FISHERIES MONITORING OF THE RIBBLE CATCHMENT 2018

The Ribble Rivers Trust

ABSTRACT

This year marks the 20th anniversary of The Ribble Trust and its catchment-based approach to conservation and river restoration. This report provides information of the inter-annual fisheries monitoring programme and an insight into the catchment's health

Adam Wheeler

Fisheries Monitoring Officer

Ribble Rivers Trust
C/O Hanson Cement
Ribblesdale Works
Clitheroe
BB7 4QF

Phone: 01200 444452
E-mail: admin@ribbletrust.com

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Prepared for: The Ribble Rivers Trust

Authored by: Adam Wheeler - Fisheries Monitoring Officer

Checked by: Mike Forty - Catchment Science Co-ordinator

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Acknowledgments

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Executive Summary

The Ribble Rivers Trust concluded its 11th year of its fisheries monitoring programme of the Calder, Hodder and Ribble catchments. Repeat surveys have also been performed on the River Darwen to continue the capital work assessment from the Ribble Life Together programme, complimentary radio tracking surveys have also been completed on this catchment to monitor the success rate of the fish easements that were installed in 2018. Results of electric fishing surveys are used to support and identify future works as well as monitoring the long-term impacts of migration and habitat restoration schemes.

Quantitative and semi-quantitative surveys are performed to assess catchment productivity using an adapted Crozier and Kennedy (1994) electric fishing method. As juvenile fish densities change rapidly with age, surveys are conducted at a similar time each year (June – October) and in the same area to allow for valid comparisons. A total of 333 sites were surveyed in 2018 covering 5 sub-catchments. Salmonids are a keystone species within the river system, they rely on ecological stability and are indicators of water and habitat quality. The Ribble Trust uses the National Fisheries Classification System (NFCS) to allow for the standardisation of results by grading sites based on the densities of fry. With 2018s summer dominated by warm weather with mean temperatures of 17.2°C and below average rainfall, drought conditions were seen across the Ribble catchment during the survey season. 70 out of the 333 electric fishing sites were revisited due to unfishable water levels or completely dry riverbeds. There were concerns for the +0 salmonids targeted during the survey season, as fry are more sensitive to extremely low flows due to poor mobility and ability to seek refuge. Surveys commenced on the 10th of June and ended on the 2nd of October.

Brown trout (*Salmo trutta*) populations remain strong with fluctuations observed over the past 9 years (Figure 1). The most notable improvements have occurred on the Calder catchment with grade-scores increasing in the past two years, this is a population that has recovered from damaging floods of Boxing Day 2015. In addition to the highest cumulative grade-score the catchment has seen the observed numbers of trout parr have more than doubled from 2017. This indicates that brown trout abundance is returning to expected levels.

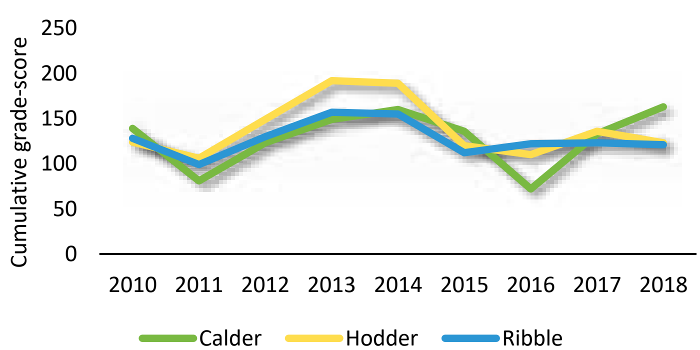


Figure 1. Total grade-score for sub-catchments electric fishing sites with 9 years of consecutive data for brown trout 2010 to 2018

Overall there has been an increase in the number of sites producing trout fry in comparison with 2015 and 2016 with 12 out of 29 sites having improved from F-grades to C-grades and above. There has also been a positive shift in A and B grade sites with 52 additional sites from last year reaching the highest grade-scores. The majority of sites that have seen a grade reduction are in areas that have been impacted by lower water and drought conditions, these sites have been highlighted for future years to monitor their recovery. This year a total of 4222 fry, parr and adult brown trout were captured in 253 out of the 333 electric fishing sites. This is an increase of 801 individuals in comparison to 2017

This year has seen an increase in the number of Atlantic salmon (*Salmo salar*) fry caught on the Ribble catchment. However even with an increase in the number of salmon fry on the Hodder and Ribble catchments there is minimal change in the cumulative grade-score (Figure 2). The Hodder once considered the best spawning habitat on the Ribble has had a second-year decline with 20 % reducing in grade-score. Strongholds for spawning are found on the tributaries around Dunsop Bridge where sites are consistently producing results as well as on the main stem below Slaidburn; this is where the highest salmon fry densities were recorded in 2018 with 97 individuals caught in a 5-minute survey (212 fry/100m²).

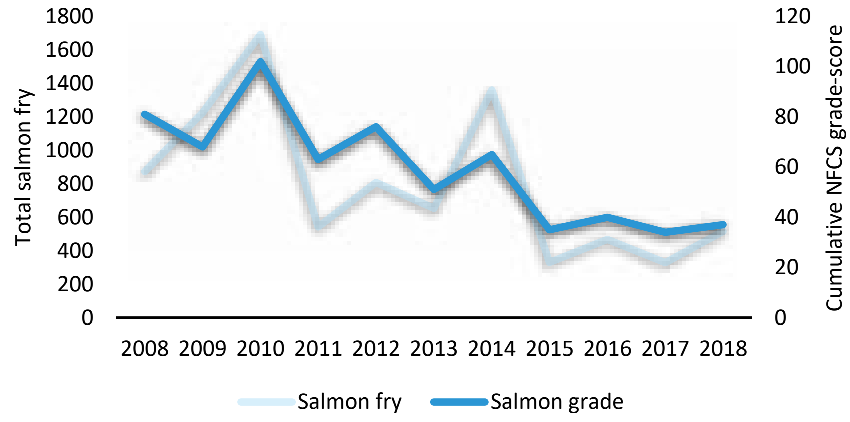


Figure 2. Cumulative NFCS grade-score and total calculated fry/100m² for the catchments 155 electric fishing sites holding 9 years of consecutive data for Atlantic salmon 2010 - 2018.

The main Ribble has seen no grade-score change for 2018, but the number of sites producing ‘Fair’ to ‘Excellent’ result are minimal with 81.6% of salmon sites been allocated D to E-grades. The Calder remains a poor catchment for salmon spawning with limited waterbodies surveyed producing fry. Sabden and Hyndburn Brook are the only two tributaries in which salmon fry are being regularly recorded and additional sites have been highlighted to try and locate established spawning location upstream of what was Padiham Weir. Additional sites have also been selected for the monitoring of the Oakenshaw by pass channel as salmon fry have again been recorded downstream of the weir and parr captured above during a radio tracking study. It is thought that the salmon parr has migrated upstream using the bypass channel as there has been no evidence of spawning in this location. During 2018 surveys a total of 1149 salmon fry and parr were captured in 67 out of 333 electric fishing sites. This is an increase of 680 individuals in comparison with 2017’s surveys

A notable change for 2018 is the number of chub (Squalius cephalus) fry and juveniles that have been recorded on the catchment with total of 21 location marked close to or on the main stem of the Ribble. Chub have also been recorded by the Trust on the River Darwen, upstream of Hoghton Weir. The Chub were captured during an electric fishing exercise meant to be targeting brown trout for a radio tracking study of the newly constructed fish easement.

The Ribble Trust has recorded a new location for white-clawed crayfish (*Austropotamobius pallipes*) on the Ribble catchment. During a fish rescue on West Bradford Brook this egg laden female (Figure 3) delayed works for the construction of an embedded rock ramp in June 2018. Once hatched the juveniles will remain attached to the mother before becoming independent at the beginning of summer. There has also been increase distribution of American signal crayfish (Pacifastacus leniusculus) with a new location on the Calder catchment near Burnley reported to the Environment Agency after juveniles were discovered in a semi-quantitative survey. Sites that have previously been reported for signal crayfish have seen no change in their presence and elsewhere a site where they have spread downstream has been reported though River Fly monitoring on the Calder catchment.

Figure 3. Female white clawed crayfish caught during RRT fish rescue with eggs developing under the abdomen.

The ever popular 'Fish Friday' has provided engagement opportunities for volunteers to come and give additional support to the electric fishing programme. 5 volunteer days were recorded with a further 6 days of work experience students from Ribblesdale High School and Clitheroe Royal Grammar School Sixth Form. Additional sites on the Upper Ribble were surveyed with the Lune Rivers Trust as part of an engagement day which coincided with volunteer fencing activities on Gayle Beck. This was a good educational opportunity to showcase the species that will benefit from the volunteer's hard work.

