallow, steep gradient, cascading upland eroding watercourse largely unsuitable for fish

3.21 Site C3 – Owengar River, Camalt

Located upstream of a bridge featuring two 1.5m pipe culverts, the Owengar River at site C3 was a high-energy upland eroding small river (FW1) with boulder cascade sequences over siliceous rock. Instream works including bridge repair and boulder revetments had evidently been previously completed at the site. However, a meandering semi-natural channel remained and was dominated by boulder substrata (70%) with large frequent cobble (30%). Smaller amounts of coarse and medium gravel were present in pockets under boulder and cobble.

The channel was 2m wide with a 3m channel with. The depth varied between 0.2m in riffles to 0.5m in pools. Historical boulder revetment works that were very well constructed maintained sinuosity and channel form, which was broadly V-shaped with a bankful height of 2.5m with occasional littoral exposed cobble bars on meanders (2 stage channel). The river profile was predominantly riffle (70%) with 20% glide and 10% pool.

Riparian areas were of scattered gorse, sally willow, bramble scrub with species poor wet grassland (GS4; rough pasture). The channel was quite open with limited overhanging trees. No macrophytes were present instream given the high energy nature of the site but epiphytic moss species such as yellow fringe-moss, along with the water earwort liverwort, were present locally attached to instream boulders. Localised rusty feather moss (*Brachythecium plumosum*) grew above the waterline on the bridge structure. The former species prefers rocky outcrops in fast flowing water in base poor habitats of the west. Big shaggy-moss was common higher up on the river banks.

Plate 3.21 Representative image of site C3, a medium-sized upland eroding watercourse with some good salmonid habitat. Historical bank works (boulder revetments) are evident in the background

3.22 Site D1 – Greaghnafarna River, Greaghnafarna

Site D1 was a semi-natural stream (FW1) located below the confluence of two small rivers (one unnamed). The Greaghnafarna River had been historically straightened but not deepened for a short distance (50m) downstream of the confluence. Averaging 3m wide and 0.2-0.3m deep with some localised deeper slacks, the stream at site D1 was high-energy and dominated by riffles (60%) with fast glide and limited pool. The substrata were dominated by cobble (60%) with 30% boulder and the remainder coarse gravels. No soft sediment was present given the high-energy nature of the site.

The river flowed through areas of dry meadow and grassy verge habitat (GS2) which supported common species such as spear thistle (*Cirsium vulgare*), marsh thistle, cocksfoot, common bent, tufted vetch, oxeye daisy (*Leucanthemum vulgare*), hogweed and wild angelica. Upstream and downstream the site was bordered by mature treelines (WL2) composed mostly of alder, sycamore and willow with bramble scrub common. A 10m^2 stand of invasive Himalayan knotweed (*Persicaria wallichii*) existed on exposed gravel shoal at the confluence of the two channels (ITM 579776, 825143). Although riparian shading was high upstream and downstream, the channel was open at the site but macrophyte and bryophyte growth was sparse due to high flows. Rusty feather moss grew on top of exposed boulders with yellow fringe-moss and water earwort on submerged boulders.

Plate 3.22 Representative image of site D1 below the confluence of two smaller high-energy channels. A Himalayan knotweed stand is evident in the centre of the image.

3.23 Site D2 – unnamed channel, Rathrower

Site D2 was situated at the confluence of two small unnamed channels, an upland eroding watercourse (FW1) from the north and an adjoining drainage channel (FW4) from the west. Downstream of the confluence the channel had been historically straightened and deepened, with a bankful height of 1-1.2m and sheer sides. The channel was 1m wide and <0.15m deep and heavily silted by peat. The gravel substrata (50% overall) were bedded and compacted. The site comprised 100% slow flowing glide, with the adjoining FW1 dominated by shallow riffles.

North of site was poor quality wet (drained) agricultural grassland (soft rush dominated) with degraded cutover bog habitat (PB4) on the south bank. There was some better-quality pockets of lowland blanket bog habitat (PB3) near the channel supporting ling, purple moor grass and tormentil. The banks were lined on both sides by a narrow strip of scrub (WS1) supporting bramble with devil's bit scabious, common catsear (*Hypochaeris radicata*), common sorrel (*Rumex acetosa*), broad-leaved dock (*Rumex obtusifolius*), soft rush, meadowsweet (*Filipendula ulmaria*), marsh thistle and rank grasses. Few trees were present in the vicinity due to previous land clearance and channel straightening. Riparian shading and encroachment by terrestrial plant species was high in the channel. In terms of bryophytes, some *Pellia* spp. on more exposed muddy banks but generally there was little macrophyte or bryophyte growth due to shading.

Plate 3.23 Representative image of site D2, a narrow, heavily shaded, silted and historically straightened drainage channel largely unsuitable for fish

3.24 Site D3 – Rathgeean River, Drumee

Site D3 was a small stream (FW1) situated at a road crossing in *Juncus* spp. dominated wet grassland (GS4, upstream) and agricultural grassland (GA1, downstream). The channel had been straightened and deepened historically and was box-culverted underneath the road. Gabion mattressing was present near the road bridge. The substrata comprised of 40% boulder, 20% cobble and 10% medium with the rest silt/peat. The substrata were heavily bedded and heavily silted. A concrete apron existed under the small masonry arch bridge, evidence of historical works to the channel. A regular otter spraint site, containing white-clawed crayfish remains, was recorded under the bridge.

The site was shallow with an average depth of 0.1-0.2m and drained upland areas but not bog as per other sites in the survey. Peat staining was low at this site compared to most others in the wider Croagh catchment (i.e. did not drain upland peat areas). The bankful height was 1-1.5m in a steep U-shaped channel, which was 1.5m in width. The site was dominated by glide habitat (60%) with limited pool and occasional riffles. Downstream of the bridge, the channel became more overgrown and less natural (straightened) and retained little natural profile. Upstream, the stream was heavily tunnelled by bramble-bracken scrub and hawthorn hedgerows. Species such as water figwort (*Scrophularia auriculata*), field horsetail (*Equisetum arvense*), reed canary grass (*Phalaris arundinacea*) and nettle all indicated enrichment of the surrounding lands. Downstream of the road bridge the channel became more open as it flowed through a GA1 landscape. Occasional osier and willow existed but channel was largely open with steep vegetated banks supporting a herbaceous riparian zone with great willowherb, meadowsweet and rank grasses.

Given the high degree of shading and terrestrial encroachment, macrophyte and bryophyte growth instream was sparse but rusty feather moss was present on top of boulders with yellow fringe-moss submerged on the downstream sides.

Plate 3.24 Representative image of site C3 (facing downstream of bridge), a small, shallow stream flowing through an agricultural landscape

4. Results

A catchment-wide electro-fishing survey of *n*=21 sites in the footprint of the proposed Croagh wind farm was conducted over Monday 19th – Wednesday 21st August 2019 following notification to Inland Fisheries Ireland (Ballina). The results of the survey are discussed below in terms of fish population structure, population size and the suitability and value of the surveyed areas as nursery and spawning habitat for salmonids, European eel and lamprey species. White-clawed crayfish habitat value was also assessed for each site. Scientific names are provided at first mention only.

4.1 Fish stock assessment (electro-fishing)

Site A1 – Killanummery Stream, Corratimore Glebe

No fish were recorded during electro-fishing at site A1 on the upper Killanummery Stream. The site had little value as salmonid habitat due to its upland, high-energy nature. Lamprey spawning and nursery habitat was absent. The substrata were largely bedded in peat and, as such, there was little spawning value for salmonids. Fish access was poor given the high-elevation, upland location. While trout can sometimes occur at steep gradients, the smaller size of the cascading boulder-pool profile of the Killanummery Stream was not considered suitable for resident fish.

Site A2 – Unnamed stream, Garvagh Glebe

No fish were recorded during electro-fishing at site A2. The site had low fisheries value due to the upland and small nature of the channel which flowed over a relatively steep gradient. Spawning and nursery habitat was impacted by siltation and bedded gravels due to adjacent peat and forestry influences. There was limited holding habitat given the high-energy flows. Lamprey habitat was absent. Access for salmonids from downstream was difficult given naturally high gradients. Overall, the site was not considered suitable for resident fish.

Site A3 – Unnamed stream, Garvagh Glebe

No fish were recorded during electro-fishing at site A3. The site had low fisheries value due to upland and small nature of the channel. As with site A2 upstream (connecting watercourse), spawning and nursery habitat was impacted by siltation and bedded gravels due to adjacent peat and forestry influences. There was limited holding habitat given the high-energy flows. Lamprey habitat was absent. Access for salmonids from downstream was difficult given naturally high gradients and there was no upstream fish passage provided at the small but vertical 0.5m-fall weir at the site. Overall, the site was not considered suitable for resident fish but may support migratory European eel at low densities, albeit none were recorded during the current survey.

Plate 4.1 Electro-fishing at site A3, which did not produce fish. The site was largely unsuitable for fish given its upland nature and access issues from the lower catchment

Site A4 – Killanummery Stream, Garvagh Glebe

Brown trout (*Salmo trutta*) was the only species recorded at site A4 on the upper Killanummery Stream. Low numbers of adult fish (*n*=3) were captured. No juveniles were recorded. Fish density was low at this upper catchment site.

The site had a moderate fisheries value due to its upland nature and small nature of the channel. There was some moderate quality nursery habitat, at best, with spawning substrata very limited due to the site's high energy nature. Some good holding habitat was present, especially in vicinity of bridge where a deep 1.5m pool existed, as well as in undercut banks. Some localised pools were also present upstream and downstream of site. There was no lamprey value due to the cascading, moderate gradient and bedded substrata. The site provided some low value European eel potential, despite their absence from the survey.

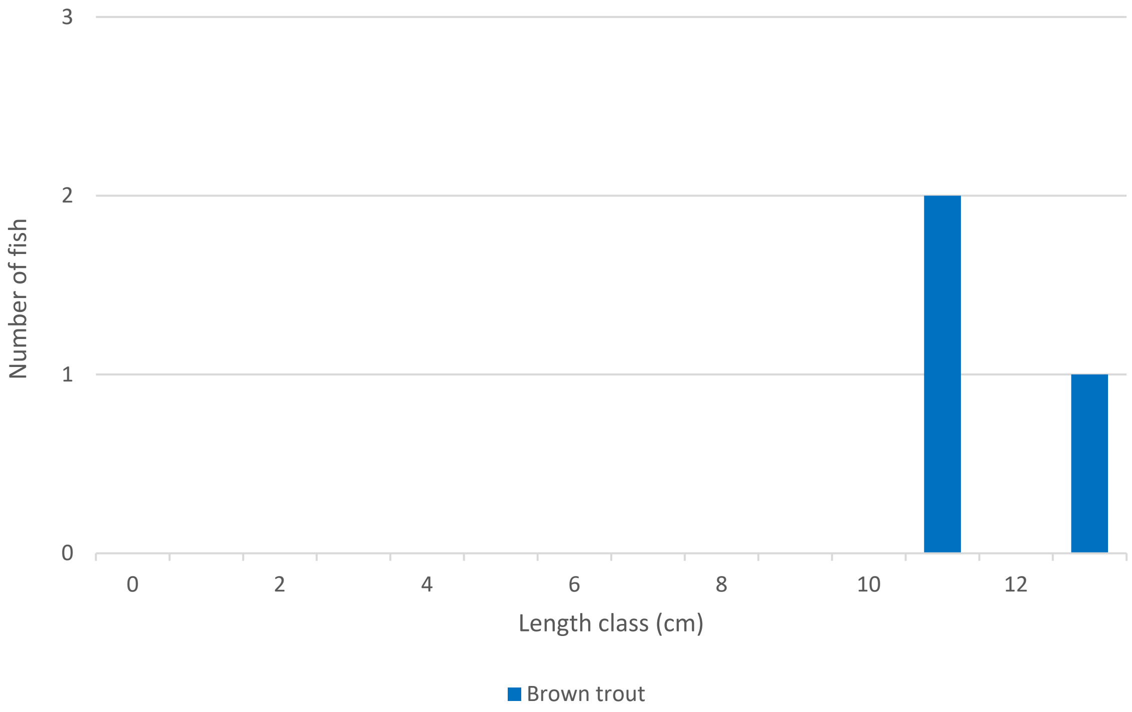

Figure 4.1 Fish stock length distribution recorded via electro-fishing at site A4 on the Killanummery Stream, Garvagh Glebe, Co. Leitrim in August 2019

Site A5 – Killanummery Stream, Corglancey

Brown trout was the only species recorded at site A5 on the Killanummery Stream at Corglancey. A range of adult size classes were captured, with low numbers of juveniles recorded (Figure 4.2).

