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**Electrofishing and habitat survey to cover
the proposed Shepherd's Rig Wind Farm**

Appendix 9.4

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Summary

Electrofishing and habitat survey to cover the proposed Shepherd's Rig Wind Farm

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Contractor: Heather Kwiatkowski (Arcus Consultancy Services Limited)

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Keywords

Brown trout, electrofishing, Shepherd's Rig Wind Farm, Kirkcudbright Dee, Water of Ken, baseline monitoring.

Background

In late June 2018, the Galloway Fisheries Trust (GFT) were contacted by Arcus Consultancy Services Limited at an early stage of the planning process for the proposed Shepherd's Rig Wind Farm, situated near Carsphairn towards the northern edge of the Glenkens, Dumfries and Galloway. GFT were provided with an initial 30 turbine layout from which an assessment of fish species and habitats within the boundary of the wind farm was planned.

This report contains findings from baseline electrofishing, carried out by the GFT during the survey season of 2018 in order to inform the EIA and also act as a useful baseline dataset upon which comparison can be made in the future. The report also outlines any particular sensitivities of watercourses and fish populations that may be impacted by the development of the Shepherd's Rig Wind Farm.

Main findings

- Nine sites were surveyed within the Water of Ken catchment to provide fisheries information for the proposed Shepherd's Rig Wind Farm development. Surveys were carried out at the end of August 2018.
- Juvenile salmon were absent from each site as the survey area is upstream of the impassable Kendoon Dam and a further dam on the Water of Deugh.
- All nine sites held juvenile brown trout, generally in low to moderate density. Of these, seven sites held trout fry and parr, one site held trout fry only and one site held trout parr only.

- Stoneloach and minnow were the only non-salmonid fish species recorded during the survey. Stoneloach and minnow were found in relatively low numbers within each of the three Water of Ken main stem sites surveyed. Minnows were also recorded within site 6, the Dry Burn and site 2, the Polifferie Burn.
- The invasive non-native North American Signal Crayfish was found at three of the nine sites surveyed within the uppermost Water of Ken sites (site 5 and the control site) and at site 2, within the Polifferie Burn.
- Instream habitat quality for salmonids encountered throughout the survey sites ranged from a good to moderate standard but unlike other watercourses in Dumfries and Galloway, and indeed the Kirkcudbrightshire Dee system, numbers of fish encountered did not reflect the habitat quality. This is most likely to be due to the fact that the survey area is inaccessible to migratory salmonids that can 'top-up' resident brown trout numbers but also, that crayfish may be beginning to out-compete resident trout for shelter and food resources and also by direct predation upon them.
- The data obtained in this survey can inform the EIA and also act as a useful baseline dataset upon which comparison can be made in the future. If consent is granted for this development then it is important to establish a robust fish monitoring plan as a condition to cover the construction and post construction phases.

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1. INTRODUCTION

The Galloway Fisheries Trust (GFT) was commissioned by Arcus Consultancy Services Limited to carry out an electrofishing survey for the proposed Shepherd's Rig Wind Farm, near Carsphairn, Dumfries and Galloway.

Surveys were carried out on the Water of Ken, its associated tributaries and one small tributary of the Water of Deugh; all in the vicinity of the proposed development site with the aim of providing an overview of the fish populations present in the area, and also to provide baseline data to inform the Environmental Impact Assessment. The Water of Ken and Water of Deugh are major tributaries and sub catchments of the Kirkcudbrightshire Dee.

Electrofishing sites were selected following examination of the initial turbine layout and following discussion and agreement from Arcus Consultancy Services Limited. Sites were selected to best represent the fish populations residing within the proposed wind farm boundary and in specific areas downstream which have the potential to be affected by the development. Nine sites were selected and agreed with Arcus Consultancy Services Limited.

Electrofishing surveys were carried out in late August 2018.

The possible impacts that any land based wind farm development and its associated infrastructure could have on surrounding fish populations are well documented. The main potential impacts may occur during the construction and/or operational phases. During the construction phase potential impacts include noise disturbance, siltation from ground disturbance, accelerated or exacerbated erosion, hydrological changes, pollution and the blocking or hindering of the upstream migration of fish. During the operational phase, concerns include the effects of poor road drainage, accelerated levels of erosion, turbine noise and the maintenance of silt traps and road crossings. These potential effects could all impact on the surrounding fish populations by causing direct mortality of juveniles and adults, changes in food availability, avoidance behaviour resulting in unused habitat, blocking of migration routes to upstream spawning beds or the damage of instream and riparian habitats.

There is a variety of legislation, regulations and guidance in place relating to fish species that may be present in the watercourses in the Kirkcudbrightshire Dee catchment however little of this is relevant as there are limited fish species present in the Water of Deugh and Water of Ken sub-catchments. This area of the catchment is inaccessible to migratory fish due to the Kendoon Dam (on the Water of Ken) having no fish pass. Brown trout present in the Ken and Deugh system are a UK Biodiversity Action Plan Priority Species and numbers here are considered in general to be low and potentially declining.