This year the condition of +1-year brown trout was investigated using Rickers (1951) modified condition factor (K') which is determined from the length-weight relationship of all +1-brown trout captured in 2018s quantitative surveys. By compiling results (Figure 4), we can visually identify catchments that have outliers of poor condition and identify sites where the carrying capacity and condition of individuals might be affected by lack of resources and habitat complexity. For this analysis condition must not be considered as the health of an individual but the growth relationship of length and weight. Ideally surveys would be carried out in

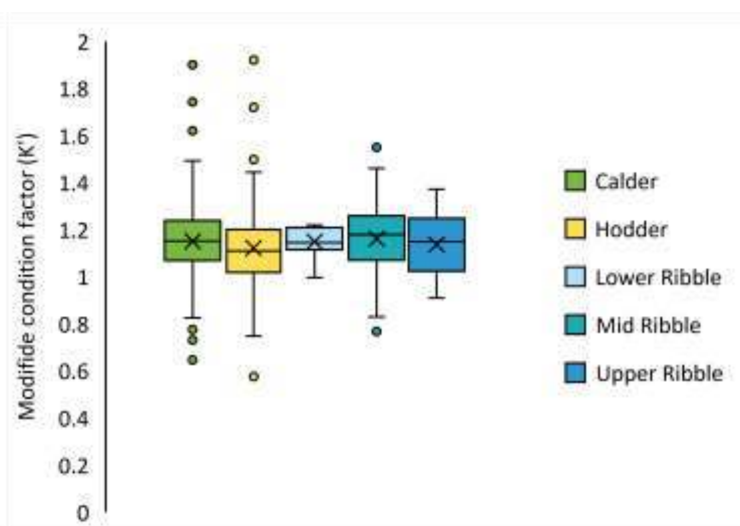


Figure 4.Rickers condition factor (K') for the sub-catchments of the Ribble. The plot shows the range of condition, lower and upper quartiles and median. The mean catchment condition is marked as X with outlying points marked.

the same locations over sequential months to monitor dispersal, survival and growth patterns.

Following on from 2017, fish biodiversity was looked at in each sub-catchment using the exponential of Shannon-Wiener Diversity Index based on quantitative survey results. As fish communities were assessed without the consideration of other aquatic species; i.e. invertebrates, and only limited to quantitative surveys, generalisations can only be inferred from the results. To utilise additional data that is collected during all surveys the presence/absence of all fish species recorded in 2018 was mapped to highlight areas of conservation importance (Figure 5). This can help use directed strategies to protect areas of spawning importance and also highlight areas that are failing to reach their full ecological potential.The Ribble is a species rich catchment which hosts 6 Annex II fish species that have high conservation interest. The connectivity of the system is highly important for the lifecycle of anadromous and catadromous species and the work that the Ribble Trust has carried out over the past 20 years has significantly increased the connectivity of the river to migration, reconnecting waterbodies to the Ribble estuary. Re-population of these areas is reliant on the ecological stability and quality of habitat that must be achieved through sustainable river management and the education of people and industries that affect it. Moreover, the increase in habitat complexity through restoration schemes will lead to a greater abundance and diversity of aquatic species.

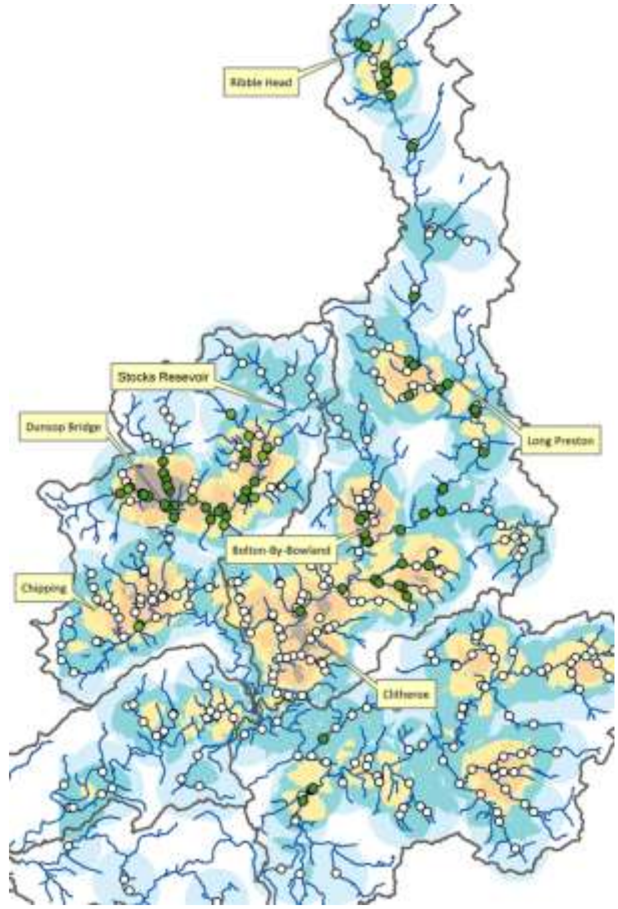


Figure 5. Ribble catchment map showing Atlantic salmon locations from surveys undertaken by RRT 2018. Green points indicating sites with fry or parr and white points show an absence of salmon. The underlaid map show species richness from high to low, yellows to blue.

Going forward there are 255 sites with six years of consecutive data (inclusive of the core sites) which will be designated as high priority sites for 2019 fisheries programme. Additional salmon sites have been selected for quantitative surveys to increase the robustness of the metrology and ensure that a range of densities are being covered for the calibration of semi-quantitative surveys. Length-weight relationships will continue to be documented and yearly changes will be noted. Additional sites have been selected on the main Ribble and main stem Calder to capture established Atlantic salmon spawning areas for future monitoring of the catchment.

1.0 Introduction

The Ribble Rivers Trust (RRT) has been conducting habitat restoration schemes and facilitating improved land management within the Ribble catchment for the past twenty years, with the aim to preserve a healthy system which in turn will provide resources and habitat to support and sustain strong populations and increase biodiversity.

This year concludes the trusts 11th year of annual electric fishing surveys across 333 selected sites which encompasses 5 sub-catchments of the Ribble: Calder, Darwen, Hodder, Lower Ribble and Upper Ribble (Figure 1.1). From the 333 sites there are 88 core sites which have 11 years of consecutive data and 155 sites that have 9 years of consecutive data. Additional electric fishing surveys have also been conducted by the Environments Agency (EA) as part of their monitoring of Restoring Sustainable Abstraction (RSA), fulfilling its obligations under the 2000 Water Framework Directive (WFD) and their core fisheries monitoring programme. Under a data sharing agreement, the EA results from overlapping sites are included in the analysis of this report as the methodology applied is synonymous and so duplicate efforts are not made in the same location.

Principally, our continuing aims are to: -

1. Assess the overall status of the juvenile population of salmonids.
2. Monitor the inter-annual variations of the salmonid population.
3. Determine underperforming areas and direct improvement works.
4. Capture the effectiveness of previous habitat improvement works.
5. Generate data and evidence in support of and to report on grant bids and applications.
6. Generate knowledge of rare species to inform responsible development.
7. Locate ecological threats posed by invasive species.
8. Derive future research questions

1.1 Sub-Catchment Map

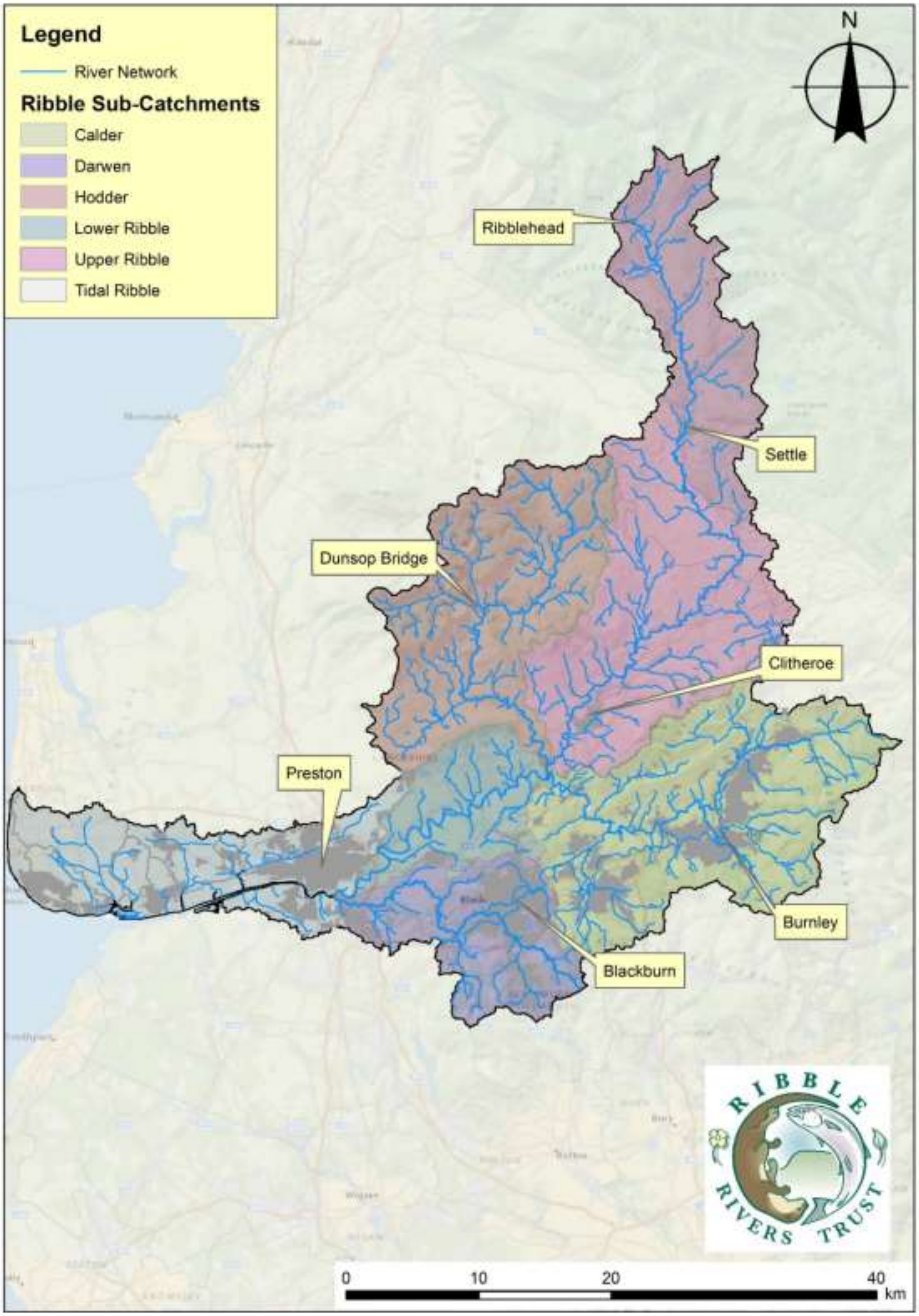


Figure 1.1. River Ribble catchment map displaying sub-catchment boundaries and reference locations.