The site was a moderate quality trout nursery given its semi-natural profile and well oxygenated broken flow patterns with cobble and gravel substrata. Overall the nursery habitat was only diminished by the fact that it was situated in an upland eroding channel with high-energy flows. The spawning value was also moderate, given that only smaller lenses of gravel were present between large substrata types. They were, however, as with all the substrata in the Killanummery at site A5, unbedded with low levels of siltation. Adult holding habitat was very good with abundant glide and pool habitat between boulder cascade areas and meanders. While some patches of sand were present the river was too high energy to support lamprey ammocoetes and none were recorded. The site provided some moderate value European eel potential, despite their absence from the survey.

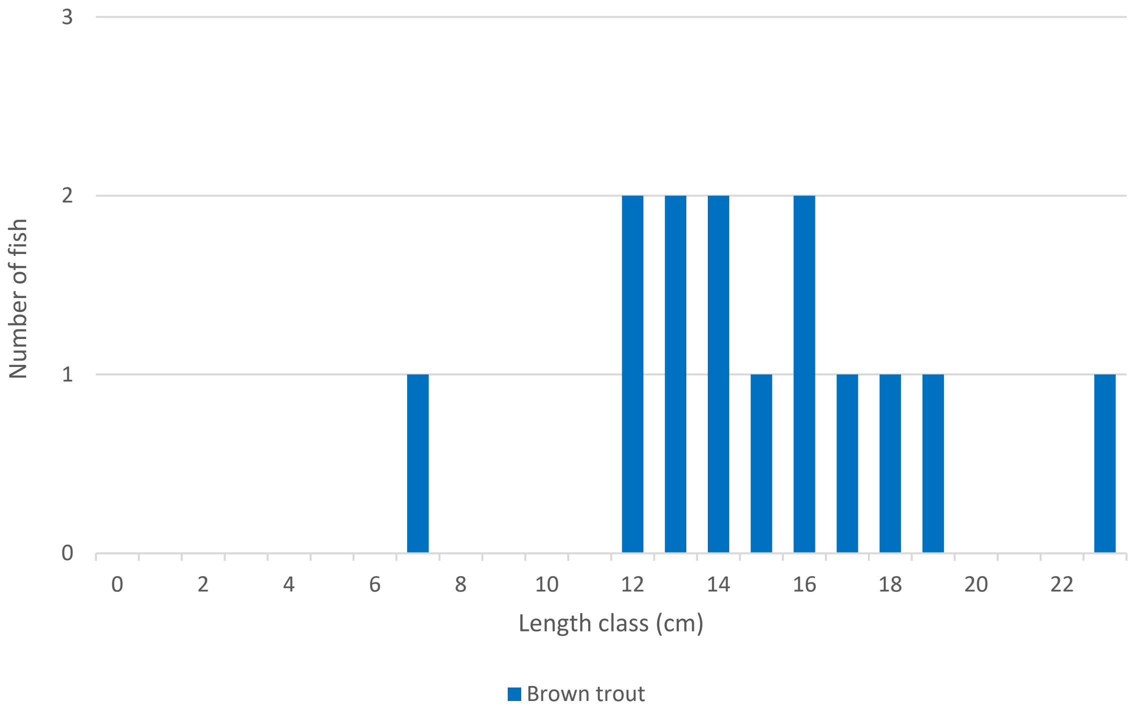

Figure 4.2 Fish stock length distribution recorded via electro-fishing at site A5 on the Killanummery Stream, Corglancey, Co. Leitrim in August 2019

Site A6 – Killanummery Stream, Carrigeen

Brown trout was the only species recorded at site A6 on the Killanummery Stream at Carrigeeen. A range of adult size classes were captured, with no juveniles recorded (Figure 4.3).

As with upstream sites on the stream, site A6 was a moderate quality trout nursery habitat given the semi-natural profile and well oxygenated broken flow patterns over cobble and gravel. Nursery value would have improved significantly had the gravels been less bedded and sedimentation by peat was reduced. These characteristics also reduced the spawning quality to moderate. Evidently the absence of 0+ fish would suggest issues with successful spawning in the Killanummery Stream at site A6. Holding habitat for adult salmonids was, however, good throughout the survey area with both deep glide and pool areas undercut into the banksides. Fair numbers of brown trout in cohorts of 1+, 2+ and 3+ year classes were present, exemplifying the better-quality holding habitat. While some sandy areas existed, they were very compacted underfoot with peat-clay fractions making them poorer quality for lamprey. Despite good fishing effort no ammocoetes emerged after targeted electro-fishing of these very localised patches located on meanders. The site provided some moderate value European eel potential, despite their absence from the survey.

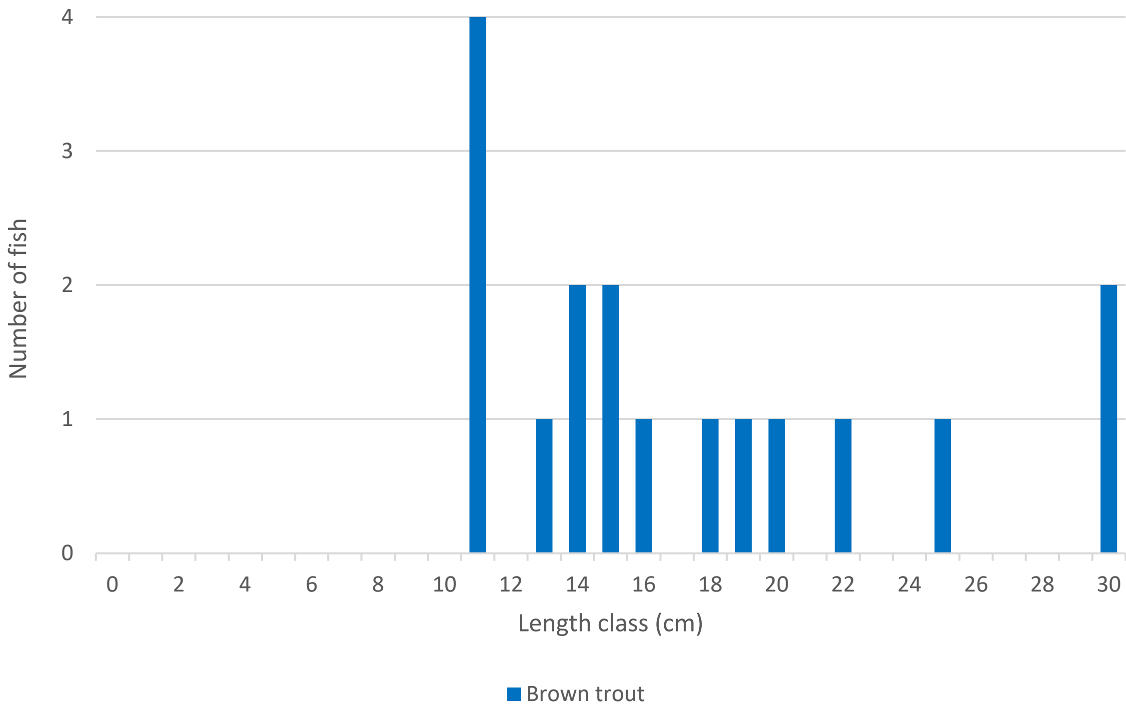

Figure 4.3 Fish stock length distribution recorded via electro-fishing at site A6 on the Killanummery Stream, Corglancey, Co. Leitrim in August 2019

Plate 4.2 A particularly large brown trout recorded at site A6 on the Killanummery Stream. Despite good nursery habitat, juveniles were scarce at this site indicating poor recruitment

Site A7 – Killanummery Stream, Killanummery

A total of four fish species were recorded at site A7 on the Killanummery Stream (Figure 4.4). Brown trout were the most abundant (*n*=23) followed by low numbers of Atlantic salmon (*Salmo salar*) parr and stone loach (*Barbatula barbatu*la). A single example of minnow (*Phoxinus phoxinus*) was also captured.

The site was evidently a very good salmonid nursery, with ample boulder and cobble refugia. Evidently the presence of both 0+ Atlantic salmon and brown trout in fair numbers exemplified the stream's value as a nursery. However, the absence of significant areas of well-sorted gravels within the survey area reduced the channel's value as a spawning site but the localised pockets of gravel within the high-energy spate channel evidently supported recruitment. The extensive bedrock and predominance of large substrata indicated that downstream, shallower-gradient areas may produce improved spawning as the energy of the river lessens. Holding habitat was good throughout the river with both deep glide and pool undercut into bedrock. The high energy of the channel resulted in very limited fines (1% by area) which were composed of shallow sand. These areas were not considered deep enough or extensive enough to support lamprey ammocoetes and none were recorded. The site provided some good potential for European eel, despite their absence from the survey.

White-clawed crayfish remains (Plate 4.4) were recorded in otter spraint under the bridge.

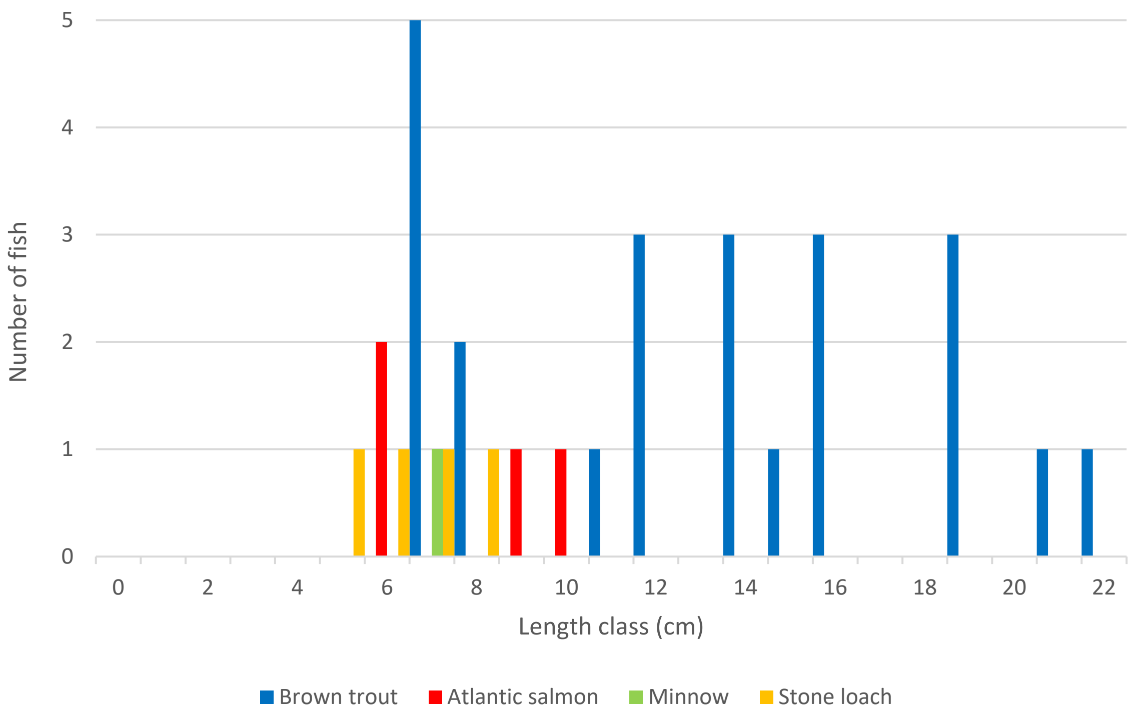

Figure 4.4 Fish stock length distribution recorded via electro-fishing at site A7 on the Killanummery Stream, Killanummery, Co. Leitrim in August 2019

Plate 4.3 A range of species were recorded at site A7 on the Killanummery River. Top to bottom: adult brown trout, juvenile brown trout, Atlantic salmon parr, minnow & stone loach

Plate 4.4 White-clawed crayfish remains were recorded in otter spraint underneath the bridge at site A7 on the Killanummery Stream

Site A8 – Tullynascreen Stream, Garvagh Glebe

No fish were recorded during electro-fishing at site A8 on the upper Tullynascreen Stream. The site had little fisheries value due to its upland elevation and high-energy nature. Fish access from the lower catchment was difficult due to naturally high gradients and fish were seemingly absent from the site. Spawning and nursery habitat were both poor due to high spate flows and likely low flows during drought periods. The absence of finer gravels for spawning and fines for larval settlement resulted in there being no lamprey potential and none were recorded. The site provided some low value European eel migratory potential, despite their absence from the survey.

Site A9 – Tullynascreen Stream, Garvagh Glebe

As with site A8 downstream, no fish were recorded during electro-fishing at site A9 on the upper Tullynascreen Stream. The site had little fisheries value due to its upland elevation and high-energy nature. Fish access from the lower catchment was difficult due to naturally high gradients and fish were seemingly absent from the site. Spawning and nursery habitat were both poor due to high spate flows and likely low flows during drought periods. The absence of finer gravels for spawning and fines for larval settlement resulted in there being no lamprey potential and none were recorded. The site provided some low value European eel migratory potential, despite their absence from the survey.

Site A10 – Tullynascreen Stream, Tullynascreen

Brown trout was the only fish species recorded at site A10 on the Tullynascreen Stream, with a low number of small adults (*n*=6) recorded (Figure 4.5).