2. METHODOLOGY

2.1 Data recording

The GFT is a partner in the Scottish Fisheries Co-ordination Centre (SFCC), an initiative involving, amongst others, the Scottish Fishery Trusts; Marine Scotland Science; The Tweed Foundation; the Spey Research Trust; the Tay Foundation and the Cromarty Firth Fisheries Trust.

This group has, in partnership, developed a set of agreed methodologies and record sheets for use with electrofishing surveys, and an associated database in which to record information gathered from such surveys.

The electrofishing surveys undertaken by the GFT have been completed to the standards that are required by the SFCC and recorded using the agreed formats.

2.2 Electrofishing techniques

To assess the fish population present within a section of river various techniques have been developed in the recent decades. The main method of determining the health of a fish population is by the use of electrofishing equipment (for full methodology see Appendix 2).

This technique involves the stunning of fish using an electric current which enables the operator to remove the fish from the water. Once captured, the fish recover in a holding container. They are then anaesthetised using a specific fish anaesthetic, identified to species, measured and recorded, and once recovered, returned unharmed to the area from which they were captured.

The method of fishing involves the anode operator drawing stunned fish downstream to a banner net held against the current by an assistant. A hand net operator completes the three-man team. Fish captured are then transferred to a water-filled recovery container. The team works its way across the section and upstream, thereby fishing thoroughly all the water in the surveyed area.

To obtain fully quantitative information on the fish populations within the river, each survey site is fished through up to four times consecutively to allow the calculation of a more accurate Zippin estimate of the fish population. A Zippin estimation of a fish population is a calculation carried out using a depletion method (multiple run fishing). This is an estimate of the fish population density per 100 m² of water, including the 95% confidence limits (this information is presented in Appendix 1). When the calculation of a Zippin estimate of the population is not possible, a minimum estimate of the fish population is given for that section of river.

Electrofishing was undertaken by a team of three SFCC accredited GFT staff at all survey sites.

It is policy to disinfect all relevant equipment both prior to and following work in each river catchment, to ensure that there is no transfer of disease organisms.

2.3 Electrofishing equipment used

A mobile, battery powered backpack electrofishing kit was used to undertake the survey. GFT employs the use of a 500 WATT E-Fish backpack electrofishing kit set to give a 300 volt output at 0.3 amps. All settings were set to maximise capture of juvenile salmonids. The backpack controller unit is linked to a stationary cathode of braided copper (placed

instream) and a mobile, single anode, consisting of a pole-mounted stainless steel ring and trigger switch is used instream to capture the fish.

Smooth direct current was used in all survey sites.

2.4 Age determination

Electrofishing surveys concentrate on juvenile salmonid species, namely salmon (*Salmo salar* L.) and trout (*Salmo trutta* L.). In the majority of cases age determination of the fish present can be made by assessment of their length and scale-sample readings. However, with older fish it is more difficult to clarify age classes by fish length alone and therefore in this survey salmonid fry (0+ fish) were classified alongside salmonid parr (1+ fish and older). Information on juvenile densities can be found in Appendix 1.

2.5 Non-salmonid fish species

At each site the presence of non-salmonid fish species was also noted. Population densities for these species were not calculated. This information is presented in Appendix 1.

2.6 Site measurement

At each site surveyed a total site length was recorded and average wet and dry widths calculated.

The average wet width was calculated from five individual widths recorded at equidistant intervals from the bottom of the site (0 m) to the top. At each site a final width was noted at the absolute upper limit of the surveyed water. From these site measurements the total area fished was calculated.

2.7 Bankside/Instream habitat assessment

At each site an assessment was made of the instream habitat available for older (parr aged) fish. This assessment graded instream cover present as none, poor, moderate, good or excellent. This grading provides an index of instream cover where diverse substrate compositions will score more favourably than areas of uniform substrate providing poorer cover.

In accordance with SFCC protocols, percentage estimates of depths, substrate type and flow type were made at each site.

Additionally, percentage estimates of the quantity of the bankside features undercut banks, draped vegetation, bare banks and marginal vegetation were made.

All of these bankside and instream habitat site features are summarised in Section 4. When reference to left or right bank is made, it is always left and right bank when facing downstream.

Specific electrofishing site and habitat information are presented in Section 4 and Appendix 1. Appendix 2 and Appendix 3 provide further information on terms used within the site description and habitat assessment.

2.8 Site selection

The sites surveyed were selected by agreement with Heather Kwiatkowski of Arcus Consultancy Services Limited. Sites were selected to best represent the fish populations

residing within the proposed wind farm boundary and in specific areas downstream which have the potential to be affected by the development.

In total, nine sites were surveyed for fish populations. Surveys were carried out over three days in August 2018.