2.0 Methodologies

2.1 Electric fishing Surveys

The Trusts applied methodology is adapted from Crozier and Kennedy (1994) and has been in operation since 2008. Riffle/pool habitat is targeted to capture both the young of year and the +1 populous of salmonids using an E-fish 500W electric fishing backpack system. Two types of survey are undertaken: semi-quantitative, where the river is actively fished for five minutes covering a measured un-isolated area; and quantitative, where a demarcated area of river is sampled over sequential depletive passes. Each survey is fished upstream in alternating widths with the anode swept through the water column, matching the flow, towards a netter. Salmonid lengths in millimeters are recorded at each site and the weight of individuals taken in quantitative surveys to the nearest gram. The abundance of other species is noted and the total weight (g) of each species is recorded in quantitative surveys. As juvenile fish densities change rapidly with age, surveys are conducted at a similar time each year and in the same area to allow for valid comparisons.

For 2018, 333 survey sites were identified for assessment with priority given to sites that hold the most significant data set, with five or more years of continuous data or in key locations for monitoring restoration works. Prior to 2018s survey programme the Ribble Rivers Trust coordinated with the EA to avoid a duplication of efforts. Commencing from the 10th June and closing on the 2nd October, 6 quantitative sites (7 in 2017) were fished on the Calder, 4 on the Hodder (9 in 2017), and 11 completed on the Ribble (10 in 2017). A total of 312 (299 in 2017) semi quantitative sites were surveyed, inclusive of 6 quantitative sites that were fished as semi-quants due extreme low flows, temperatures rising above maximum fishing threshold or very low abundances in comparison to site area.

From the above activities the young of year are determined by establishing a maximum fork length discerned from the frequency-length distribution of the species. This method is applied to each major catchment individually to reflect the temporal and spatial differences in fry as the electric fishing season progresses (Appendix B.1 – B.6). Quantitative surveys provide fry densities per 100m² from the depletion of a known measured area, whereas, semi-quantitative results are calculated from the number of fry captured in an active five minutes. The equation applied to semi-quants' is formed from the quantitative fry population relationship between a 5 minutes fry capture in the first pass and the total electric fishing result (fry per 100m²) (Appendix C.1 and C.2). Data used must reflect the variation in fishing results based on the constant effort of the electric fishing team for each site surveyed. This relationship uses all quantitative data collected as well as the addition of a zero, zero point to represent a total absence of salmonids. The resulting equation is taken from the fitted linear regression for 0 + salmonids where:

$$ln(y + 1) = a + b\ ln(x + 1)$$

The densities of trout and salmon fry per 100m² are allocated a grade-score (Table 1) which standardises the Trust's field observations with those of the National Fisheries Classification System (NFCS).

Table 2.1 National Fisheries Classification System for trout and salmon fry density per 100m²

Grade	Description	Trout fry per 100m²	Salmon fry per 100m²
A	Excellent	>38	>86
B	Good	17 – 38	45 – 86
C	Fair	8 – 16	23 – 44
D	Poor	3 – 7	9 – 22
E	Very Poor	1 – 2	1 – 8
F	No Fish Present	0	0

Graded results are transferred to a map layer using ArcGIS 10.3.1 to display catchment scale results. Within the result section the inter-annual comparison of data based on sites which hold 9 years of consecutive data and the grade change evaluation is the comparison of all sites fished in 2017 and 2018. Grade results have been organised within the analysis of this report according to geographical coverage determined by sub-catchment.

3.0 Monitoring Results

3.1 Brown Trout (*Salmo trutta*)

During the surveys of 2018, a total of 4222 fry, parr and adult brown trout were captured in 253 out of the 333 electric fishing sites which is an increase of 801 individuals in comparison to 2017. Fluctuations in brown trout populations have been observed over the past 9 years in response to a changing environment. However, as populations have recovered and no downward trends are evident, there is little concern for the overall population (Figure 3.1). The most notable recovery has occurred on the Calder catchment with fry densities increasing over the past two years which corresponds with results documented in 2012 – 2015. The number of sites yielding trout fry has improved in comparison with 2016 and 2017, with 12 out of 29 sites devoid of fry now recorded with C-grades and above (Figure 3.2).

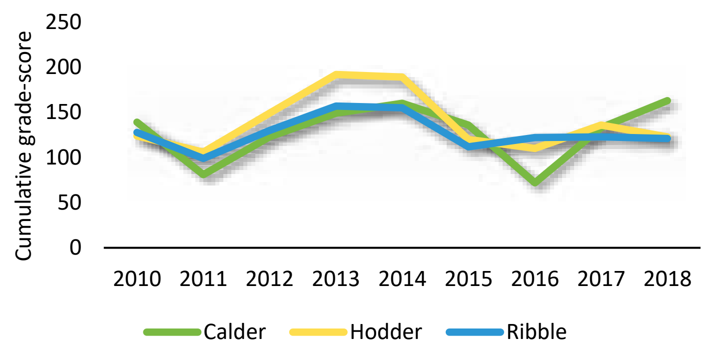


Figure 3.1. Total grade-score for sub-catchments electric fishing sites with 9 years of consecutive data for brown trout 2010 to 2018

The absence of trout fry will always be of concern, especially in areas where they have previously been documented. Brown trout provide the best indicator of a catchment's health due to the majority of individuals spending their lifecycle residing in the river system. Locations that have had long term absences will be highlighted for investigation in this year's actions and strategies. Yet there has also been a positive shift in A and B grade sites with 52 additional sites from last year reaching the highest grade-scores (Figure 3.2). Due to the drought conditions of this summer, sites with the largest reductions in grade-score have been observed in areas affected by lower water, high temperature and associated algae blooms.

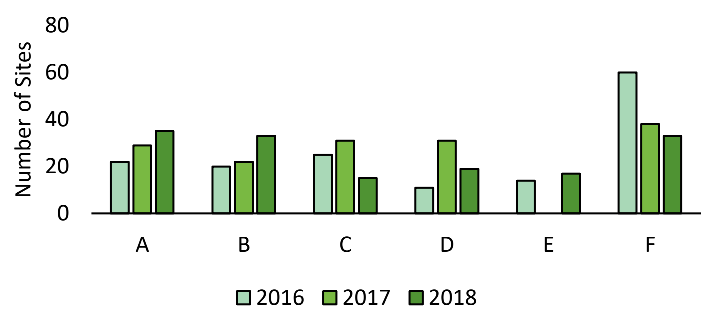


Figure 3.2. Frequency comparison of brown trout NFCS grades in the Ribble catchment 2016 to 2018

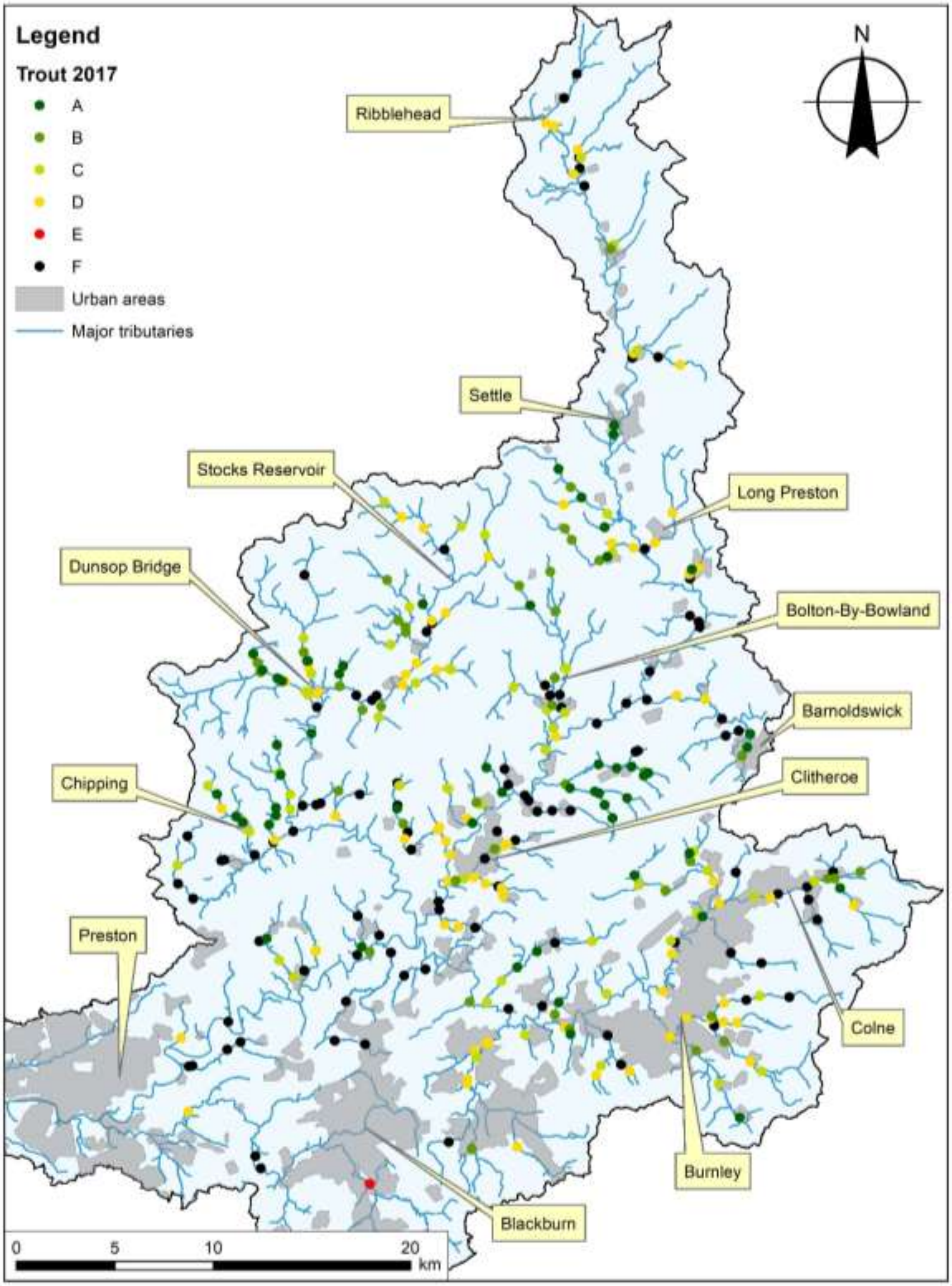


Figure 3.3. Catchment map [1:250,000] showing brown trout fry NFCS grades from surveys undertaken by RRT in 2017. Green to red points indicate higher to low grades. Black indicates an absence of trout fry.