The site had a moderate value as a salmonid nursery with a low density of salmonids present. No juveniles were recorded which likely reflects the high-energy nature of the stream at this site. The overall densities observed may also be related to upland afforestation influences plus peat escapement in the wider catchment. Some good adult holding habitat was present locally. Spawning habitat was very limited and localised, with the site dominated by boulder and cobble. Finer gravels and sediment accumulations were absent and, as such, no lamprey habitat was present. Access to the adjoining confluence stream was poor due to a naturally steep gradient. Overall, the Tullynascreen was likely to support trout further upstream. The site provided some low to moderate value European eel migratory potential, despite their absence from the survey.

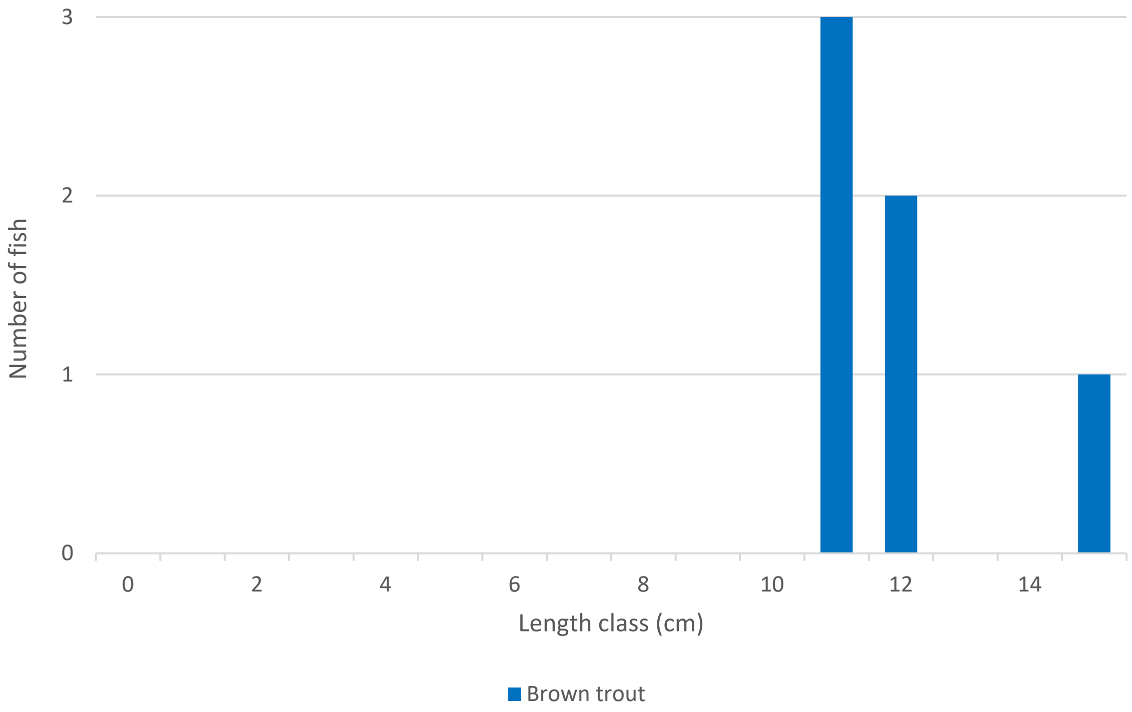

Figure 4.5 Fish stock length distribution recorded via electro-fishing at site A10 on the Tullynascreen Stream, Tullynascreen, Co. Leitrim in August 2019

Plate 4.5 A sample of adult brown trout recorded from site A10 on the Tullynascreen Stream. Juveniles were absent from this high-energy, upland site

Site B1 – Argina River, Garvagh Glebe

No fish were recorded during electro-fishing at site B1 on the upper Argina River. The site had little fisheries value due to its upland elevation and high-energy nature. Overall, the site offered very poor salmonid habitat given the small size of the channel (often <0.5m in width), heavy shading from afforestation and peat-stained water. The bedded substrata in peat reduced the spawning value of the stream and the deeply-cut shaded peat channel with more limited broken water was considered a poor nursery habitat. While some pool holding habitat existed, no salmonids were recorded present. As with other sites in the Argina River, the quality of the river as a spawning habitat would have improved significantly had the erosion of peat in the catchment not impacted the river gravels (i.e. sedimentation & compaction). The channel was of no importance to lamprey given the upland high energy nature of the site and lack of suitable soft sediment. The site provided some low value European eel migratory potential, despite their absence from the survey.

Plate 4.6 Electro-fishing site B1 on the upper extremities of the Argina River. The site was found to contain no fish at the time of survey

Site B2 – Unnamed stream, Carrowmore

No fish were recorded during electro-fishing at site B2 in the upper Argina River catchment. The site had little fisheries value due to its upland elevation and high-energy nature. Overall, the site offered very poor salmonid habitat given the small size of the channel, heavy shading from afforestation and peat-stained water. The bedded substrata in peat reduced the spawning value of the stream and the deeply-cut, shaded peat channel was considered a poor nursery habitat. While some pool holding habitat existed, no salmonids were recorded present. As with other sites in the Argina River catchment, the quality of the river as a spawning habitat would have improved significantly had the erosion of peat in the catchment not resulted in impacts to the instream gravels (i.e. sedimentation & compaction). The channel was of no importance to lamprey given the upland high energy nature of the site and lack of suitable soft sediment. The site provided some low value European eel migratory potential, despite their absence from the survey.

Site B3 – Unnamed stream, Carrowmore

As with site B2 upstream, no fish were recorded during electro-fishing at site B3 in the upper Argina River catchment. The site had little fisheries value due to its upland elevation and cascading, high-energy nature. Overall, the site offered very poor salmonid habitat given the small size of the channel in addition to the bedded substrata (peat laden), that reduced the spawning value of the stream. Furthermore, the deeply-cut, shaded peat channel was considered a poor nursery habitat. While some pool holding habitat existed, no salmonids were recorded present at this moderate gradient site. As with other sites in the Argina River catchment, the quality of the river as a spawning habitat would have improved significantly had the erosion of peat in the catchment not impacted the instream gravels (i.e. sedimentation & compaction). The channel was of no importance to lamprey given the upland high energy nature of the site and lack of suitable soft sediment. The site provided some low value European eel migratory potential, despite their absence from the survey.

Site B4 – Argina River, Carrowmore

Brown trout was the only fish species recorded from site B4 on the upper Argina River (Figure 4.6). A range of both juvenile and adult year classes were recorded, with a moderate density of fish present (*n*=11).

The site was a moderate to good trout nursery habitat given the semi-natural profile and well oxygenated broken flow patterns with boulder and cobble refugia. The bedded substrata in peat reduced the spawning value of the stream somewhat but the presence of localised unbedded gravel areas indicated it had localised spawning areas. The quality of the river as a spawning habitat would have improved significantly had the erosion of peat in the upper catchment had not impacted the river gravels (i.e. sedimentation & compaction), as with sites B5 and B8 downstream. However, the very localised pockets of coarse gravel did facilitate spawning, a indicated by the presence of a low-density of young-of-the-year 0+ trout. Holding value for adults was moderate given the presence of deep pools between boulder pockets, in addition to good areas of deeper glide habitat. The channel was of no importance to lamprey given the upland high-energy nature of the site. The site provided some moderate value European eel potential, despite their absence from the survey.

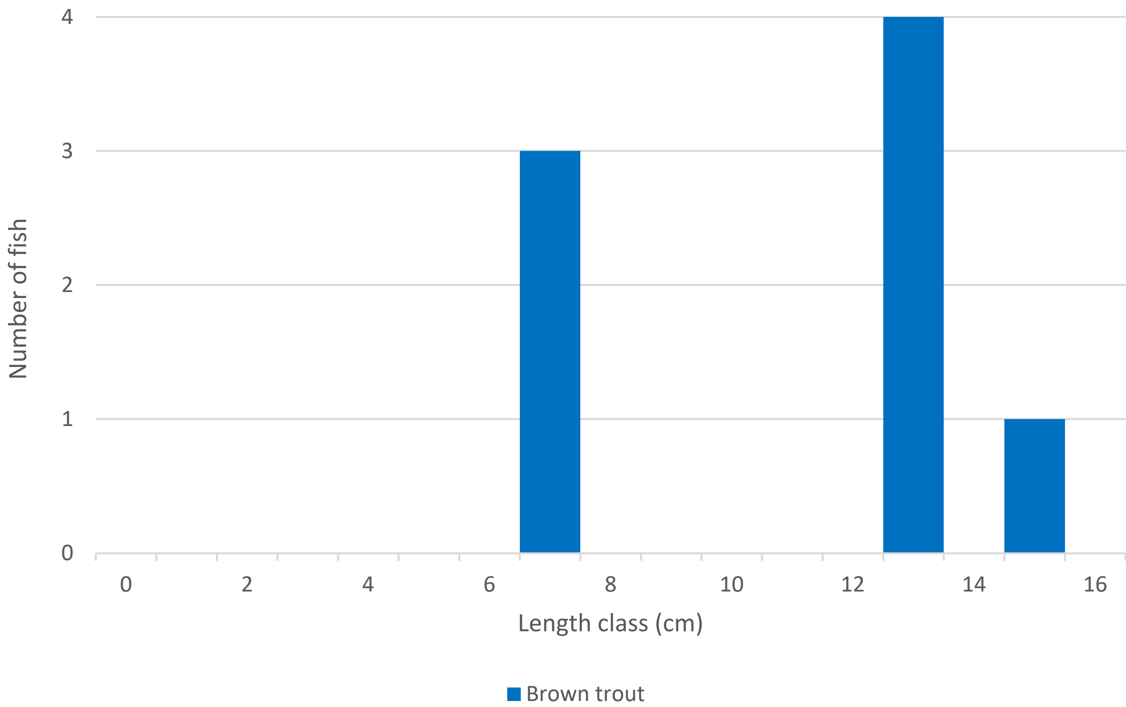

Figure 4.6 Fish stock length distribution recorded via electro-fishing at site B4 on the Argina River, Stream, Carrowmore, Co. Leitrim in August 2019

Plate 4.7 Low densities of adult and juvenile brown trout were recorded at site B4 on the upper Argina River. Fish were considered to be in excellent condition

Site B5 – Argina River, Carrownadargny

As with upstream site B4, brown trout was the only fish species recorded from site B5 on the upper Argina River (Figure 4.7). A range of both juvenile and adult year classes were recorded, with a low density of fish present (*n*=17).

The site was evidently a moderate to good trout nursery habitat given semi-natural profile and well oxygenated broken flow patterns with boulder and cobble refugia. The bedrock dominated substrata with very localised angular gravel patches reduced the spawning value of the river at this site, but evidently supported small numbers of 0+ trout. Holding value for larger fish was moderate given the presence of deep pools and glide runs between boulder pockets and bedrock. The channel was of no importance to lamprey given the upland, high-energy nature of the site and absence of soft burial ammocoete habitat. The site provided some moderate European eel potential, despite their absence from the survey.

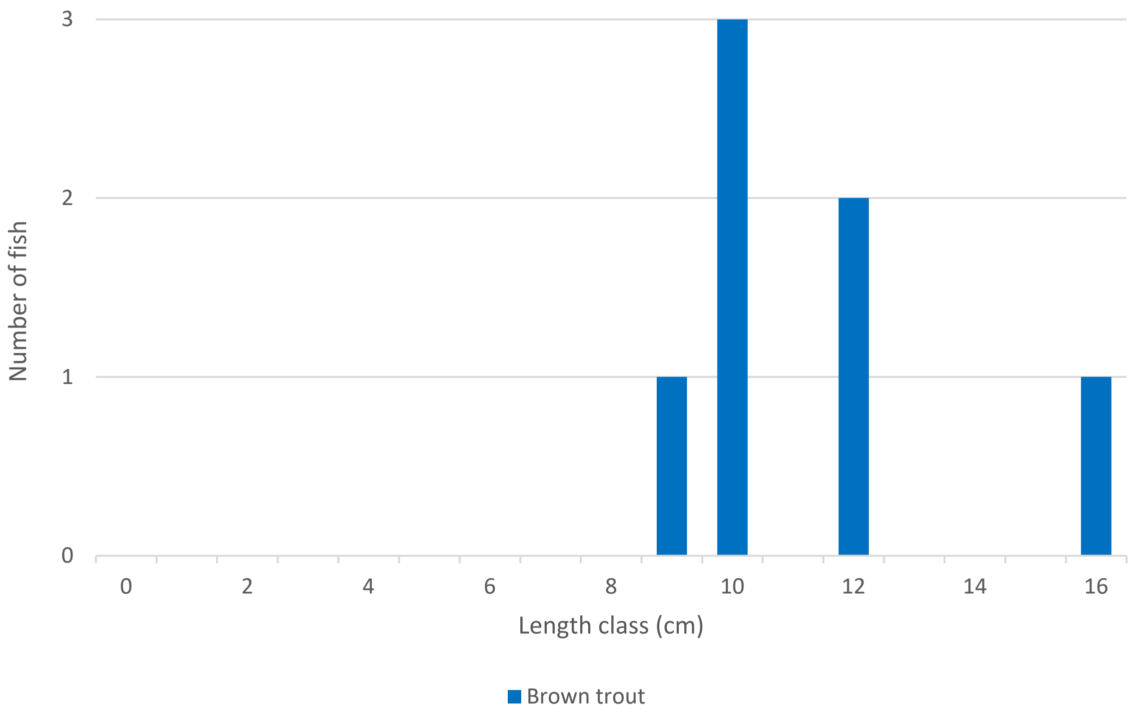

Figure 4.7 Fish stock length distribution recorded via electro-fishing at site B5 on the Argina River, Stream, Carrownadargny, Co. Leitrim in August 2019

Site B6 – unnamed stream, Boleymaguire

No fish were recorded during electro-fishing at site B6 in the upper Argina River catchment. The site had little fisheries value due to its upland elevation, very steep gradient and cascading, high-energy nature. There was very poor salmonid nursery, spawning and holding habitat given the shallow, small and upland nature of the channel in an afforested area. The bedded substrata and limited glide and pool areas for fish to rest would further diminish the fisheries value. Channels such as site B6 in high-energy, upland environments with poor fish access to the upper reaches on peaty bases are typically of low fisheries value. The absence of fish recorded during electro-fishing was most likely a consequence of the small size and upland nature of the channel in addition to adjoining land use impactors. The site was of no importance to lamprey given the upland, high-energy nature of the site. The site provided little to no European eel potential and none were recorded.