3. RESULTS

3.1 Electrofishing results

3.1.1 Figures presented

The results of the electrofishing survey are outlined in Section 3.1.3 and presented in detail in Appendix 1 (*Results from baseline electrofishing survey on tributaries within and surrounding the proposed Shepherd's Rig Wind Farm, 2018*). These provide information on the population densities of juvenile salmonids at each site. Site code, watercourse, site location, O.S. Grid reference, survey date, non-salmonid species and area fished (m²) are also shown.

With regard to the juvenile salmonid age classes, these are separated into four categories, which are defined in Table 1:

Table 1: Salmonid age classes

Salmon Fry (0+):	Refers to young fish less than one year old resulting from spawning at the end of 2017.
Trout Fry (0+):	Refers to young fish less than one year old resulting from spawning at the end of 2017.
Salmon Parr (1+ and older):	Refers to young fish of greater than one year and greater than two years old (where present) from spawning years 2016 and 2015.
Trout Parr (1+ and older):	Refers to young fish of greater than one year and greater than two years old (where present) from spawning years 2016 and 2015. If captured, trout of up to three or four years old are also included in this category.

Within the electrofishing results, juvenile salmonid numbers recorded have been classified into several categories. A classification scheme for densities of salmonids was previously generated by the SFCC using data collected from 1,638 Scottish electrofishing survey sites, covering the period 1997 to 2002 (Godfrey, 2005¹). From this, regional figures were created to allow more accurate local ranges. The categories are based on quintile ranges for one-sample electrofishing surveys in the Solway region (Solway Salmon Fishery Statistical Region), allowing densities of fish observed to be put into a regional context. Table 2 shows these quintile ranges.

Table 2: Quintile ranges for juvenile salmonids (per 100 m²) based on one-sample electrofishing events, calculated on densities >0 over 291 sites in the Solway Statistical Region

	Salmon 0+	Salmon 1++	Trout 0+	Trout 1++
Minimum (Very Low)	0.22	0.38	0.38	0.35
20 th Percentile (Low)	5.21	2.86	4.14	2.27
40 th Percentile (Moderate)	12.68	5.87	12.09	4.71
60 th Percentile (High)	25.28	9.12	26.63	8.25
80 th Percentile (Very High)	46.53	15.03	56.49	16.28

¹ Godfrey, J. D., 2005; Site Condition Monitoring of Atlantic Salmon SACs: Report by the SFCC to Scottish Natural Heritage, Contract F02AC608.

- Site 8 (SRWF8): Marbrack Burn

Grid reference: 261375 595062

Salmon were absent at this site. Trout fry were present in moderate to high density. Trout parr were present in a low density. No non-salmonid fish species were recorded.

- Site 9 (SRWFC): Water of Ken

Grid reference: 264836 596140

Salmon were absent at this site. Trout fry were present in low density. Trout parr were not recorded. From the non-salmonid fish species, stone loach and minnows were also found. Five crayfish were also recorded at this site, increasing in number with each successive electrofishing pass.

4. DISCUSSION

4.1 Electrofishing sites

4.1.1 Site 1: Poldores Burn

Site 1 (*Figure 1*) was located on the Poldores Burn, a short distance upstream of an old bridge at the northern extent of the proposed wind farm site boundary.

The instream habitat at this site was considered to be of a good standard with substrates dominated by cobbles (50%) and boulders (10%). An underlay of smaller spawning material including gravels and pebbles accounted for 35% of substrates recorded alongside a small area of bedrock. Substrates were recorded as stable, uncompacted and not silted. Water depth throughout the site was relatively deep with 60% of the site recorded as over 40 cm deep. Wetted width averaged 2.5 m with flow types recorded as 60% torrent and 40% run, accounting for the recent heavy rainfall. Despite the lack of bankside cover (both bank faces were recorded as bare), canopy cover largely provided by out-reaching willow branches provided cover across 60% of the site. The burn lies within steep banksides, in a landscape of felled conifer forestry to the right bankside and rough pasture to the left bankside.



Figure 1: Site SRWF1, looking upstream

Salmon fry and parr were absent in this site. Trout fry were present in a low density (>4 fry per 100 m^2 of water) and trout parr were recorded at a high density (21 ± 2 parr per 100 m^2 of water). *Figure 2* shows a trout fry (bottom fish in picture) amongst various age classes of trout parr captured during this year's survey. No other fish species were present at this site.



Figure 2: Trout parr and a single fry found at site SRWF1

4.1.2 Site 2: Proliferie Burn

Site 2 (Figure 3) was located on the Polifferie Burn, a short distance downstream of a padlocked forestry gate where the burn could be safely accessed beyond a dyke from the road side.

The instream habitat at this site was considered to be of a very good standard with substrates primarily cobbles and boulders (together 85%) with some gravels and pebbles. Substrates were noted as stable, uncompacted and not silted. A wide range of water depths and flow types (60% of faster run/riffle and 40% of slow flowing glide flow type) combined to provide a diverse range of instream fish habitat. Wetted width averaged 6.6 m. Although both banks directly adjacent to the site were bare (due to low flows), overhanging vegetation in the form of tall herbs and long grass provided 10% cover from the left bankside and a mature willow tree provided overhang across 70% of the right bankside. Canopy cover was recorded as 15% shading the site. Land use to the right and left banksides was predominantly conifer forestry.