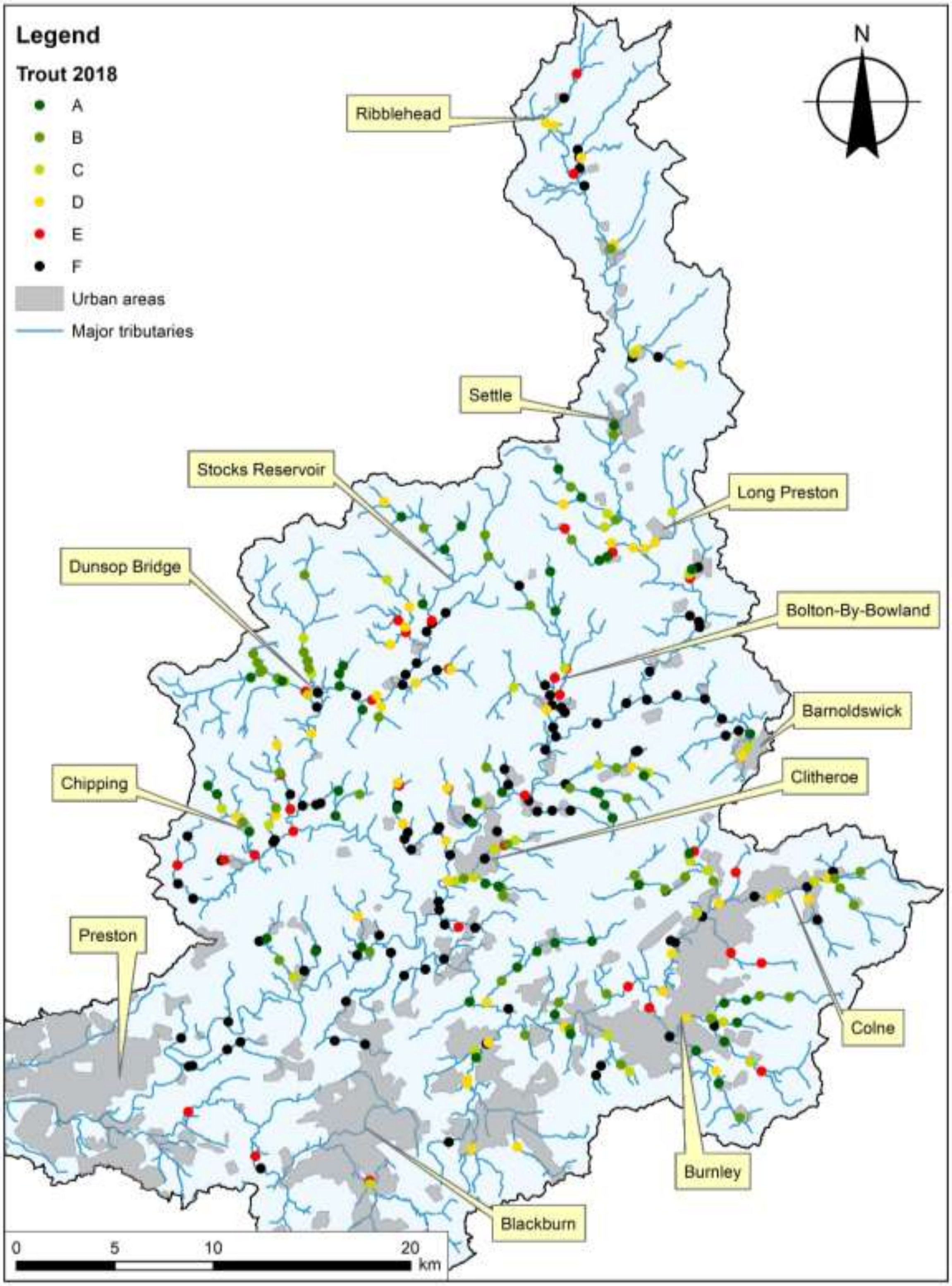


Figure 3.4. Catchment map [1:250,000] showing brown trout fry NFCS grades from surveys undertaken by RRT in 2018. Green to red points indicate higher to low grades. Black indicates an absence of trout fry.

The Calder Catchment

In addition to the highest cumulative grade-score recorded on the Calder catchment, the observed numbers of trout parr have more than doubled from 2017. This indicates that brown trout abundance is returning to expected levels after the impacts of the Boxing Day floods of 2015. A prime example of the recovery has been seen on Thursden Brook which runs in to the River Don and the adjacent Swinden Water (Figure 3.5). These tributaries were highly affected by habitat disturbance and redd washout with only a single trout fry site recorded in 2016. By 2018 there has been a notable recovery of all sites with A-grade locations producing some of the highest fry density on the catchment.

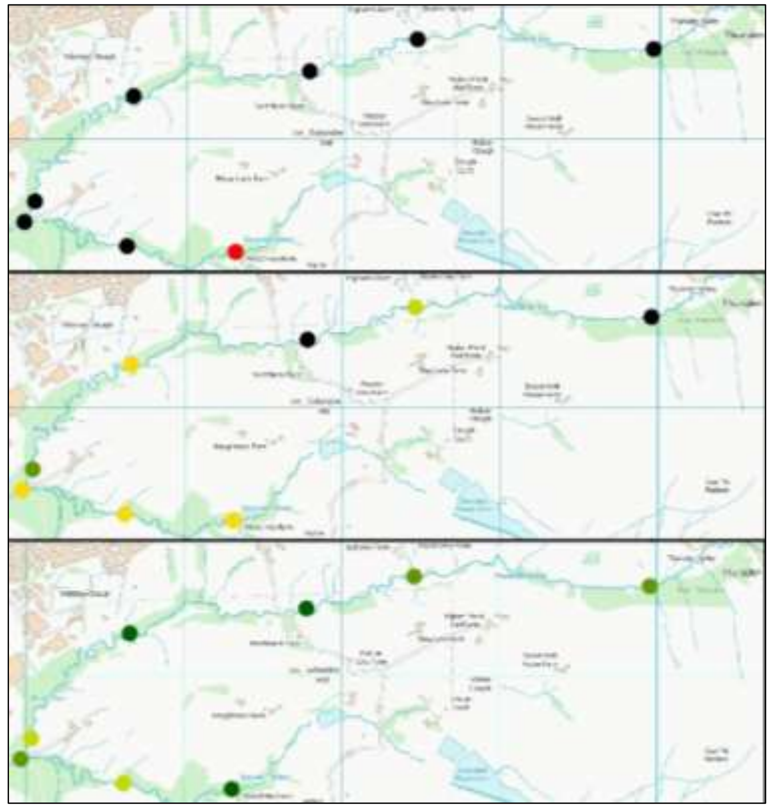


Figure 3.5. Electric fishing grades from the River Don, Thursden Brook and Swinden water 2016 to 2018 for brown trout fry (top to bottom). Green to red = high to low densities, black = 0

In comparison to 2017 there has been a 40% grade-score increase across the Calder catchment (Figure 3.6), with a Sabden site having the greatest rise in trout densities from F to A. This site is above a fish pass which was constructed in May 2017 to improve the connectivity of the brook. Sea trout were recorded during monitoring of this work which is a positive sign that the fish easement may have contributed to the spike in abundance.

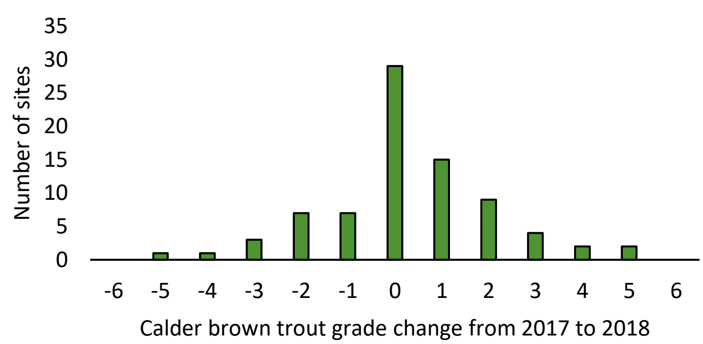


Figure 3.6. NFCS grade change comparison of brown trout on the Calder catchment 2017 to 2018 (0 = no change).