Site B7 – unnamed stream, Boleymaguire

No fish were recorded during electro-fishing at site B7 in the upper Argina River catchment. Very similar to site B6, the site had little fisheries value due to its upland elevation, very steep gradient and cascading, high-energy nature. There was very poor salmonid nursery, spawning and holding habitat given the shallow, small and upland nature of the channel in an afforested area. The bedded substrata and limited glide and pool areas for fish to rest would further diminish the fisheries value. Channels such as site B6 in high-energy, upland environments with poor fish access to the upper reaches on peaty bases are typically of low fisheries value. . The absence of fish recorded during electro-fishing was most likely a consequence of the small size and upland nature of the channel in addition to adjoining land use impactors. The site was of no importance to lamprey given the upland, high-energy nature of the site. The site provided little to no European eel potential and none were recorded.

Plate 4.8 RM electro-fishing site A7 downstream of the culvert. No fish were recorded and the stream was considered unsuitable for resident fish given its high-energy, high-gradient and upland nature

Site B8 – Argina River, Boleymaguire

Brown trout was the only fish species recorded at site B8 on the Argina River (Figure 4.7). A moderate density of both juvenile and adult fish were present (total *n*=12).

The site was evidently a good trout nursery habitat given semi-natural profile and well oxygenated broken flow patterns with boulder and cobble refugia. The bedded substrata in peat reduced the spawning value of the stream but the presence of localised unbedded gravel areas indicated it was a moderate trout nursery and spawning area. However, the very localised pockets of coarse gravel did facilitate spawning, with low numbers of 0+ trout captured. Holding value for larger fish was moderate given the presence of deeper pools between boulder pockets but no extensive areas of pool or deep glide were present. The site was of no importance to lamprey given the upland, high-energy nature of the site. Localised softer peat and clay beds were highly compacted and did not contain any lamprey ammocoetes during the electro-fishing. Small numbers of 1+ and 2+ adult trout were also recorded in the lower reaches of the adjoining unnamed stream (same channel as site B7). The site provided some moderate European eel potential, despite their absence from the survey.

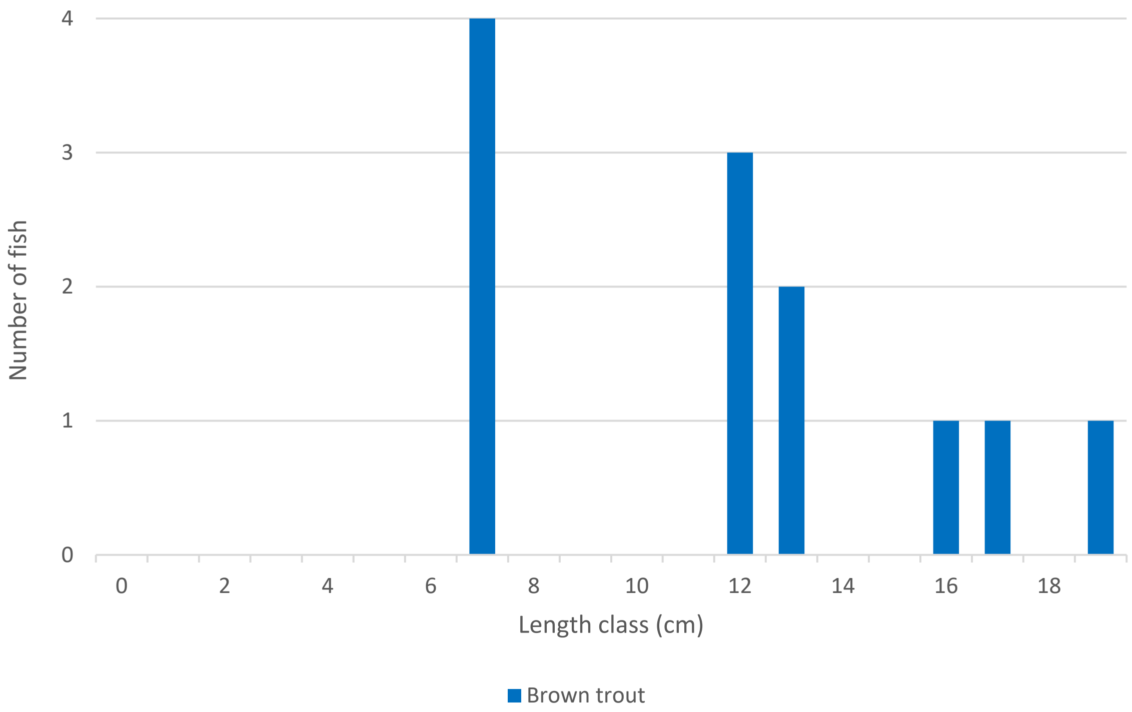

Figure 4.8 Fish stock length distribution recorded via electro-fishing at site B8 on the Argina River, Stream, Boleymaguire, Co. Leitrim in August 2019

Plate 4.9 A range of brown trout age classes were recorded from site B8 on the upper Argina River although juveniles were present in low densities

Site C1 – Owengar River, Knocknacosta

No fish were recorded during electro-fishing at site C1 in the upper Owengar River catchment. Overall, the site had little fisheries value due to its upland elevation, relatively steep gradient (especially immediately downstream) and cascading, high-energy nature

Site C1 offered poor trout nursery habitat given the shallow, small nature of the channel. The high-energy upland environment and dominance of large substrata (i.e. boulder & unstable cobble) reduced the spawning value to poor. However, the very localised pockets of coarse gravel may have facilitated some spawning by trout present downstream, despite none being recorded during the current survey. Holding value for larger fish was poor given the absence of any significant pools between boulder pocket or extensive areas of deep glide. This, however, was considered normal for an upland eroding channel of this size (i.e. smaller and shallower in nature). Salmonid remains (scales and bones likely from brown trout) were present in otter spraint sites (3 number) indicating brown trout presence in the wider channel. The site was of no importance to lamprey given the upland, high-energy nature of the site and lack of suitable soft sediment areas for larval settlement. The site provided only low value European eel potential and were not recorded during the survey.

Plate 4.10 RM electro-fishing site C1 on the upper Owengar River. No fish were captured and the river was considered largely unsuitable for resident fish at the time of survey

Site C2 – Unnamed stream, Knocknacosta

No fish were recorded during electro-fishing at site C2 in the upper Owengar River catchment. Similar to the adjacent but unconnected site C1, the site had little fisheries value due to its upland elevation, relatively steep gradient (especially immediately downstream) and cascading, high-energy nature.

The site offered poor trout nursery habitat given the shallow, small and upland nature of the channel. The high-energy upland environment and dominance of large substrata (i.e. boulder & cobble) reduced the spawning value to moderate, at best. However, the very localised pockets of coarse gravel may facilitate some spawning by upland trout that exist downstream, despite none being recorded during the current survey. Site C2 did have more gravel fractions than the nearby site C1 but the absence of juvenile trout at the site exemplified its poor nursery value. Holding value was also poor given the absence of any significant pools between boulder pockets and or extensive areas of deep glide. However, this would be considered normal for an upland eroding stream channel of this size (i.e. smaller and shallower in nature). The adjoining mature sitka spruce plantation likely reduced the viability of the spawning value for fish given a higher likelihood of acidification, despite some buffering by native scrub and willow vegetation (Triturus pers. obs.). The site was of no importance to lamprey given the upland, high- energy nature of the site and lack of suitable soft sediment areas for larval settlement. The site provided only low value European eel potential and were not recorded during the survey.

Site C3 – Owengar River, Camalt

Brown trout was the only fish species recorded at site C3 on the Owengar River (Figure 4.9). A moderate density of both juvenile and adult fish were present (total *n*=10).

Evidently, the site provided some good brown trout nursery habitat given the semi-natural profile and well-oxygenated broken flow patterns with boulder and cobble refugia. The high energy upland environment and dominance of large substrata (i.e. boulder & cobble) reduced the spawning value to moderate, at best. However, the very localised pockets of coarse gravel likely facilitated spawning by the upland, low-density trout population. Despite recent instream works related to bridge repairs (boulder revetments, two-stage channel construction etc.), holding value for larger fish was moderate given presence of some localised pools between installed boulder pockets but no extensive areas of pool or deep glide were present. This, however, would be considered normal for an upland eroding channel. The site was of little importance to lamprey given the high-energy, upland nature of the site and lack of suitable spawning and or ammocoete burial habitat. The site provided some moderate European eel potential, despite their absence from the survey.

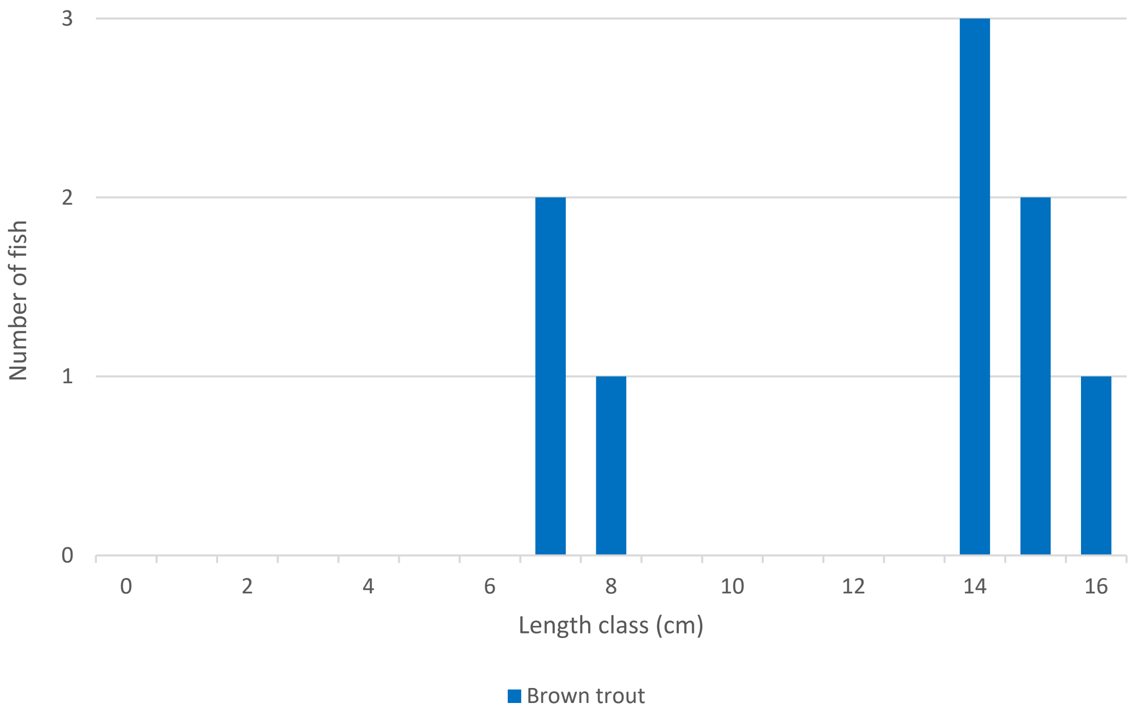

Figure 4.9 Fish stock length distribution recorded via electro-fishing at site C3 on the Owengar River, Camalt, Co. Leitrim in August 2019

Plate 4.11 A moderate density of juvenile and adult brown trout were recorded from site C3

Site D1 – Greaghnafarna River, Greaghnafarna

Whilst no electro-fishing was undertaken at site D1, a broad fisheries appraisal was made. The Greaghnafarna River at site D1, downstream of the confluence, offered good nursery habitat for salmonids. However, spawning was moderate (at best) given the compacted/bedded and larger size of harder substrata as result of high-energy flows. Deeper pools for holding were also limited in their distribution, although this improved downstream of the site in a more tunnelled section. Upstream of the confluence, the eastern channel (unnamed) had been dammed historically at a farm access track and upstream fish passage was not provided (>1m high barrier). Lamprey habitat in terms of finer spawning substrata was scarce to absent with the only soft sediment present being sand-dominated, compacted, localised and not considered suitable for ammocoete burial. European eel habitat was considered moderate given the general lack of deeper pools and accessible instream refugia.