Figure 3: Looking upstream at site SRWF2

Salmon fry and parr were absent in this site. Trout fry were present in a low density (10 ± 3 fry per 100 m^2 of water). Trout parr were recorded in a good density of 8 ± 1 parr per 100 m^2 of water. Despite the findings of two crayfish at this site (including a large adult pictured in *Figure 5*) the trout appeared to be in good health. Minnows were the only other fish species recorded at this site.



Figure 4: Healthy brown trout parr captured within site SRWF2



Figure 5: The larger of two crayfish found within site SRWF2

4.1.3 Site 3: Craigengillan Burn

Site 3 (*Figure 6*) was located on the Craigengillan Burn, a short distance downstream of where a dyke reaches the burn from the left bankside. The Craigengillan Burn captures water shed from two burns and will be an indicator site of pressures that may arise directly from the construction of at least seven turbines to the north end of the potential wind farm site.

The instream habitat at this site was considered to be of a moderate standard, given the presence of soft peatland base and bedrock that accounted for 25% of substrates recorded. Where substrates could be felt (most substrates were not visible given the peaty colour of the water), these were considered to be mostly cobbles and very fine gravels, with small amounts of pebbles and boulders also recorded. Substrates were noted as stable, partly compacted and silted. Water depths and flow types ranged from deeper, slow-flowing glide and pool towards the upper and lower limits of the site; to shallow run and riffle upon the falls across the top third of the site. Wetted width averaged 1.5 m. Despite both banks being bare due to the peat base, overhanging rushes and grasses and some good undercuts provided 20% bankside cover on both banks. Land use to the right bankside was felled forestry and to the left bankside, lay a mature crop of conifer forestry.



Figure 6: Looking upstream at site SRWF3

Salmon fry and parr were absent in this site. Trout fry were present in a low density (>6 fry per 100 m^2 of water). Trout parr were found in a good density (12 ± 4 parr per 100 m^2 of water). No other fish species were recorded at this site.

The Craigengillan Burn captures two watercourses that drain the area of land within which up to eight turbines (turbines 5 to 12) are proposed. The burn's position within the proposed development make it highly susceptible to pollution events that may arise from the development of the wind farm construction and is considered sensitive from a fish perspective because it currently sustains a healthy population of juvenile brown trout (*Figure 7*).



Figure 7: Healthy brown trout fry and parr found within site 3

4.1.4 Site 4: Black Burn

Site 4 (*Figure 8*), was located on the Black Burn, a short distance upstream of the road. The Black Burn will capture pressures that may arise directly from the construction of turbines 23, 19 and 15 (which are positioned close to its path) and up to eight turbines positioned within 300 meters.

The instream habitat at this site was considered to be of a moderate standard. Despite a good range of substrates recorded (50% cobble/boulders and 40% gravel/pebble), the site also contained 10% sand and was felt to be partly compacted, particularly within pool areas where the only two trout found in the survey were captured. Given the gradual incline of the site, water depths and flow types recorded were mainly shallow fast-flowing run and riffle. A small amount of deeper holding water and slow-flowing shallow glide was also recorded. Wetted width averaged 1.6 m. Despite both banks being bare due to the peat and sand base, overhanging bracken and grasses provided 10% fish cover on both banks. Small areas of undercut bankside was also evident but gave little cover due to lack of flow reaching the bankside under the current water height. Mature conifer forestry over 10 m back from each bank allowed dappled shading across the site and provided a canopy cover of 40%.



Figure 8: Looking upstream at site GWF4

Salmon fry and parr were absent in this site. Trout fry were absent and trout parr were present in a moderate density (>4 parr per 100 m² of water). No other fish species were recorded at this site. Poor water quality, over shading and partly compacted gravels may be some of the pressures which are presently limiting fish production at this site.

4.1.5 Site 5: Water of Ken

Site 5 (*Figure 9*), was located on the Water of Ken, out with and to the East of the wind farm boundary. This site will be key to monitoring pressures that may arise from the majority of watercourses draining the wind farm boundary.

The instream habitat at this site was considered to be of a good standard, given the generous fish cover provided by 60% cobbles and 20% boulders. An area of 143 m² of channel was electrofished where a shallow gradient upwards provided a range of river

depths (up to 50 cm deep) and faster flow types (60% riffle and 40% run), especially towards the left bankside. Substrates were recorded as stable, uncompacted and not silted. Wetted width averaged 15.2 m. Bankside cover was recorded as negligible on the left bankside, however larger rocks and some draped vegetation contributed 20% fish cover along the right bankside. Although the river is fenced off along the right bankside (most likely to isolate the forestry), the banksides are lightly grazed by sheep. No tree cover exists adjacent to the site and on each bank along the entire length of river in this area. Open moorland and rough pasture are the main land uses to the left bankside whilst young conifer forestry covers the reach of land on the right bankside up to the road.