The locations that have been recorded as having no salmonid fry on the Calder catchment have been observed in areas with low or poor spawning potential and have a long-term absence. These areas will be discussed in the actions and strategies as these sites consistently fail to produce acceptable grades year on year. From these sites, 8 out of the 19 location have +1-year tout recorded in 2018, this shows that there is a potential spawning population, but as these individuals are highly mobile, they will migrate to the most suitable spawning areas available.

As the Calder is the first catchment to be sampled during the survey season it was least affected by the high temperatures and low water conditions with only Dean Brook being revisited after rain due to unfishable flows. Pool habitat was still available to resident fish for refuge, but there was no flow between features. These sites are located above a newly constructed fish easement from The Trust (2018) which will improve the spawning potential of the brook by increasing its accessibility from the main stem of the Calder.

The Hodder Catchment

The Hodder catchment during the survey season was most affected by the drought conditions with 31 out of 95 sites being delayed due to low water levels and restricted flows between features. 41.9% of sites on the Hodder catchment have seen a decline in trout grade-scores in comparison to 2017 (Figure 3.7). Locations that have dropped more than 2 grades were observed in areas that have previously been recorded with minimal flows. Areas that have seen a decline in results have been compared to the long-term dataset, and as they fall within previously recorded ranges there is little concern for these sites. Parr numbers on the catchment have been recorded at similar levels to last year. Although this age class is not targeted in the surveys, habitat types are included in the sites allowing for these observations to be made.

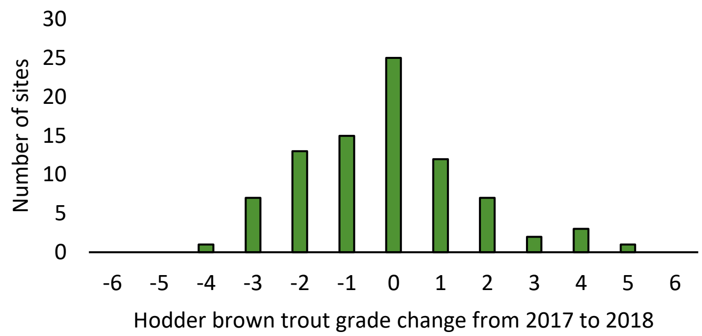


Figure 3.7. NFCS grade change comparison of brown trout on the Hodder catchment 2017 to 2018 (0 = no change).

All but one site on Lees Brook were completely dry (Figure 3.8), and no fish species were recorded when returning after the rains. The upper sites on this brook do not normally produce salmonids, however other species returning to the area might be impacted by in-river barriers, therefore these sites will be highlighted for 2019 to monitor its recovery. Without question the most affected site on the catchment from drought conditions was Greystoneley Brook. This brook is a renowned sea trout run and normally produces excellent trout fry numbers. However, the lowest ever densities on the brook have been recorded in this year's surveys. These locations have been flagged for next year's fisheries programme as early flow restrictions on sea trout movement may affect next year's spawning success.

Figure 3.8. Lees brook on the Hodder catchment August 2018.

The River Dunsop has had a productive year with overall 'good' grade-scores for the waterbody. This catchment is affected by a quick lag-time and can be flashy in heavy rain due to its slope. Also, the substrate on this catchment is more optimal for salmon rather than trout due to its larger grain size and higher percentage of cobble, so to see good trout fry abundance in 2018 is a positive.

The Upper Loud has again been identified as a problem area with only 2 'very poor' sites (E-grades) out of 6 surveyed. This catchment is not achieving 'good' status in the EAs Water Framework Directive cycle 2 assessment as it is affected by point source pollution and poor nutrient management. The Loud facilitation group run by The Ribble Rivers Trust is working towards reducing fine sediment inputs and diffuse pollution following on from 'Diffusing the Issue' project. The Loud has been recommended in the 'actions and strategies' as a catchment that needs targeted improvements to restore in-river habitat, as salmonid recruitment is suffering due to the lack of spawning substrate.

The Lower Ribble Catchment

There has been very little change in brown trout grades in the tributaries from the tidal limit to Calder Foot. There has been no change in 17 out of the 22 sites surveyed, 15 of which are devoid of salmonids. This may be partially due to unsuitable habitat and spawning substrate. In 2018's surveys on Dean Brook, Boyce's Brook, Cowley Brook and Duddel Brook (below the weir) are the only sites that produced brown trout young. The site in Duddel Wood above the weir (Figure 3.9) has mostly produced extremely poor results year on year, as this is an isolated population that probably suffers from the lack of connectivity and migrating salmonids. Bezza brook on the lowermost tributary of the Lower Ribble was affected by drought conditions and had to be revisited after rain and water level rises. Although no salmonids were recorded on this tributary large numbers of chub, dace and roach fry were observed in pool sections below a RRT fish pass. This pass has been designed to increase salmonid migration with a set of low head weirs, however these structures are barriers to non-salmonid fish due to their poor swimming and leaping ability.

Figure 3.9. Duddel Brook weir on the Lower Ribble August 2018.

The Main Ribble Catchment

There has been very little change on the Main Ribble catchment with half of the 133 sites producing the same grade as the previous year. Twiston Beck again has produced excellent grades in all of its sites, contributing to the highest densities of the Mid-Ribble (2018) as these sites rarely fall below an A-grade. Rathmell and Wiggleswoth beck have provided the best trout results on the Upper-Ribble and are relatively consistent in delivering good results. Areas that have seen a large grade drop have been in areas impacted by the summer droughts with 6 sites running dry and 19 sites marked as having low water and unfishable flows. Due to these extremes, Waddington Brook and Bond Beck (Figure 3.11) saw a large decrease in fry abundance, however trout parr were recorded in the lower site of bond beck, since parr are more mobile than 0-year fish they can seek out deeper pool refuge habit during drought conditions. Sites on Stock Beck remain very poor with the majority of sites failing to produce fry. As a tributary that struggle with point source pollution from the water industry and poor nutrient management, fry numbers only improve when they reach the town of Barnoldswick. This waterbody receives a 'Poor' overall classification status in the EA Water Framework Directive's cycle 2 monitoring.

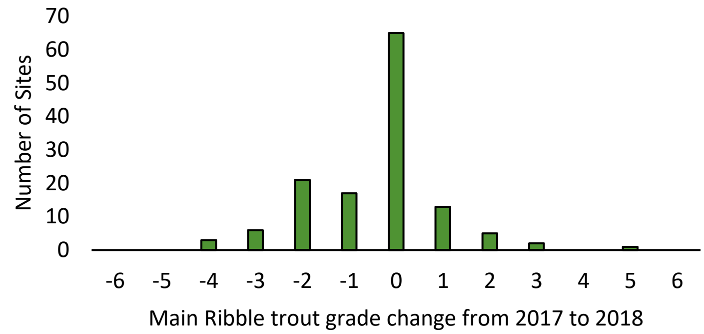


Figure 3.10. NFCS grade change comparison of brown trout on the Main Ribble catchment 2017 to 2018 (0 = no change).

Figure 3.11. Bond Beck at Lower Knotts on the Hodder catchment 2018.

3.2 Atlantic Salmon (*Salmo salar*)

During the 2018 surveys, a total of 1149 salmon fry and parr were captured in 67 out of 333 electric fishing sites. This is an increase of 680 individuals in comparison with 2017's surveys. Even with an increase in the number of salmon fry on the Hodder and Ribble catchments, there is minimal change in the cummulative grade-score as this result seems to reflect the distribution of salmon somewhat (Figure 3.12). Sites that have low abundance can have a large impact on the cumulative result if they are lost as small changes in density result in larger changes in grade score at lower densities. If a site is already an A-grade site increasing densities futher is not reflected in a grade change. Out of the sites that have been reduced to F grades, all but one site was already classed as 'very poor' (E-grades). The Hodder, once considered the best spawning habitat on the Ribble, has had a second year grade-score decline and there has been no overall change on the Main Ribble catchment while the Calder continues to produce minimal returns (Figure 3.13). An investigation into areas that are failing to produce salmon fry and areas that are classed as spawning stonghold could direct conservational efforts to improve and protect the long term sustainability of the population.

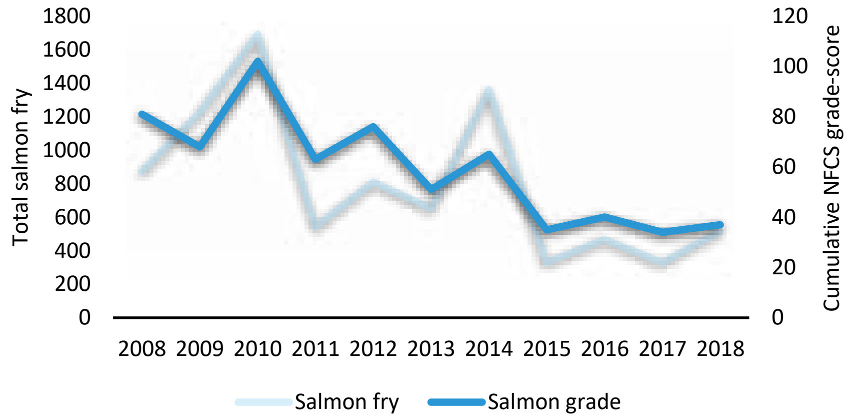


Figure 3.12. Cumulative NFCS grade-score and total calculated fry/100m² for the catchments 155 electric fishing sites holding 9 years of consecutive data for Atlantic salmon 2010 - 2018.