Site D2 – unnamed channel, Rathrower

Whilst no electro-fishing was undertaken at site D2, a broad fisheries appraisal was made. Site D2 offered little if any fisheries value for salmonids. The drainage channel was heavily silted with any harder substrata present bedded in peat, resulting in a lack of spawning habitat for both salmonids and lamprey. Flow rates and water levels were low (even after heavy rainfall) and this likely precluded lamprey. The site had some moderate potential for three-spined stickleback. European eel may have used the channel for migratory purposes, in season. Despite higher flow rates, the small unnamed stream adjoining the site from the north also offered poor overall fisheries value given the very shallow depth and silted/bedded nature of the channel.

Site D3 – Rathgeean River, Drumee

Whilst no electro-fishing was undertaken at site D3, a broad fisheries appraisal was made. The site featured a lack of deeper pooling areas which reduced the value for supporting resident salmonids in such a small, shallow watercourse. Spawning habitat was also poor given the silted, bedded (peat) nature of the substrata. Nursery habitat was also poor overall although the stream did offer some low suitability for brown trout. The generally high-energy, non-depositing characteristics of the site (except for localised bedded peat) greatly reduced the value for larval lamprey, which were considered unlikely to be present. White-clawed crayfish remains were recorded in otter spraint underneath the bridge structure which indicated some suitability and presence locally. Sweep netting of limited boulder refugia failed to reveal any live crayfish at the site. The Rathgeean Stream offered some moderate potential for European eel, especially as a migratory route.

4.2 Fisheries habitat

Salmonids

Given the range of physical differences between sites, the quality of salmonid habitat varied across the *n*=24 locations assessed (Table 4.1). Whilst *n*=9 sites achieved 'good' Life Cycle Unit score, *n*=5 were moderate and *n*=10 graded as 'poor' based on combinations of spawning, nursery and holding habitat. No sites achieved 'excellent' Life Cycle Unit scores, i.e. optimal spawning, nursery and holding. In general, smaller more upland watercourses received higher (worse) scores given their lack or even absence of suitable spawning substrata and nursery habitat resulting from higher gradients, higher-energy flows and spate nature.

Table 4.1 Summary of the salmonid Life Cycle Unit scores for the sites surveyed in the footprint of Croagh wind farm, August 2019 (after Kennedy, 1984; O Connor & Kennedy, 2002). *sites D1, D2 & D3 were Q-sampling sites only

Site	Salmonid habitat value	Spawning	Nursery	Holding	Total Score	Salmonids recorded
A1	Poor	4	4	4	**12**	No
A2	Poor	4	4	4	**12**	No
A3	Poor	4	4	4	**12**	No
A4	Moderate	4	3	2	**9**	Yes
A5	Good	3	3	2	**8**	Yes
A6	Good	3	3	2	**8**	Yes

Site	Salmonid habitat value	Spawning	Nursery	Holding	Total Score	Salmonids recorded
A7	Good	3	2	2	**7**	Yes
A8	Moderate	4	3	3	**10**	No
A9	Moderate	4	3	3	**10**	No
A10	Good	3	3	2	**8**	Yes
B1	Poor	4	4	4	**12**	No
B2	Poor	4	4	4	**12**	No
B3	Moderate	4	3	3	**10**	No
B4	Good	3	2	2	**7**	Yes
B5	Good	4	2	1	**7**	Yes
B6	Poor	4	4	4	**12**	No
B7	Poor	4	4	4	**12**	No
B8	Good	3	2	2	**7**	Yes
C1	Poor	4	4	4	**12**	No
C2	Poor	3	4	4	**12**	No
C3	Good	3	2	3	**8**	Yes
D1*	Good	3	2	3	**8**	n/a
D2*	Poor	4	4	4	**12**	n/a
D3*	Moderate	3	3	3	**9**	n/a

Lower scores indicate superior habitat. n/a = site not electro-fished

Lamprey species

Lamprey habitat was almost universally poor across all survey sites in the footprint of Croagh wind farm and cable route (Table 4.2). Suitable spawning habitat by way of finer, unbedded gravels were absent from almost all sites, with the only exception being site A6 (Killanummery Stream, moderate quality habitat present). Finer sediment (silt) accumulations suitable for larval (ammocoete) settlement were absent from all sites surveyed. No lamprey were recorded during electro-fishing across *n*=21 sites and no records were available for any lamprey species in the watercourses surveyed.

Table 4.2 Lamprey Habitat Quality Index (LHQI) scoring system for lamprey habitat value for the sites surveyed in the footprint of Croagh wind farm and cable route, Co. Leitrim (Macklin et al., 2018), adapted from Kennedy (1984). Habitat type for ammocoetes is assessed according to Applegate (1950) and Slade et al. (2003).

Site	Lamprey habitat value	Spawning	Nursery	Total Score	Lamprey recorded	Habitat type present
A1	Poor	4	4	**8**	No	Type 3
A2	Poor	4	4	**8**	No	Type 3
A3	Poor	4	4	**8**	No	Type 3
A4	Poor	4	4	**8**	No	Type 3
A5	Poor	4	4	**8**	No	Type 3
A6	Moderate	3	4	**7**	No	Type 3
A7	Poor	4	4	**8**	No	Type 3
A8	Poor	4	4	**8**	No	Type 3
A9	Poor	4	4	**8**	No	Type 3
A10	Poor	4	4	**8**	No	Type 3
B1	Poor	4	4	**8**	No	Type 3
B2	Poor	4	4	**8**	No	Type 3

Site	Lamprey habitat value	Spawning	Nursery	Total Score	Lamprey recorded	Habitat type present
B3	Poor	4	4	**8**	No	Type 3
B4	Poor	4	4	**8**	No	Type 3
B5	Poor	4	4	**8**	No	Type 3
B6	Poor	4	4	**8**	No	Type 3
B7	Poor	4	4	**8**	No	Type 3
B8	Poor	4	4	**8**	No	Type 3
C1	Poor	4	4	**8**	No	Type 3
C2	Poor	4	4	**8**	No	Type 3
C3	Poor	4	4	**8**	No	Type 3
D1	Poor	4	4	**8**	No	Type 3
D2	Poor	4	4	**8**	No	Type 3
D3	Poor	4	4	**8**	No	Type 3

*lower scores indicate superior habitat. n/a = site not electro-fished

European eel

European eel habitat quality was typically poor across the survey sites and no eels were recorded at any site via electro-fishing. Many sites were considered sub-optimal (or in some cases even unsuitable) for the species given the often-high gradients, high-energy profiles and typically upland nature of the channels. However, some moderate to good suitability was present across the larger watercourses (Killanummery Stream, Owengar River), especially in terms of seasonal migratory value (despite their absence from electro-fishing efforts).

4.3 White-clawed crayfish

No white-clawed crayfish were recorded via trapping or sweep netting surveys across the *n*=21 sites in the footprint of Croagh and cable route wind farm. However, crayfish remains were recorded in otter spraint under bridges at sites A7 on the Killanummery Stream (Plate 4.4) and site D3 on the Rathgeean River. These were recorded in otter spraint and thus likely originated from a downstream population given that ranges of male otter can extend up to 20km.

There were no existing records for white-clawed crayfish in the watercourses within the footprint of the proposed Croagh wind farm development. The nearest records were available for the Douglas and Feorish Rivers approx. 4km south/southwest of the catchment and the Bonnet River near Dromahair (approx. 6km north), as well as the River Shannon catchment upstream of Lough Allen (NBDC, 2019).

Plate 4.12 Crayfish traps at site A7 on the Killanummery River before overnight deployment. Trapping returned zero crayfish at all sites in the study area although remains were recorded in otter spraint at two sites (A7 and D3), indicating cryptically-low presence locally

4.4 Q-sampling (macro-invertebrates)

Q-samples were collected and analysed from *n*=13 sites on the Killanummery, Argina, Owengar and Tullynascreen Rivers as well as several unnamed watercourses in the wider Croagh wind farm catchment. A total of *n*=32 species across *n*=21 families were recorded in the *n*=13 kick samples collected from the Croagh catchment (see Table 4.3 & Figure 4.10 below for site locations).

Samples were collected from riffle-glide areas of channel as per standard practice (i.e. Toner et al., 2005) although sample D2 (unnamed stream, Rathrower) was considered a **tentative** Q-sample given that it was collected from semi-stagnant drainage channel habitat.

Following the methodology of Toner et al. (2005), the Environmental Protection Agency (EPA) group invertebrates into classes whereby pollution intolerant species are denoted class A, and species with greater pollution tolerance fall into successive classes (B through E, respectively). As such, the presence or absence of these groups and their relative abundance facilitates an assessment of biological river health. Good status (Q4) unpolluted water quality is achieved according to the EPA if at least one Group A taxon is present in, at least, fair numbers (5-10% total sample composition). Group B taxa may be common or absent and *Baetis rhodani* (large dark olive mayfly) is often dominant. Other Group C taxa are never excessive and group D / E taxa are present in small numbers or absent (Toner et. al 2005). Our results are discussed in this context in order to interpret potential changes in the macroinvertebrate community composition.

Only a single sampling site (A7, Killanummery River) achieved **Q4** good status water quality, with fair numbers numbers of class A Heptageniidae stoneflies present in addition to class B Leuctridae stoneflies (*Leuctra hippopus*). The site also had EPA Class B pollution intolerant cased caddis species *Apatania muliebris* and *Drusus annulatus*. Moderate numbers of class C, pollution tolerant species such as *Gammarus duebenii* and *Potamopyrgus antipodarum* were present. As such site A7 achieved 'good status' water quality (i.e. Q-rating of 4).

Site C1 on the Owengar River had the EPA class A and B stonefly families Heptageniidae and Leuctridae present but in low numbers. This, coupled with a dominance of moderate water quality indicators (i.e. EPA class C *Gammarus dubenii*) indicated slightly polluted **Q3-4** water quality.

All of the remaining sampling sites (i.e. sites A1, A2, A4, A8, B1, B3, B8, C3, D1, D2 & D3) had an absence of EPA class A clean-water mayfly and stonefly species. Their invertebrate composition was composed of low numbers (or even absent) EPA class B invertebrate taxa such as Luectridae stonefly and Limnephilidae caddis families. Typically, they were dominated by EPA class C invertebrates such as the freshwater shrimp *Gammarus dubenii* and the widespread mayfly species, *Baetis rhodani*. As such, the biological water quality at these sites was recorded as **Q3** moderately polluted water.

No rare macroinvertebrate species were recorded from the *n*=13 samples across the Croagh wind farm catchment (summarised below). The invertebrate Q-sampling was summarised as follows at the *n*=13 sites, with only site A7 on the Killanummery Stream achieving good status **Q4** water quality as required under the Water Framework Directive (2000/60/EC) as implemented by the recently amended European Union Environmental Objectives (Surface Waters) (Amendment) Regulations 2019 (S.I. No. 77 of 2019). These regulations specify a minimum target EQR of 0.75 or equivalent **Q4** for all rivers.