Figure 9: Site SRWF5, looking upstream

Salmon fry and parr were absent in this site. A low density of trout fry and parr were present (>7 fry and >2 parr per 100 m² of water). Minnows and stone loach were recorded in good numbers at this site. Two North American Signal Crayfish were also captured. The damage noted on some of the trout tails recorded may be as a direct result of crayfish attacks (*Figure 10*).



Figure 10: Trout fry and a parr captured in site 5

4.1.6 Site 6: Dry Burn

Site 6 (*Figure 11*), was located on the Dry Burn, a 100 m upstream of the road. This site will be key to monitoring pressures that may arise from construction of turbines at the southern end of the proposed wind farm boundary (particularly from turbines 25, 26, 29 and 30).

An area of 56.6 m² of gently winding channel was electrofished through a variety of pool and run/riffle flow types. The instream habitat at this site was considered to be of a moderate standard. Despite the good range of substrates present including 40% cobbles and 10% boulders, the presence of sand and silt was notable as limiting spawning potential in the burn by partially compacting smaller substrates present. In general, instream cover was fairly limited under the low flow conditions that the survey was undertaken. Wetted width averaged 1.3 m. Bankside cover was recorded as negligible on the left bankside and only 5% on the right bankside provided by some undercut banking (any bankside cover available was largely underutilised due to the most marginal areas being dry under the low flow conditions that the survey was undertaken). Bankside verges were notably soft and susceptible to collapse given their soft clay sediment construction. Mature conifer forestry lay around 10 m back from each banking, allowing dappled light to reach the burn. However, the lack of vegetation layers beneath the forestry is one reason for bank instability surrounding the site.



Figure 11: Site SRWF7, looking upstream

Salmon fry and parr were absent in this site. A low density of trout fry and parr were present (>5 fry and >3 parr per 100 m² of water). Minnows were also recorded in low density at this site. Because of the lack of fish in this burn, the burn is not considered particularly sensitive for fish.

4.1.7 Site 7: Water of Ken

Site 7 was located on the Water of Ken at the most southerly point of the wind farm boundary. This site captures all watercourses draining the wind farm except for the Marbrack Burn which drains to the Western edge of the proposed development.

A site of 184 m² was electrofished from the left bankside across half of the channel. River levels were rising during the survey and prevented the entire channel from being electrofished. Wetted width averaged 10.5 m. The site contained a good mixture of substrates to provide shelter for parr (50% cobbles and 10% boulders) and suitable habitat for spawning (30% pebble and 10% gravel). Water levels were mostly deep, given the very recent heavy rainfall. 20% of flow was recorded as torrent reflecting the high water conditions and otherwise, the channel presented fast flowing run/riffle flow type. Both banksides were bare. The left bankside was not reached under the survey river level but was highlighted as impacted by bank erosion and pressures of livestock grazing. Canopy cover was limited by the lack of tree cover on the left bankside. Should the right bankside have been fished, it is expected that overhanging willows would provide some cover for resident brown trout.



Figure 12: Site SRWF7, looking upstream from the right bankside

Salmon fry and parr were absent in this site. A very low density of trout fry and parr were present (>1 fry and >1 parr per 100 m² of water). Minnows and stone loach were also recorded, particularly in marginal habitat along the left bankside. Because of the lack of fish recorded, the river is not considered particularly sensitive for fish species in this location.

4.1.8 Site 8: Marbrack Burn

Site 8 was selected to monitor fish species that may be impacted by the construction of the turbines and associated access roads along the north western fringe of the development (turbines 1, 5 and 10).

A site of area 33.1 m² was electrofished in open moorland adjacent to a large crop of mature conifer forestry, where the burn captured all watercourses draining west from the proposed wind farm boundary. Substrate cover was moderate and comprised of 80% gravel and 20% fine organic matter. The fine gravels present were recorded as stable and partly compacted. No silt was recorded at this site. Flows were recorded primarily as faster run/riffle type (60%) except within a deep pool towards the middle reaches (covering 10% of site) and some shallow glide. Overhanging bankside vegetation in the form of rushes provided fish cover across 50% of the right and left banksides. Some undercut banking was also noted across 20% of each bankside. No tree cover existed at the site. In general, given the good bankside cover and open moorland setting upon which the burn lies, this site was expected to contain a good density of juvenile trout.



Figure 13: Site SRWF8, looking upstream

Salmon fry and parr were absent in this site. A moderate to good density of trout fry (21 ± 3 fry per 100 m^2) and a low density of trout parr were present (>3 parr per 100 m^2 of water). This site is considered sensitive from a fisheries perspective since it contains the greatest abundance of trout fry within the sites sampled to gather baseline fisheries data to inform the development of Shepherd's Rig Wind Farm.