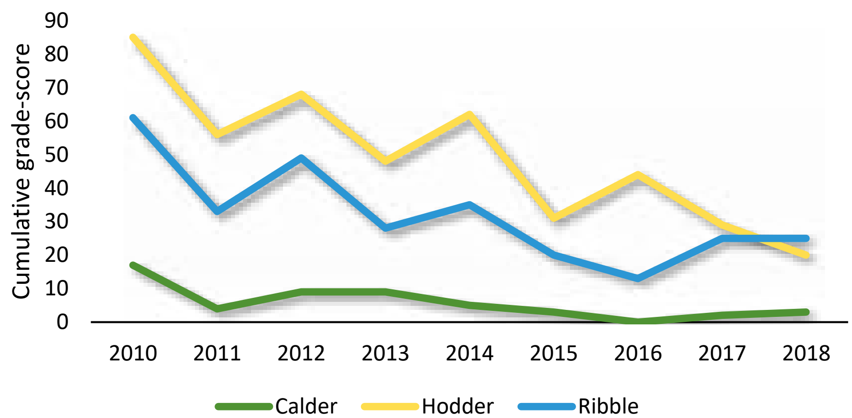


Figure 3.13. Total grade-score for sub-catchments electric fishing sites with 9 years of consecutive data for Atlantic salmon 2010 to 2018.

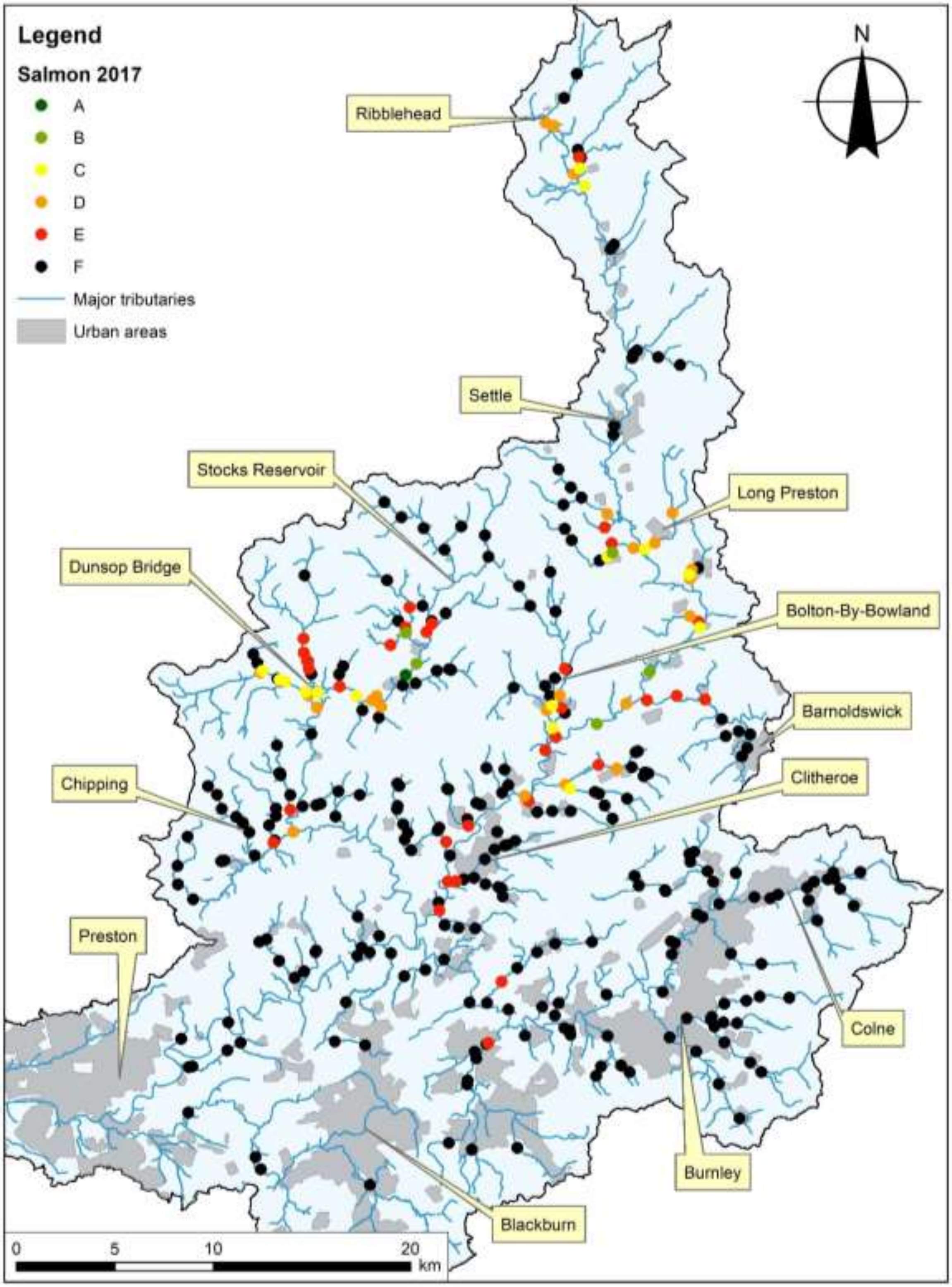


Figure 3.14. Catchment map [1:250,000] showing Atlantic salmon fry NFCS grades from surveys undertaken by RRT in 2017. Green – red points indicate higher to low grades. Black indicates an absence of salmon fry.

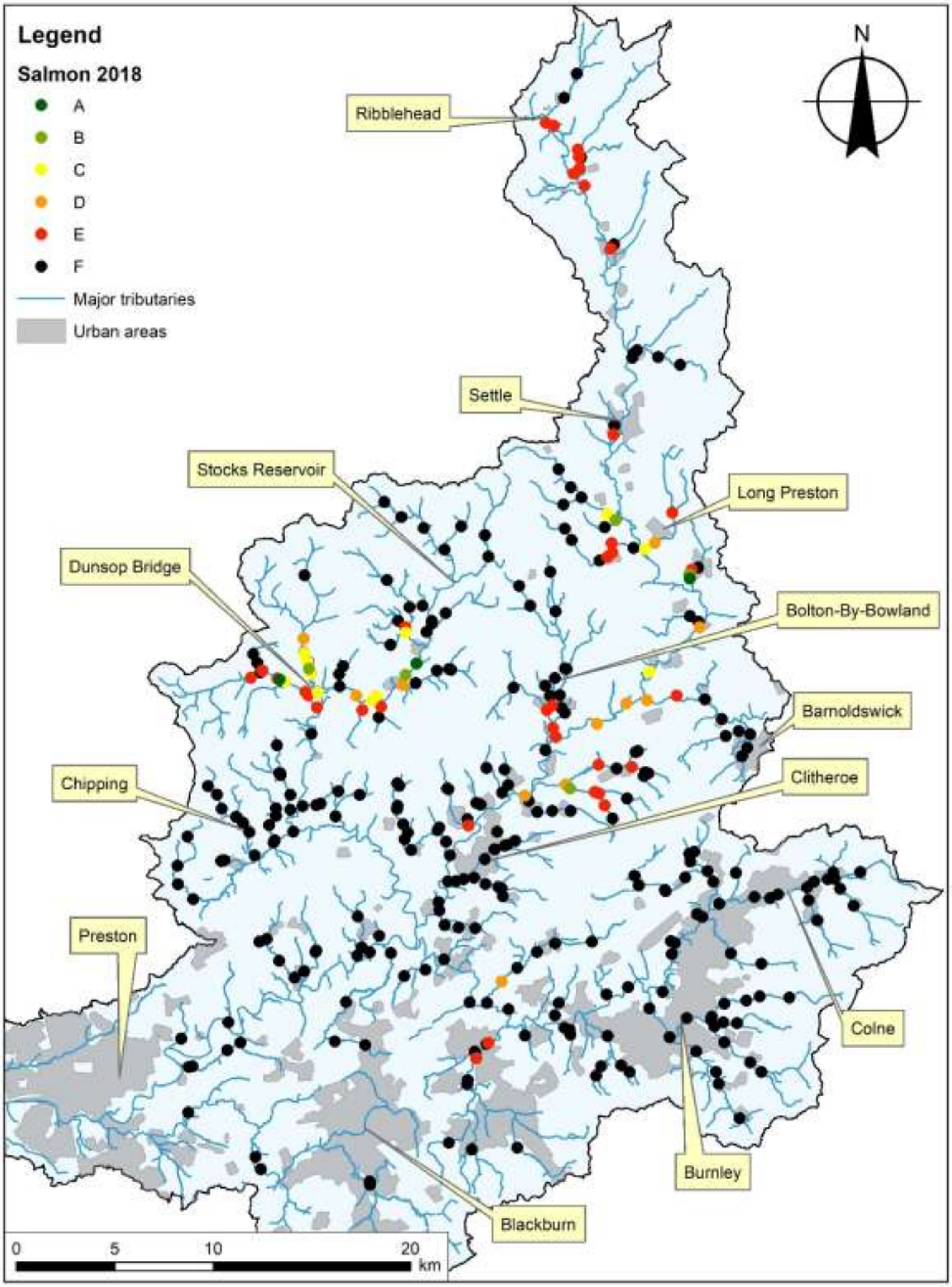


Figure 3.15. Catchment map [1:250,000] showing Atlantic salmon fry NFCS grades from surveys undertaken by RRT in 2018. Green – red points indicate higher to low grades. Black indicates an absence of salmon fry.

The Calder Catchment

The Calder remains a poor catchment for salmon spawning with limited waterbodies and fewer sites yielding fry. Sabden and Hyndburn Brooks are the only two tributaries in which salmon fry are being regularly recorded, these sites are historic spawning areas which were established before the removal of Padiham Weir. Current RRT survey locations are failing to identify an increased and sustainable distribution of salmon spawning on the Calder catchment, therefore additional main stem sites have been selected for investigation in 2019. In 2015 salmon were located at Carry Bridge on Colne Water and in Towneley Park on the River Calder, however, as yet there has not been a return to this area but hopes are high for 2019. This year salmon parr have been recorded up stream of Oakenshaw Weir during monitoring works for the 2017 bypass channel. As there has been no evidence of spawning upstream of the weir, it is thought that parr have used the bypass channel to migrate to this location.