- Site A1 (Killanummery Stream) **Q3** Moderately polluted (WFD Moderate status)
- Site A2 (unnamed stream) **Q3** Moderately polluted (WFD Poor Status)
- Site A4 (Killanummery Stream) **Q3** Moderately polluted (WFD Moderate status)
- Site A7 (Killanummery Stream) **Q4** Unpolluted (WFD Good status)
- Site A8 (Tullynascreen Stream) **Q3** Moderately polluted (WFD Poor Status)

- Site B1 (Argina River) **Q3** Moderately polluted (WFD Poor Status)
- Site B3 (unnamed stream) **Q3** Moderately polluted (WFD Poor Status)
- Site B8 (Argina River) **Q3** Moderately polluted (WFD Poor Status)
- Site C1 (Owengar River) **Q3-4** Slightly polluted (WFD Moderate Status)
- Site C3 (Owengar River) **Q3** Moderately polluted (WFD Poor Status)
- Site D1 (Greaghnafarna River) **Q3** Moderately polluted (WFD Poor Status)
- Site D2 (unnamed stream) **Q3** Moderately polluted (WFD Poor Status)
- Site D3 (Rathgeean River) **Q3** Moderately polluted (WFD Poor Status)

Table 4.3 Macro-invertebrate composition & associated Q-ratings for *n*=13 sites in the footprint of Croagh wind farm near Drumkeeran, Co. Leitrim (August 2019)

Group	Species	Common name	Site A1	Site A2	Site A4	Site A7	Site A8	Site B1	Site B3	EPA Class
Heptageniidae	*Heptagenia sulphurea*	Stonefly				7				A
Leuctridae	*Leuctra hippopus*	Stonefly		2		4				B
Leuctridae	*Leuctra moselyi*	Stonefly								B
Ephemerellidae	*Seratella ignita*	Blue winged olive								C
Baetidae	*Baetis rhodani*	Dark olive			3	1	12	3	9	C
Ephemerellidae	*Seratella ignita*	Blue winged olive								C
Goeridae	*Goera pilosa*	Cased caddis						1		B
Limnephilidae	*Apatania muliebris*	Cased caddis	2			1				B
Limnephilidae	*Drusus annulatus*	Cased caddis				2				B
Limnephilidae	*Micropterna sequax*	Cased caddis								C
Limnephilidae	*N/D early instar*	Cased caddis							1	B
Ryacophilidae	*Ryacophila dorsalis*	Caseless caddis			1					C
Polycentropodidae	*Polycentropus flavomaculatus*	Caseless caddis				3				C
Polycentropodidae	*Plectronemia geniculata*	Caseless caddis					2	6		C
Gammaridae	*Gammarus duebenii*	Freshwater shrimp	27	9	6	8				C
Elmidae	*Elmis aenea*	Riffle beetle	3	1						C
Elmidae	*Limnius volckmari*	Riffle beetle				4		1		C
Elmidae	*Oulimnius parallelepidus*	Riffle beetle								C
Dytiscidae	*Agabus bipustulatus*	Water beetle						1		C
Dytiscidae	*Oreodytes sanmarkii*	Water beetle								C
Dytiscidae	*Dytiscid larvae early instar*	Water beetle							1	C

Group	Species	Common name	Site A1	Site A2	Site A4	Site A7	Site A8	Site B1	Site B3	EPA Class
Ancylidae	*Ancylus fluviatilis*	River limpet				2				None
Sphaeriidae	*Sphaerium corneum*	Horny orb mussel						1		D
Hydrobiidae	*Potamopyrgus antipodarum*	Jenkin's spire snail				13				C
Erpobdellidae	*Erpobdella octoculata*	Leech								D
Simuliidae	*Simulium sp.*	Blackfly		1	4		6			C
Chironomidae	n/d (Tanypodinae subfamily)	Non-biting midge				2				C
Chironomidae	n/d (Chironominae subfamily)	Non-biting midge							1	C
Pediciidae	*Dicranota sp.*	Cranefly larvae			1		2			C
Tubificidae	*Limnodrilus sp.*	Worm		2	1			1		D
Lumbricidae	*Eiseniella tetraedra*	Worm					1		2	n/a
Veliidae	*Velia sp.*	Small water slider					1	1		C
Taxon richness (*n*)			**3**	**5**	**6**	**11**	**6**	**8**	**5**	
Q-rating			**Q3**	**Q3**	**Q3**	**Q4**	**Q3**	**Q3**	**Q3**	
WFD status			**Poor**	**Poor**	**Poor**	**Good**	**Poor**	**Poor**	**Poor**	

Table 4.3 (continued) Macro-invertebrate composition & associated Q-ratings for *n*=13 sites in the footprint of Croagh wind farm near Drumkeeran, Co. Leitrim (August 2019)

Group	Species	Common name	Site B8	Site C1	Site C3	Site D1	Site D2	Site D3	EPA Class
Hetageniidae	*Heptagenia sulphurea*	Stonefly		1					A
Leuctridae	*Leuctra hippopus*	Stonefly							B
Leuctridae	*Leuctra moselyi*	Stonefly	3	4	3			3	B
Ephemerellidae	*Seratella ignita*	Blue winged olive			5				C
Baetidae	*Baetis rhodani*	Dark olive	2		8	8			C
Ephemerellidae	*Seratella ignita*	Blue winged olive							C
Goeridae	*Goera pilosa*	Cased caddis				1			B
Limnephilidae	*Apatania muliebris*	Cased caddis							B
Limnephilidae	*Drusus annulatus*	Cased caddis							B
Limnephilidae	*Micropterna sequax*	Cased caddis				2			C
Limnephilidae	*N/D early instar*	Cased caddis			1				B
Ryacophilidae	*Ryacophila dorsalis*	Caseless caddis		2	2				C
Polycentropodidae	*Polycentropus flavomaculatus*	Caseless caddis			1				C
Polycentropodidae	*Plectronemia geniculata*	Caseless caddis		1		1			C
Gammaridae	*Gammarus duebenii*	Freshwater shrimp	5	12	3	22	103	16	C
Elmidae	*Elmis aenea*	Riffle beetle						2	C
Elmidae	*Limnius volckmari*	Riffle beetle					2	7	C
Elmidae	*Oulimnius parallelepidus*	Riffle beetle						3	C
Dytiscidae	*Agabus bipustulatus*	Water beetle							C

Group	Species	Common name	Site B8	Site C1	Site C3	Site D1	Site D2	Site D3	EPA Class
Dytiscidae	*Oreodytes sanmarkii*	Water beetle	1						C
Dytiscidae	*Dytiscid larvae early instar*	Water beetle							C
Ancylidae	*Ancylus fluviatilis*	River limpet		2	5	2		3	None
Sphaeriidae	*Sphaerium corneum*	Horny orb mussel							D
Hydrobiidae	*Potamopyrgus antipodarum*	Jenkin's spire snail						31	C
Erpobdellidae	*Erpobdella octoculata*	Leech			1				D
Simuliidae	*Simulium sp.*	Blackfly							C
Chironomidae	n/d (Tanypodinae subfamily)	Non-biting midge							C
Chironomidae	n/d (Chironominae subfamily)	Non-biting midge							C
Pediciidae	*Dicranota sp.*	Cranefly larvae			2				C
Tubificidae	*Limnodrilus sp.*	Worm	3						D
Lumbricidae	*Eiseniella tetraedra*	Worm	1	1					n/a
Veliidae	*Velia sp.*	Small water slider							C
Taxon richness (*n*)			**6**	**7**	**10**	**6**	**2**	**7**	
Q-rating			**Q3**	**Q3-4**	**Q3**	**Q3**	**Q3**[2]	**Q3**	
WFD status			**Poor**	**Moderate**	**Poor**	**Poor**	**Poor**	**Poor**	

[2] Site D2 was a **tentative** Q-sample, taken from semi-stagnant glide habitat, and, as such, should be interpreted with caution

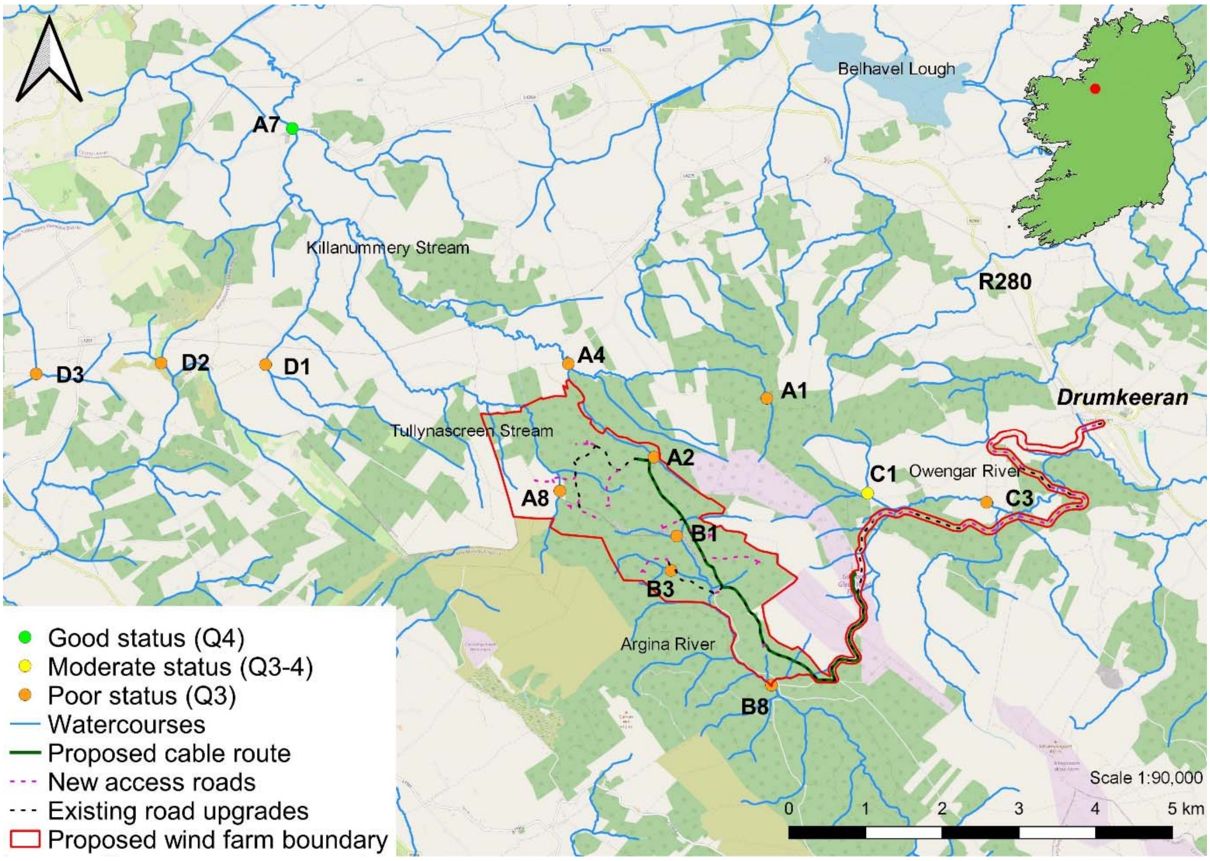

Figure 4.10 Water quality (WFD) status of the *n*=13 Q-sampling sites sampled in the footprint of the proposed Croagh wind farm, Co. Leitrim (August 2019)

5. Discussion

5.1 Most and least valuable sites

Salmonids

Atlantic salmon were only recorded from one site (A6, Killanummery Stream), with brown trout composing over 90% of all fish captured across all sites. Salmonid habitat across the *n*=24 survey sites ranged from poor to good according to Life Cycle Unit scores (Table 4.1) with their potential determined by a number of factors, mostly relating to physical site characteristics. Whilst *n*=9 sites achieved 'good' Life Cycle Unit scores, *n*=5 were moderate and *n*=10 graded as 'poor' based on combinations of spawning, nursery and holding habitat. No sites achieved 'excellent' Life Cycle Unit scores, i.e. optimal spawning, nursery and holding.

In general, smaller more upland watercourses received higher (worse) scores given their lack or even absence of suitable spawning substrata and nursery habitat resulting from higher gradients, higher-energy flows and spate natures. Some sites which offered good or excellent adult holding habitat (e.g. A4-A7, B4, B5, B8 etc.) would have received better overall scores had spawning, and to a lesser extent, nursery habitat been superior. Stream gradient is known to be one of the principal determinants of juvenile salmonid production, with medium gradients most optimal in terms of successful recruitment and population persistence (Wood & Budy, 2009; O'Grady, 2006; Amiro, 1993; Kennedy & Strange, 1982). As would be expected in upland catchments exposed to pressures from afforestation and peat escapement (see below), the lower reaches of the Killanummery Stream, Argina River and Owengar River sub-catchments typically offered better quality salmonid habitat and supported higher densities of salmonids.

A total of 57% of *n*=21 electro-fishing sites did not support resident fish (any species) at the time of survey. These sites were located in upland areas and invariably featured high-energy flows exposed to regular spate conditions, often flowing over moderate to steep gradients. Upstream fish access for salmonids was difficult or blocked entirely due to such physical characteristics in several cases e.g. sites A1, A2, A3, C1, C2 etc.

Many of the watercourses surveyed were small, shallow, high-energy, upland eroding streams draining afforested and or blanket bog areas. These featured cobble/boulder-dominated substrata which were often bedded in peat and had a lack (not absence) of finer gravels for spawning. Smaller gravel fractions are vital in structuring salmonid populations (Meredith et al., 2017; Hudy et al., 2010), being necessary for successful spawning and egg development, and there is generally a strong correlation between the availability of spawning substrata and the size of populations (Montgomery et al., 1999). Additionally, peat-based catchments such as that in the vicinity of Croagh wind farm are less productive than those flowing over other geologies (O'Grady, 2006), with reduced primary productivity, reduced macro-invertebrate communities, and, generally speaking, lower fish biomass (Richardson, 1993). This can also be validated from the invertebrate samples collected in the current study that typically had lower overall diversity of species and also densities (pers. obs.). Channels with higher proportions of peat substrata can also suffer from increased siltation and bedding (compaction) of instream gravels and cobbles necessary for salmonid spawning, further limiting local populations.