4.1.9 Site 9: Water of Ken – Control Site

Site 9 was selected out with and upstream of the proposed wind farm development to represent a control site (a site representative of fish populations in the catchment but lying out with any impacts imposed by the development of the wind farm).

A site of area 157.4 m^2 was electrofished upstream of a bend where the channel contained a suitable break point beneath a tree at the upstream limit (*Figure 14*). Substrate cover was moderate and comprised of 60% gravel and 40% pebble. Gravels were recorded as very mobile and some sink holes were noted in the downstream section of river bed surveyed. Along the left bankside, the channel was shallow with little flow, becoming much deeper towards the right bankside where run/riffle flow types were present and water depths recorded exceeded 50 cm. An exposed gravel bed running the entire length of the left bankside accounted for the lack of cover on this bank. Despite notable bankside erosion on the lower section of the right bankside, 30% fish cover was provided along this length through a mixture of marginal rooted vegetation, overhanging vegetation and some undercut banking. Land use was dominated by rough pasture and tall herbs with the road running parallel to the channel some 20 m away from the site.



Figure 14: Site SRWFC, looking upstream

Salmon fry and parr were absent in this site. A low density of trout fry were recorded (>4 fry per 100 m^2). No parr were sampled within the site although one was disturbed in a pool downstream and out with the site when testing equipment. Minnows and stone loach were also recorded at this site. Five crayfish were also collected, increasing in numbers with each successive survey fishing run. Recruitment of crayfish looks to be well established in the Water of Ken catchment judging by the variety of age classes present within this single site. It was noted that the bare and eroded steep banking along the right bankside of site 9 would provide excellent burrowing habitat for crayfish to utilise although they were not noted to be doing so at present.



Figure 15: Trout fry from site 9 displaying typical tail damage as a result of direct crayfish attacks



Figure 16: A well-established population of crayfish found inhabiting the Water of Ken within the control site

5. APPENDIX 1: RESULTS FROM BASELINE ELECTROFISHING SURVEY ON TRIBUTARIES WITHIN AND SURROUNDING THE PROPOSED SHEPHERD'S RIG WIND FARM, 2018

Site Code	Watercourse	Site Location	Grid Ref	Survey Date	Presence Of Other Species*	Area Fished (m ²)	Density per 100 m ² **			
							Salmon Fry (0+)	Salmon Parr (1+ and older)	Trout Fry (0+)	Trout Parr (1+ and older)
SRWF1	Kirkcudbright Dee, Water of Ken, Poldores Burn	Upstream of bridge	263244 596208	23/08/18	-	42.8	0	0	>4	21±2
SRWF2	Kirkcudbright Dee, Water of Ken, Polifferie Burn	Downstream of padlocked gate	263553 595151	30/08/18	M, ASC	116.8	0	0	10±3	8±1
SRWF3	Kirkcudbright Dee, Water of Ken, Craigengillan Burn	Adjacent to dyke	262530 594270	23/08/18	-	42.9	0	0	0	12±4
SRWF4	Kirkcudbright Dee, Water of Ken, Black Burn	Upstream of road	263256 593715	22/08/18	-	41.8	0	0	0	>4
SRWF5	Kirkcudbright Dee, Water of Ken	Downstream of deer fence	263448 593168	30/08/18	SL, M, ASC	143.5	0	0	>7	>2
SRWF6	Kirkcudbright Dee, Water of Ken, Dry Burn	Upstream of road	262884 591670	23/08/18	M	56.6	0	0	>5	>3
SRWF7	Kirkcudbright Dee, Water of Ken	Adjacent to forest ride	262566 590956	22/08/18	SL, M	184.0	0	0	>1	>1
SRWF8	Kirkcudbright Dee, Water of Deugh, Marbrack Burn	Adjacent to corner of forest block	261375 595062	22/08/18	-	33.1	0	0	21±3	>3
SRWFC	Kirkcudbright Dee, Water of Ken	Upstream of Strahanna Bridge	264836 596140	30/08/18	SL, M, ASC	157.4	0	0	>4	0

* E = Eel, SL = Stoneloach, M = Minnow, Pi = Pike, Pe = Perch, North American Signal Crayfish = ASC

** Where a Zippin calculation could be carried out, 95% confidence limits are shown. Where only the number appears, a Zippin estimation could not be carried out. In these cases the number represents a minimum estimate of fish density per 100 m² of water.

6. APPENDIX 2: SFCC ELECTROFISHING METHODOLOGY

- **Introduction**

Electrofishing is a technique that is widely used in fisheries research. In order to ensure that the technique is used in a consistent way and collects comparable data, the SFCC have a protocol that is used by its members when undertaking electrofishing surveys. There are separate protocols dependent upon the type of survey being carried out.

- **Personnel**

As a standard, the SFCC protocol states that a minimum of three people are required for generator powered electrofishing operations for Health and Safety reasons.