Figure 3.16. Salmon parr captured above the bypass channel at Oakenshaw

The Hodder Catchment

Despite the aforementioned increase in the number of salmon fry caught in 2018's surveys, the Hodder catchment has continued in a downward trend (Figure 3.13). Sites that have become devoid of salmon fry have previously received 'very poor' results and even with positive improvements on key waterbodies there is an overall decrease in the distributions. The highest salmon fry densities were recorded below Slaidburn, on the River Hodder, with 212 salmon fry per 100m², while other locations on the River Hodder show the importance of main stem spawning for the sustainability of the catchment. The greatest improvement has been observed on the River Dunsop with all locations surveyed showing a grade shift towards the upper limits. The river Dunsop has been highlighted in the long-term data set as a highly important tributary for salmon spawning.

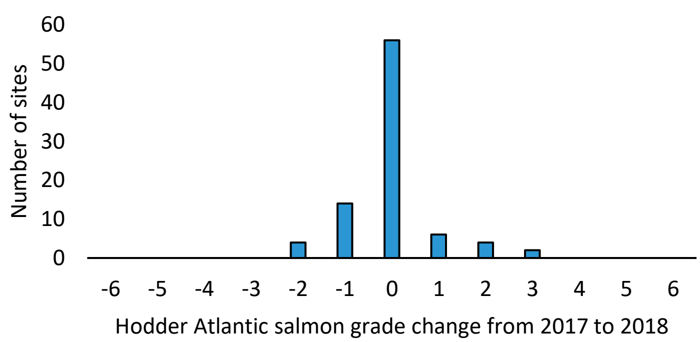


Figure 3.17. NFCS grade change comparison of Atlantic salmon on the Hodder catchment 2017 to 2018 (0 = no change).

The Main Ribble Catchment

Similarly, there has been an increase in the numbers of salmon fry recorded on the main Ribble catchment. However, very little change in cumulative grade has been observed over the past 4 years (Figure 3.13). There has been a reduction in the number of sites holding salmon fry in comparison to 2017 (3.18) and 31 out of the remaining 38 salmon sites have been allocated 'poor' D and E grade-scores. The number of F grade sites has increased in the locations normally associated with low abundance (E-grades). Locations yielding good fry densities are limited for 2018 with the top grade boundary only seen on Pan Beck (A-grade), with Hellifield Beck, Ings Beck and Rathmell producing B-grades. This Rathmell site is a new addition to the survey programme which is to monitor the lower reaches of the waterbody, where restoration and habitat improvements took place over the winter of 2017. Skirden Beck has been flagged due to the reduction in grade-score observed in the long-term dataset, with 2018 being the lowest recruitment recorded on the tributary. This waterbody, from the EA's Water Framework Directive (WFD) classification status, is given a "bad" rating due to point source pollution from water industry and agricultural pressures. On a more positive note, Twiston Beck has seen salmon spawn for the first time in 4 years. This location is to receive a RRT woodland scheme in January 2019, with the reduction of diffuse pollution by the planting of this riparian zone and increase in river shading, the hope is to see more regular returns of spawning adults in the future.

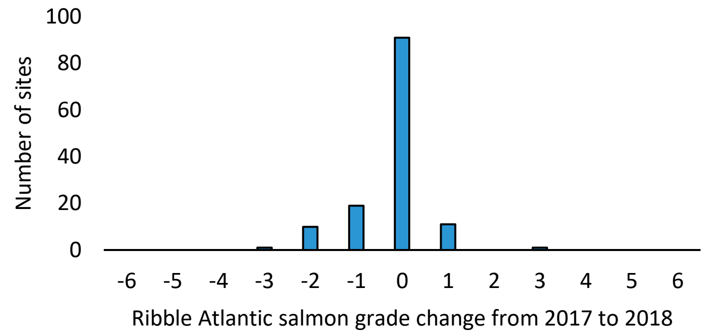


Figure 3.18. NFCS grade change comparison of Atlantic salmon on the main Ribble catchment 2017 to 2018 (0 = no change).

Additional sites on the Upper Ribble have been surveyed with the Lune Rivers Trust as part of a volunteer and engagement day. 4 riffle features downstream of established RRT sites on Gayle Beck produced salmon grades matching those of the 2018's programme. In addition to salmon, bycatch species such as bullhead and minnow were synonymous. A review of the upper catchment has shown that the spread of sites is restricted to smaller tributaries and there are large areas in which monitoring is not capturing data. It has been suggested that the Ribble is a main stem spawning catchment for salmon and additional sites will be designated to capture areas above Settle and Horton-In-Ribblesdale.

Figure 3.19. Fisheries engagement day with the Lune Rivers Trust 2018

3.3 Other Species

The Ribble Trusts monitoring programme targets brown trout and Atlantic salmon fry as keystone indicator species of a catchment's health. However, other non-target species captured during surveys can provide useful information to direct conservation efforts. Quantifiable calculation methods are not used on bycatch and applied to semi-quantitative surveys, therefore presence/absence data must be used.

Bullhead (*Cottus gobio*) remain the dominant non-targeted species on the catchment found within 77% of sites Figure 3.20 and 3.21). This annex II species is rare in some parts of England but the Ribble is a stronghold for this species of conservational interest. The reduction in the number of sites in 2018 can be attributed to the number of dry or extremely low sites during the electric fishing season. Locations that have been affected by the drought conditions will be flagged for future fisheries programmes to monitor the return of species that have a slow dispersal and are more affected by migration barriers i.e. Downham, Heys and Chatburn Brook on Mid-Ribble. This tributary link runs into the main Ribble but is an isolated due to impassible barriers.

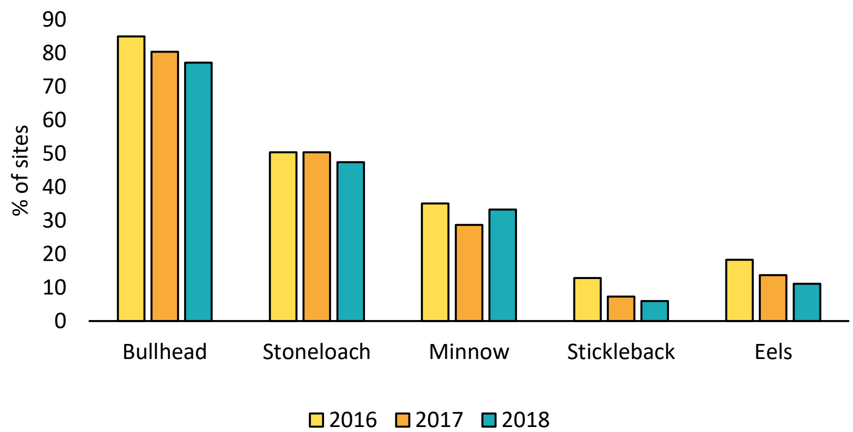


Figure 3.20. Dominant bycatch by species % presence of sites from 2016 to 2018.

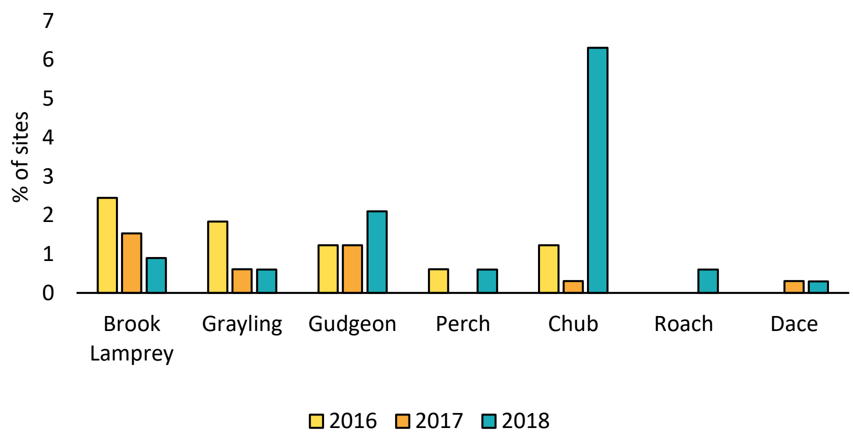


Figure 3.21. Accompanying bycatch by species % presence of sites from 2016 to 20018.

The number of eels caught as bycatch by the Ribble Trust has seen an annual decrease over the past five years. This reduction does not truly reflect the population as they are not a targeted species, but the reduction is worth noting. If we are to understand more about the habitat, movement and populations of eels within the catchment, a more targeted surveying approach is required. The distribution of eels recorded by the Ribble Trust over the catchment is remarkable, with some individuals traveling over 80km to the Upper Ribble. Eel have also been found in surprising locations, such as above Roughlee Weir and High Laith Beck Weir, as these barriers were thought to be impassible to all species.