Compacted gravels can no longer function as salmonid spawning areas and it has been shown that eggs laid in clean gravels which have subsequently been silted over by peat have failed to hatch (Crisp 1993, 2000). Peat escapement would appear to be impacting salmonid recruitment in numerous channels across the Croagh catchment, given lower-than-expected densities of trout parr at several sites on the Killanummery Stream, Tullynascreen River and Argina River.

The loss of dissolved organic carbon (DOC) is a phenomenon also associated with peat catchments and can result in changes (reductions) in pH and general ecosystem processes (Feeley et al., 2016), leading to reduced fish biomass and recruitment. Furthermore, clear-felling (as recorded in the upper Argina River catchment) is known to contribute greatly to DOC loss in peat catchments, impacting Atlantic salmon in particular (Harrison et al., 2014). Coniferous afforestation can also have various impacts on water quality and salmonid populations, namely through a reduction in water pH (increased acidity), increases in heavy metal concentrations and eutrophication (Giller & O'Halloran, 2004; Lehane et al., 2004; Graham et al., 2010). The impacts from afforestation can influence fish survival and growth and are typically most marked in winter and spring, when salmonids are at their most vulnerable life stages (Giller & O'Halloran, 2004). This may be a factor impacting salmonid populations of several watercourses throughout the wider Croagh catchment.

Biological water quality was typically of Q3 (poor status) across the survey sites, with only sites A6 on the Killanummery Stream and C3 on the Owengar River offering improved water quality (Q4 and Q3-4, respectively). Site A6 on the Killanummery Stream was the only river site meeting the Water Framework Directive (i.e. ≥Q4) and Surface Water Regulations (S.I. No. 77/2019)(ammended) standards (i.e. EQR good ≥0.75). The abundance of salmonids (especially Atlantic salmon as opposed to brown trout) is more stable at better quality sites (≥Q4), with salmon populations tending to oscillate due to fry abundance 'pulses' at moderate quality sites (i.e. Q3-4) (Kelly et al., 2007; Champ et al., 2009). As such, the paucity of Atlantic salmon in all but one survey site, as well as the predominance of Q2-3 tolerant brown trout, is perhaps unsurprising given the observed biological water quality results.

Lamprey species

Lamprey habitat was assessed as poor across almost all *n*=24 survey sites in the footprint of Croagh wind farm (Table 4.2), with the only exception being site A6 on the Killanummery Stream. Generally, survey sites were located on upland watercourses not considered suitable for lamprey species. Suitable spawning habitat by way of finer, unbedded gravels were absent from all sites apart from site A6. Additionally, finer sediment accumulations suitable for larval (ammocoete) settlement were absent given the high-energy nature of the sites. The majority of sites represented upland eroding watercourses and naturally such sites do not encourage the deposition of fine, organic rich sediment required by larval lamprey (Goodwin et al., 2008; Aronsuu & Virkkala, 2014). Invariably, any finer sediment present was typically sand-dominated and or compacted/bound in peat. Typically, *Lampetra* spp. are not present in sites with average water velocities of >0.5m/s (Taverney et al., 2012) – many of the Croagh survey sites were considered to exceed this (no flow rate data available). No lamprey were recorded during electro-fishing across *n*=21 sites and no records existed for any lamprey species in the watercourses surveyed.

European eel

No European eels were recorded across the *n*=21 electro-fishing sites and overall habitat quality was typically poor. On both a global and Irish scale the species is listed as 'critically endangered' (Jacoby & Gollock, 2014; King et al., 2011).

While eels are known for their remarkable ability to often climb and navigate even near-vertical structures as juveniles (glass eels, Watz et al., 2019; Tamario et al., 2019; Podgorniak et al., 2015), many sites were considered sub-optimal or even unsuitable for the species given the often high gradients, high-energy profiles and typically upland nature of the channels. The lower reaches of the Killanummery Stream, Argina River and, to a lesser extent the Owengar River, provided the best potential eel habitat overall, despite their apparent absence at the time of survey. However, given the life history of European eels, even sub-optimal (e.g. drainage channel or high-energy sites) may be utilised by the species as seasonal migration routes (i.e. adult migration seawards, usually from September/October onwards).

White-clawed crayfish

No white-clawed crayfish were recorded via trapping or sweep netting surveys across *n*=21 sites assessed in the footprint of Croagh wind farm. However, crayfish remains were recorded in otter spraint under bridges at sites A7 on the Killanummery Stream and site D3 on the Rathgeean River. Mustelid spraint surveys can help identify crayfish when present at cryptically low densities (Triturus pers. obs.). Previous studies in the wider catchment (IFI, 2016) noted that crayfish were absent from the upper reaches of the Killanummery although our record from the underneath the bridge at Killanummery suggests the species may be present further upstream than previously thought. It appears that crayfish are absent from the study area given conditions inimical to their survival (i.e. unsuitable geology, peatland afforested catchments & high energy channels). As stated however, the species may occur at locations further downstream where conditions improve (i.e. lower gradient channels with influences from geological changes with higher pH and alkalinity).

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APPENDIX 6-5

PEATLAND ENHANCEMENT AND BIODIVERSITY MANAGEMENT PLAN

Planning and Environmental Consultants

Peatland Enhancement and Biodiversity Management Plan

Croagh Wind Farm, Co. Leitrim & Co. Sligo

DOCUMENT DETAILS

Client: **Coillte Teoranta**

Project Title: **Croagh Wind Farm, Co. Leitrim & Co. Sligo**

Project Number: **180511**

Document Title: **Peatland Replacement and Enhancement Plan**

Document File Name: **PREP F – 2020.07.07 - 180511**

Prepared By: **MKO**
Tuam Road
Galway
Ireland
H91 VW84

Planning and Environmental Consultants

Rev	Status	Date	Author(s)	Approved By
01	Final	07/07/2020	DMN	PR

Table of Contents

1. INTRODUCTION

1.1 Background

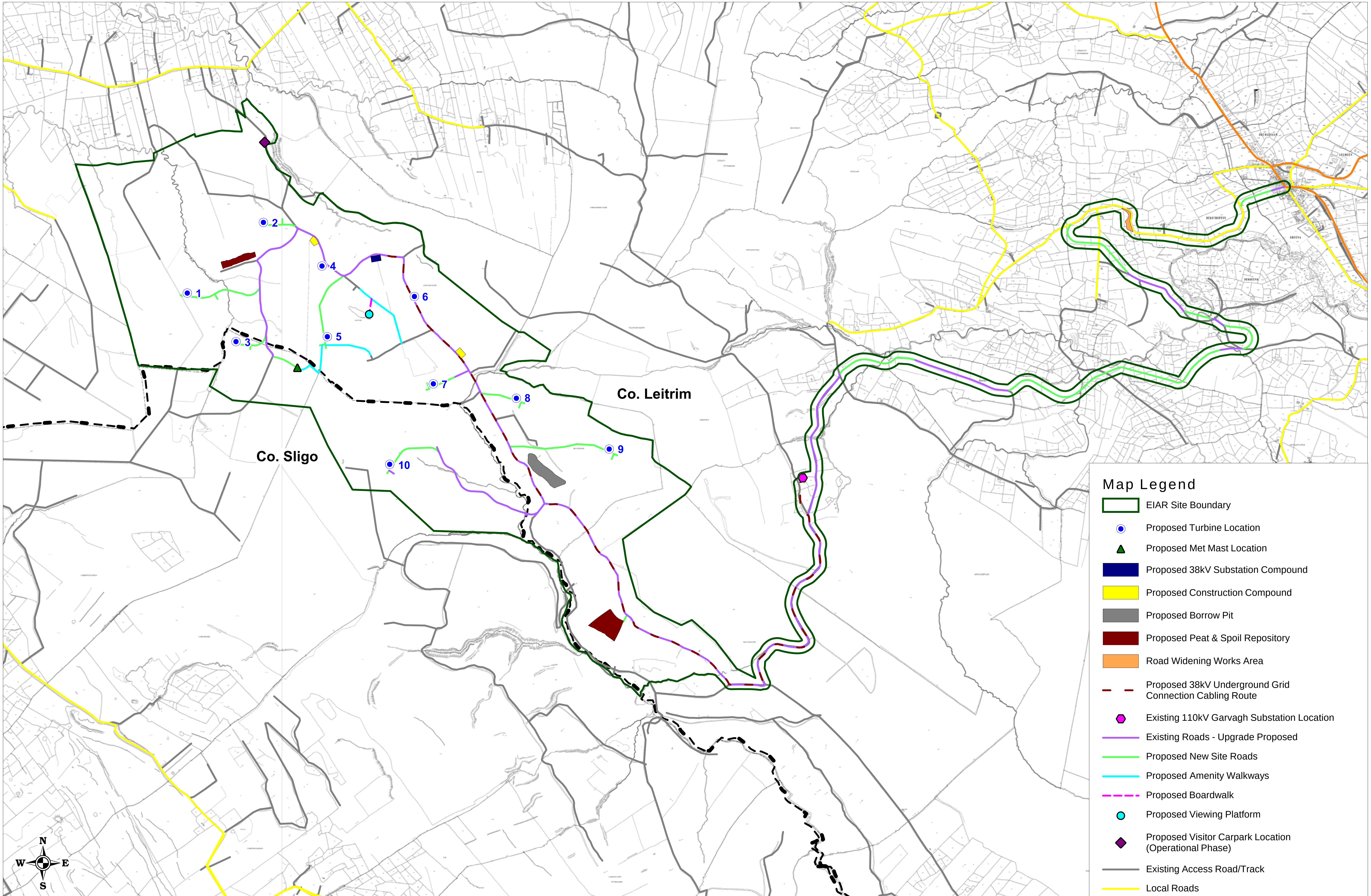
The proposed Croagh windfarm will result in the loss of approximately 0.38 hectares of peatland habitat that has been classified as conforming to the EU Habitats Directive Annex I habitat; Blanket Bog [7130]. However, this habitat does not form part of any Special Area of Conservation (SAC). The habitat loss is associated with a single turbine, Turbine no. 1. The drainage plan for the site has been specifically designed to limit the extent of impacts outside the immediate footprint of this turbine as much as possible. The proposed development layout is provided in Figure 1.1.

The area that will be lost, or degraded through drainage, to facilitate Turbine no. 1 will be compensated for in full by felling an equivalent area of land where conifers have been planted on blanket bog habitat. In addition, an area of blanket bog adjoining the proposed restoration area will also be enhanced through the implementation of drain blocking and encroaching conifers. This blanket bog covers an area of 3.74 hectares within the Coillte landholding. The establishing conifers on this area of bog have spread as a result of natural seed dispersal from the nearby plantation forestry, see Plate 1.1. Both the replacement area and enhancement area are provided in Figure 1.2. The combination of enhancing 3.74 hectares of degraded blanket bog (due to drainage and establishing conifers, growing as a result of natural seed dispersal) and locating the proposed compensation area of 0.38 hectares adjacent to this aims, to maximise the potential overall biodiversity benefits associated with the restoration plan.

Plate 1.1 Area of blanket bog identified for enhancement, drain blocking and coniferous tree removal, located to the north of T7.

The bog restoration programme will be implemented in accordance with the published guidelines and best practice such as the guidelines arising from the EU–LIFE/Coillte '*Irish Blanket Bog Restoration Project*' (2002-2007)', Scottish Natural Heritage (SNH)'s guidance note Planning for development: *What to consider and include in Habitat Management Plans* (Version 2, January 2014).

The areas to be restored will be located where forestry is to be felled to facilitate Turbine no. 7 and will be equal to or greater than the area lost to facilitate the Turbine no. 1.