- **Semi and Fully-Quantitative surveys**

Semi-quantitative electrofishing surveys allow population estimates with a low precision to be made. The simplest form of a semi-quantitative survey is a single run electrofishing survey, where the numbers of fish caught give a minimum estimate of the fish population density within the site, presented as fish per 100 m². This method is used to evaluate broad differences in fish populations where exact numbers are not required.

If a more accurate estimate of fish population density is to be made then fully-quantitative electrofishing surveys must be undertaken by depletion sampling. Here, an estimate of fish population is made by collecting fish from a series of electrofishing runs performed at the same site. The number of runs undertaken depends on the proportion of fish caught during each run (to limit runs to two; there must be a good depletion in fish caught between run one and run two). Under the SFCC protocol, surveyors have the opportunity to perform up to four electrofishing runs per site and an accurate population estimate will require that at least 30% of the fish within the site are caught during each run. Confidence limits for a given population estimate can be derived from this method.

- **Methodology**

Site selection is carried out prior to undertaking the electrofishing survey. The specific location of the survey site is assessed by surveyors whilst on site as there may be features within the river environment that naturally delineate the specific area to be surveyed. In cases where stop nets are not in use; a site is selected where a natural barrier forms the upstream end of the site (this is usually a set of falls or area where fish are likely to be deterred from easily passing upstream of).

Once the site has been selected, the electrofishing team will set up the equipment and begin fishing. As fish are attracted to the anode, they are swiftly removed from the vicinity of the electrofishing ring by the hand net operator and placed in a bucket of water. As the team moves through the site, in an upstream direction, any fish captured are placed in the bucket. When the upstream end is reached, the fishing run ends and the fish are kept in a clearly marked bucket for further processing. The water in the bucket is replenished to reduce stress due to de-oxygenation of the water. The bucket is placed in a shaded area to prevent temperature stress.

Before processing of the fish can begin, they are transferred into a bucket of anaesthetic, where they remain until no longer exhibiting signs of movement. They are then placed upon a wet measuring board and measured. Fork length measurements (the distance from the snout of the fish to the fork in its tail) are used as a standard way of measuring the fish.

Scale samples may also be taken at this time, by using either a pair of tweezers or a sharp knife to remove scales from a specific area on the fish. This is generally only suitable for large fry or parr. Using fish measurement alone, it is usually possible to clearly identify fry (0+) aged fish from parr (1+) aged fish due to a distinctive gap in fish found between the two age classes. Where this gap is not distinctive, it may be necessary to take a scale sample to determine with use of a microscope, the age class of the fish. Reading of scale samples is also useful if parr are to be individually aged (1+, 2+, 3+ etc). Once the fish have been processed, they are placed in a bucket of fresh water to recover. Once processing has been fully completed, the fish are released back into the river.

A habitat survey for the electrofishing site is recorded using SFCC protocol. Photographs of the site may be taken to allow the exact area of river to be identified in future surveys.

7. APPENDIX 3: SFCC GENERAL HABITAT SURVEY

• Introduction

The Scottish Fisheries Co-ordination Centre (SFCC) developed a general habitat survey method that addresses the needs of fisheries managers and researchers. It was specially developed to assess habitat for juvenile salmon and trout and not used to evaluate habitat for other fish species.

Although a full SFCC habitat survey (which involves surveying the whole river and its tributaries) was not undertaken, smaller but detailed general habitat surveys were undertaken at each electrofishing site.

The survey methodology takes into account many recording requirements and information gathered about river stretches using SFCC fish habitat survey protocol can be used by trained interpreters and within reason to:

- Evaluate quality of habitat for juvenile salmonids
- Identify the potential location of salmonid spawning gravels
- Identify stream stretches that would benefit from habitat improvements
- Target areas for stocking
- Identify and classify point pollution sources
- Identify and grade obstacles to fish migration
- Identify location and type of past channel/bank modifications

Juvenile salmonids have specific habitat requirements. For example, water quality, shelter, feeding territory and availability of food. Table A describes some basic habitat requirements for different life stages of salmon and trout. The precise habitat requirements for each species and life stage are extremely complex, and have therefore been simplified here.

Table A: Age class habitat requirements of salmonids

Life stage	Salmon	Trout
Eggs/alevins	Golf ball to tennis ball sized substrate	Dependent on fish size: Golf ball to tennis ball sized substrate for large brown trout and sea trout, pea to golf ball sized material for smaller trout.
Fry	Golf ball to tennis ball sized substrate, fast flowing, shallow broken water	Golf ball to tennis ball sized substrate, slow to medium flowing shallow water, often concentrated at stream margins.
Parr	Tennis ball to football sized substrate, fast flowing broken water, often slightly deeper than fry	Variety of substrate, undercut banks, tree roots, big rocks, deeper slower water.
Smolts	Unknown	Unknown.
Adults	Deep pools	Deeper areas, sustained flow but not too fast, undercut banks, tree roots, good instream vegetation and large rocks.

- **Data recording**

During the electrofishing survey, habitat survey data is collected on the following to obtain a full review of the suitability of fish habitat along a river system:

- Water depth
- Water flow type
- Instream characteristics
- Bankside characteristics
- Riparian vegetation
- Surrounding land use

Information may also be collected on potential causes of unsuitable habitat, particularly with a view to taking action against further degradation. Characteristics are collected such as:

- Bankside fencing and grazing
- Bankside erosion and collapse
- Pollution sources

- **Method**

The habitat survey is undertaken after electrofishing the site has been completed.

- **General definitions**

- *Instream cover*

At each site a subjective assessment was made of the instream habitat available for older (parr-aged) fish. This assessment graded instream cover present as none, poor, moderate, good or excellent.

- *None* - No cover; stream bed composed entirely of fine uniform particles (e.g. silt, sand, gravel, pebbles) or continuous hard surfaces (bedrock, concrete).
- *Poor* - Little cover; stream bed composed predominantly of fine to medium particles (e.g. gravel, pebbles and cobbles), little or no cover from aquatic vegetation.
- *Moderate* - Moderate cover; stream bed composed of a mix of substrate sizes (e.g. gravel to boulders) and/or with some areas of Good cover (e.g. pebbles, cobbles, boulders), which may or may not have some aquatic vegetation cover.
- *Good* - Good cover; stream bed composed predominantly of medium to large size substrate (e.g. pebbles, cobbles, boulders) and/or with some aquatic vegetation cover.
- *Excellent* - Excellent cover; stream bed composed predominantly of large size substrate (e.g. cobbles and boulders) and/or with extensive aquatic vegetation cover.

- *Site area*

The site length is taken along with wetted width, bed width and bank width at a representative number of points within the site. This gives a value for the area fished in order to calculate the Zippin (1958) estimate (number of fish per 100 m²).

- *Water depths*

The survey stretch wetted are is recorded as percentage depths in six categories:

- <10cm
- 11-20cm
- 21-30cm
- 31-40cm
- 41-50cm
- >50cm

- *Substrates*

In each survey stretch the percentages of each substrate type is recorded. Substrate is always recorded from the point of view of fish cover.

- High organic - Very fine organic matter
- Silt - Fine, sticky, mostly inorganic material
- Sand - Fine, inorganic particles, <=2mm diameter
- Gravel - Inorganic particles 2-16mm diameter
- Pebble - Inorganic particles 16-64mm diameter
- Cobble - Inorganic particles 64-256mm diameter
- Boulder - Inorganic particles > 256mm diameter
- Bedrock - Continuous rock surface
- Obscured - Something obscuring substrates that cannot physically be moved

- *Flows*

Flow percentages of the survey stretch wetted are recorded.

Table B: Flow percentages and descriptions

<i>Flow type</i>	<i>Description</i>
Still marginal	<10cm deep, still or eddying
Deep pool	>=30cm deep, water slow flowing, smooth surface appearance
Shallow pool	<30cm deep, water slow flowing, smooth surface appearance
Deep glide	>=30cm deep, water flow moderate/fast smooth surface appearance
Shallow glide	<30cm deep, water flow moderate/fast, smooth surface appearance
Run	Water flow fast, unbroken standing waves at surface, water flow silent
Riffle	Water flow fast, broken standing waves at surface, water flow audible
Torrent	White water, chaotic and turbulent flow, noisy and difficult to distinguish substrates

- *Bankside cover*

For each bank the percentage of bank length creating physical cover for fish in the site is recorded under the following categories:

- *Undercut* - Fish cover provided by undercut banks.
- *Draped* - Fish cover provided by vegetation rooted on the river bank and draping on to the water surface.
- *Bare* - No cover for fish, or fish cannot get to the cover due to lack of water.

- *Marginal* - Fish cover provided by plants rooted in the stream bed (includes tree roots). Fully aquatic vegetation is excluded from this category.

- *Bank face vegetation*

For each bank the predominant vegetation structure on each bank face. Vegetation must be rooted on the bank face and/or overhanging the bank face. Information is characterised in the following categories:

- *Bare* - Predominantly bare ground (or buildings/concrete), <50% vegetation cover.
- *Uniform* - Predominantly one vegetation type, but lacking scrub or trees.
- *Simple* - predominantly 2-3 vegetation types, with or without scrub or trees, but including tall and short herbs (e.g. nettles and grasses).
- *Complex* - Four or more vegetation types which must include scrub or trees.

Vegetation type does not refer to which species of plant are present. Reference is made primarily to structural complexity (e.g. short grasses versus long grasses/nettles versus taller trees).

- *Overhanging boughs*

For each bank the percentage of bank length is recorded where there are branches from trees and shrubs rooted in the riparian zone overhanging the site.

- *Canopy cover*

The percentage of the site (wetted area) which is covered by overhanging branches is estimated.