MAP TITLE: **Proposed Development Layout**	MAP NO.: **Figure 1.1**	SCALE: **1:22,500**	
PROJECT TITLE: **180511 - Croagh Wind Farm**		DATE: **04-06-2020**	
DRAWING BY: **Eoin McCarthy**	CHECKED BY: **Michael Watson**	ISSUE NO.: **180511-2020.06.04-F**	

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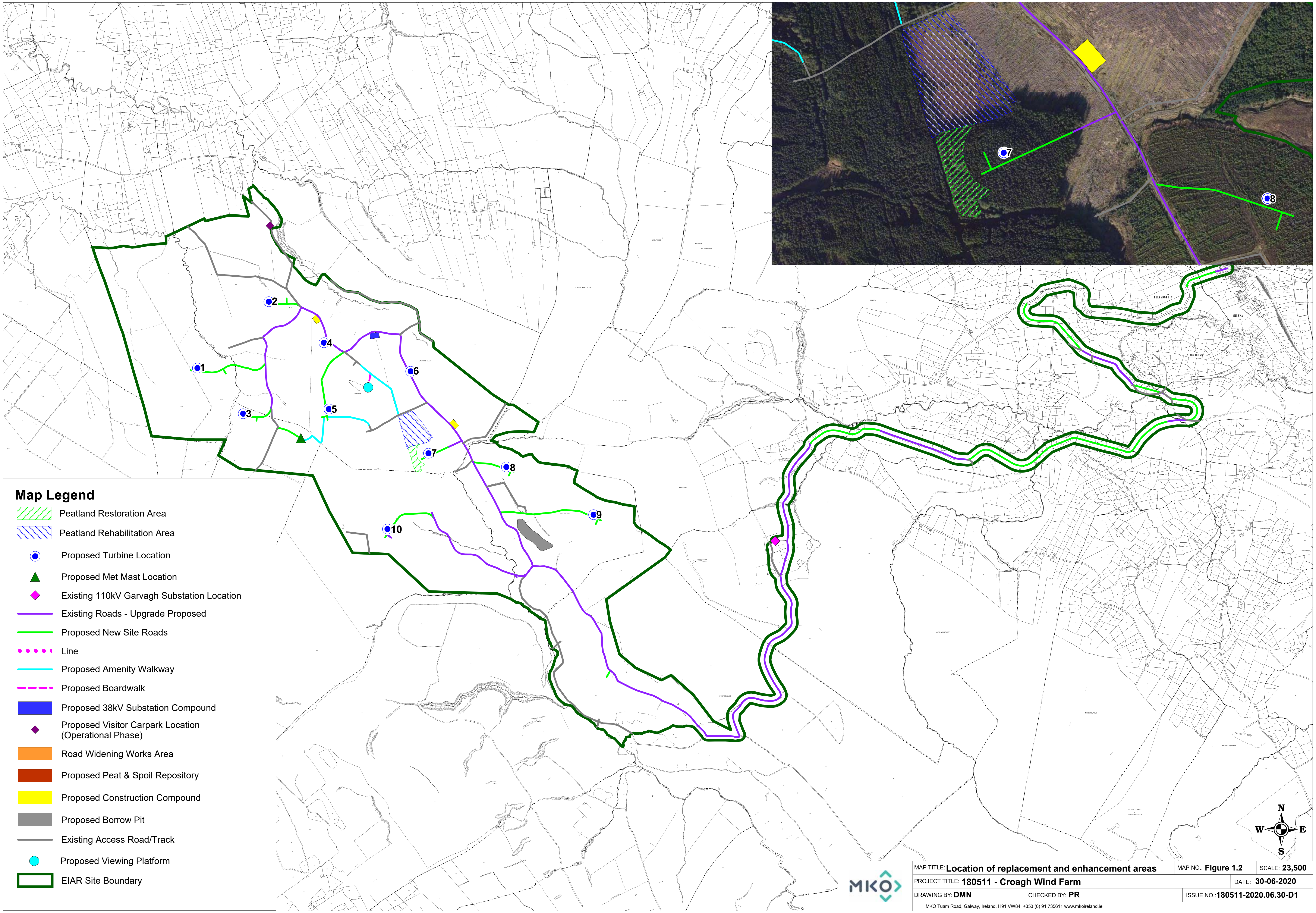

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1.1.1 Statement of Authority

This report has been prepared by David McNicholas and Pat Roberts (B.Sc. Environmental Science, MCIEEM). David McNicholas has over 9 years' professional ecological consultancy experience and is a full member of the Chartered Institute of Ecology and Environmental Management. Pat has over 14 years' experience in ecological management and assessment. The baseline ecological surveys were undertaken by David McNicholas (BSc., MSc., MCIEEM) and James Owens (BSc., MSc). James has over 4 years' consultancy experience and is a competent expert in undertaking ecological surveys.

2. MANAGEMENT PRESCRIPTIONS

2.1 Management techniques

2.1.1 Measures to be implemented within the peatland replacement area

The management techniques to be undertaken within the replacement area located around Turbine no. 7 are as follows:

- All coniferous forestry will be felled.
- Drains will be blocked, where appropriate, using peat dams or plastic dams, see Plate 2.1 & 2.2.
- The planting of forestry will not be permitted in this area.
- No vehicular access will be permitted to or within the dedicated peatland reinstatement area once all initial works are completed.
- Self-seeded conifers from adjacent conifer plantation areas will be cleared and removed (by hand or brushcutter) from the newly created peatland reinstatement areas on an ongoing basis, following the felling of the existing forestry.
- Peat extraction within the proposed peatland reinstatement area will not be permitted.
- Burning and dumping will not be permitted.

Plate 2.1 Example of peat dams to be used for on-site drain blocking.

Plate 2.2 Example of plastic dams to be used for on-site drain blocking.

2.1.2 Management measures to be implemented within the peatland enhancement area

The management techniques to be undertaken within the peatland enhancement area will include:

- Drains within and adjacent to the enhancement area will be blocked using peat dams or plastic dams.
- Self-seeded conifers that have established within this area of peatland from the adjacent conifer plantation will be cleared and removed (by hand or brushcutter). This will continue on an ongoing basis, following the implementation of the plan and any subsequent new growth.
- No vehicular access will be permitted to or within the peatland enhancement area once all initial works are completed.
- The planting of forestry will not be permitted in this area.
- Peat extraction within the proposed enhancement area will not be permitted.
- Burning and dumping will not be permitted.

2.2 Timing of Works

Replacement works will be conducted in line with the provisions of the Wildlife Acts 1979-2012 as amended.

2.3 Monitoring

The plan will be the subject of ongoing monitoring to assess the effectiveness of the measures proposed and employed and to contribute to advances in habitat management methods, which can be applied to future similar projects. The monitoring measures will include:

- Vegetation sampling: A number of fixed relevé sites (i.e. permanent quadrats) will be set up in areas where active management is proposed of previously forested areas. Baseline data will be recorded prior to the commencement of habitat management activities set out in this outline plan. The character of each relevé will be recorded (e.g. species proportions present, vegetation structure and height) and photographs will be taken of each relevé from a fixed point. These relevés will then be re-examined during years 1, 2, 3, 5, 10, 15 and 25 following commencement of the plan in place in order to establish the extent of habitat improvement resulting from management practices.

- Hydrological monitoring: Water levels within areas where drains are blocked will be recorded quarterly for two years. A number of phreatic stand pipes will be installed (prior to restoration) to allow monitoring of water levels within both the restoration and enhancement areas. In this way, any positive impacts on the local hydrology can be verified and quantified.

The efficacy of the habitat rehabilitation and enhancement measures employed will be reviewed in years 1, 2, 3, 5, 10, 15 and 25 following commencement of the plan on the basis of the results of vegetation sampling and water level readings from the managed areas. Analysis of the data collected will be the basis for a review of the measures and techniques employed.

2.4 Reporting

Reports detailing the monitoring works carried out, the results obtained and a review of their success, along with any suggestions for amendments to the plan will be prepared and submitted to the planning authority in years 1, 2, 3, 5, 10, 15 and 25 following commencement of the plan's implementation.

3. BIODIVERSITY ENHANCEMENT MEASURES

3.1 Native Tree Planting

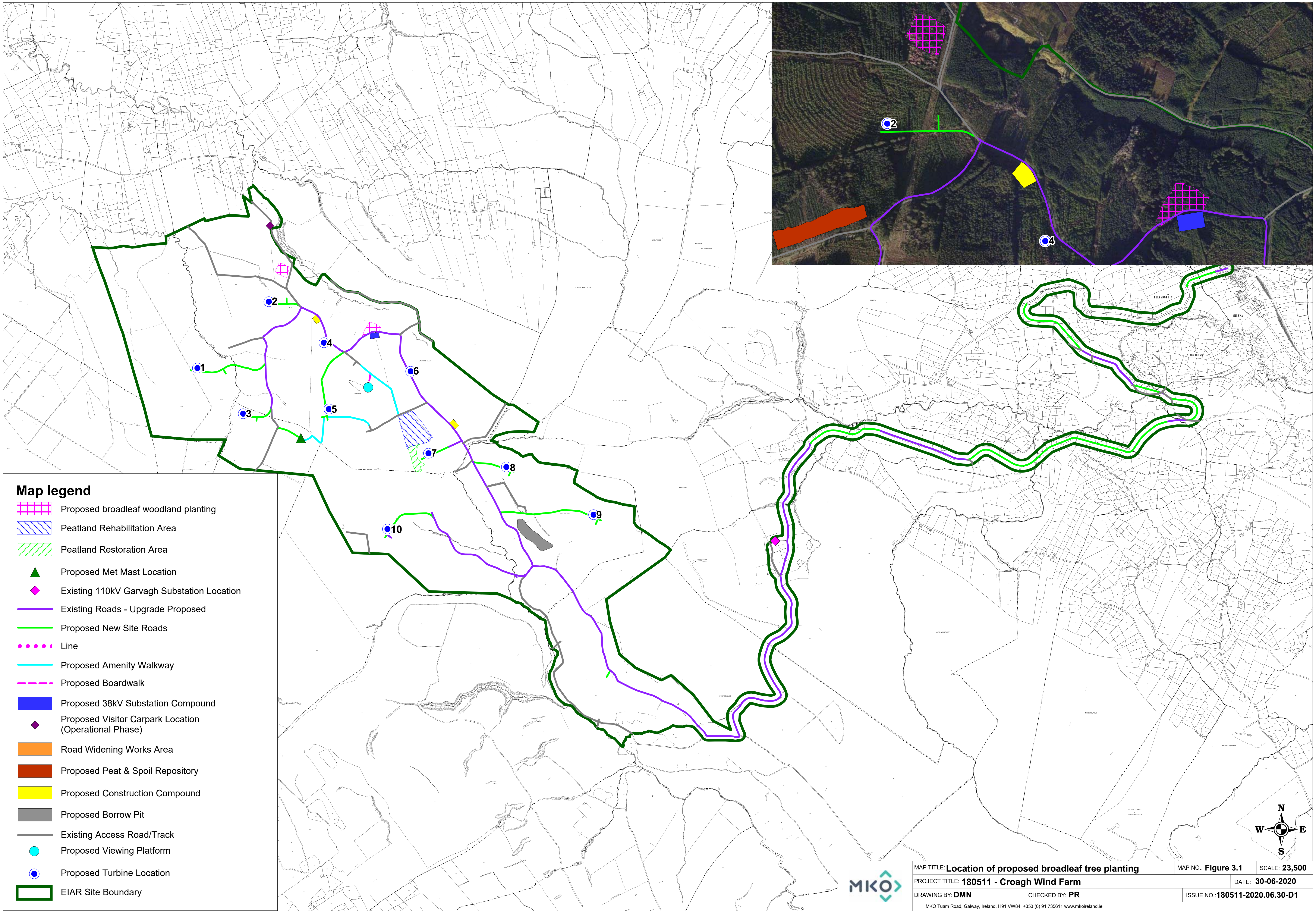
As part of the proposed amenity walkway infrastructure incorporated into the proposed project, as fully described in Chapter 4 of the EIAR, it is proposed to include native tree planting along this linear infrastructure. It is proposed to plant a 5-meter-wide strip on either side of the infrastructure. This will result in the creation of approximately 3 kilometers of native tree planting along the proposed amenity walkway'. An example of where native broadleaf tree species occur as a corridor along a forestry access track is provided in Plate 3.1.

Plate 3.1 Example of native willow's (Salix sp.) growing along a forestry access track. The proposed planting will be broader and more continuous, providing a commuting corridor for local faunal species.

The native tree species chosen for planting along the amenity infrastructure will include species already occurring in the wider area, as well as species adapted to establishing in upland acidic soils. For this reason, it is proposed to plant a mix of roan (*Sorbus aucuparia*), willow (*Salix* spp.), Scots pine (*Pinus sylvestris*), birch (*Betula pendula*) and hawthorn (*Crataegus monogyna*).

The planting of native woodland as part of the amenity aspect of the proposed development will enhance biodiversity locally as the species proposed are native, provide flowering plants for pollinators and seed for a wide variety of wintering bird and other faunal species.

In addition to planting along the amenity access tracks, it is also proposed to plant an additional two areas of broadleaf woodland comprising of 6,598.3 m^2 & 6,914.3 m^2. The location of these are shown in Figure 3.1. This equates to over 13,512.6 m^2 or 1.35 hectares of native broadleaf woodland planting within the site. This will provide a greater cover of native broadleaf woodland in the area. Such additional broadleaf woodland will contribute to a biodiversity net gain associated with the proposed development as well as the enhancement of the recreation and amenity walks proposed.



MAP TITLE: Location of proposed broadleaf tree planting	MAP NO.: Figure 3.1	SCALE: 23,500
PROJECT TITLE: 180511 - Croagh Wind Farm		DATE: 30-06-2020
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