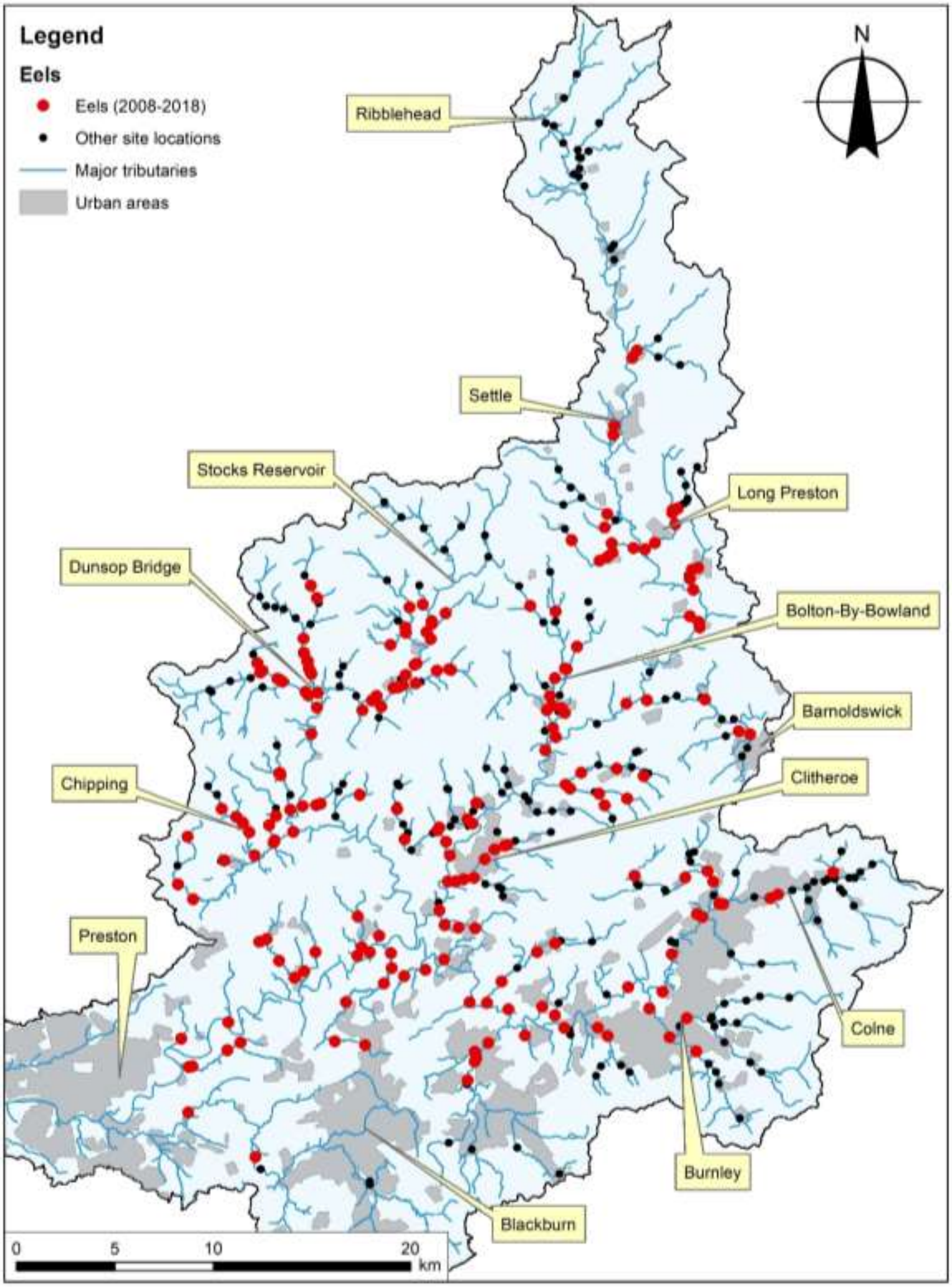


Figure 3.22. Catchment map [1:250,000] showing eel distribution from sites surveyed by RRT between 2008 and 2018. Red points indicate the presence of eels and black points are other electric fishing sites.

On the lower Ribble large shoals of chub, dace and roach fry were observed on Bezza Brook in pool sections below a RRT fish pass. This pass has been designed to increase salmonid migration with a set of low head weirs, however these structures are barriers to non-salmonid fish due to their poor swimming and leaping ability and might only be passible in elevated water conditions. Non-salmonid fish passage of barriers is limited due to swimming capacity, and even small in-river barriers can impede the movement of riverine species. Benthic species such as stone loach (Barbatula barbatula) and bullheads (Cottus gobio) are particularly susceptible and 100% efficiency cannot be achieved without removal.

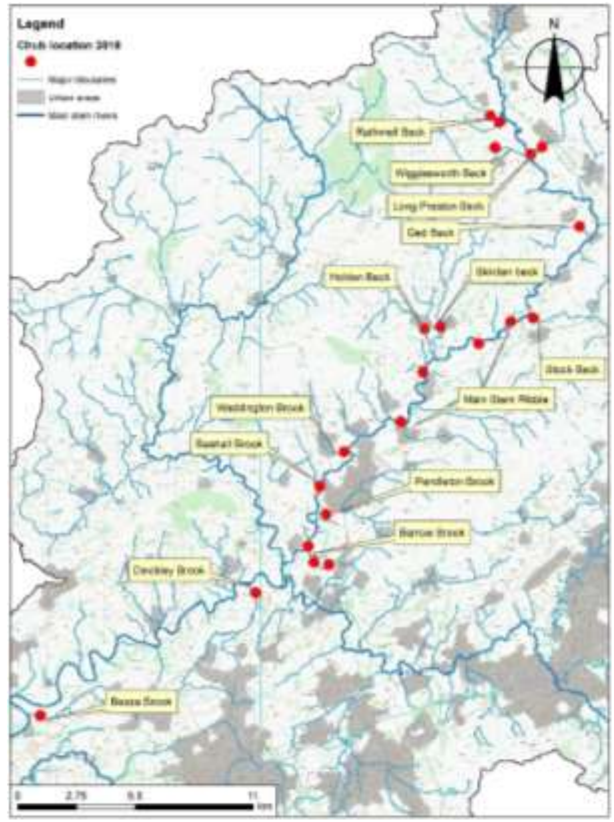


Figure 3.23. Site location of juvenile chub and fry captured in 2018s RRT fisheries programme.

A notable change for 2018 is the number of chub (*Squalius cephalus)* fry and juveniles that have been recorded, all of which are close to the main stem Ribble (Figure 3.15). Chub can migrate up to 25km for spawning, taking them to inflowing tributaries in search of suitable riffles optimal for spawning and nursery habitat (Fredrich, et al., 2003). Chub have also been recorded by the Trust on the River Darwen at Houghton Bottoms with 20 individuals captured and released during a brown trout electric fishing and tagging exercise to monitor the newly constructed fish easement on Houghton Weir. Chub take approximately 6-8 years to reach 1lb and have been recorded in the wild to live up to 22 years.

Figure 3.23. A good brace of chub captured during electric fishing above Houghton Weir on the River Darewn 2018.

The Ribble Trust has recorded a new location for white-clawed crayfish (Austropotamobius pallipes) on the Ribble catchment. An egg ladened femail was captured during a fish rescue on West Bradford Brook delaying works for the construction of an embedded rock ramp in June 2018. There has also been increase distribution of American signal crayfish (Pacifastacus leniusculus) with a new location on the Calder catchment near Burnley reported to the Environments Agency and an additional downstream location has been reported though River Fly monitoring on the Trawden Brook.

4.0 Evaluation Results

4.1 Radio Tracking of Capital Works

Oakenshaw Bypass Channel

Figure 4.1. Oakenshaw weir and bypass channel Summer 2017 before 1.2ha of woodland planting took place in the winter.

Constructed in 1844 to supply water to the local printworks, Oakenshaw weir has been a barrier to migrating fish on the River Hyndburn ever since. The Ribble Trusts fisheries programme has recorded Salmon fry below this structure demonstrating that the upper reaches of the river are inaccessible to migrating fish. The Oakenshaw bypass project has seen 1.3km of river reconnected by a specially designed channel that circumvents the structure. The extent to which diadromous and potadromous fish can migrate will be extended in 2019 with the construction of a fish easement on Dunkenhalgh weir. The long-term success of these projects will be monitored through the core fisheries programme, with new site locations selected to monitor the potential spawning success of migrating adult salmon. In 2018, monitoring of the bypass channel has been carried out by The Trust by applying manual radio tracking techniques. 19 brown trout caught above Oakenshaw Weir have been fitted with 1.3g ATS whip antenna tags and transported downstream of the fish easement. Through natural homing responses and the impulse to migrate for spawning these salmonids have been tracked to access the possibility of the channel. As of October 31st 2018, there has been 4 successful assents of the channel with 2 trout returning to downstream locations. One individual migrated to the next in river barrier showing the importance of the Dunkenhalgh 2019 fish easement to further improve connectivity. This Ribble Trust project has been funded through the Heritage Lottery Fund, the Environment Agency, Natural Course an EU LIFE funded project, and the Windfall Fund – a partnership between EnergieKontor and The PROSPECTS Foundation.

Hoghton Bottoms Fish Pass

Figure 4.2. Houghton Bottoms Weir and fish pass. Summer 2018

Hoghton Bottoms is one of two fish easements constructed by the Trust in 2018 with grants awarded from the European Regional Development Fund and the Heritage Lottery Fund (as part of its Ribble Life Together project). This fish pass has reconnected 14km of the River Darwen impacted by obsolete structures constructed for mills which have since been demolished. Like Oakenshaw, manual tracking with a handheld antenna was conducted regularly to follow fish movements. 16 Brown trout caught above the structure were fitted with 1.3g ATS whip antenna tags and relocated downstream of the barrier. While the tags used in the study have a battery life of approximately 50 day and have since stopped transmitting 3 out of the 16 individuals have been tracked upstream of the fish pass, homing to areas where they were first captured. With only a few fish moving above the weir during the monitoring this project is still a big success as the structure at Houghton Bottoms was classed as impassible to migrating species.

Lower Darwen Fish Pass

Figure 4.3. Lower Darwen Weir and fish pass. Autumn2018

Prior to the construction of the fish easement at Lower Darwen, The Ribble Rivers Trust performed a PIT telemetry study to assess if the structure was passible. Due to the size and dimension of the weir 5 out of the 16 fish tagged managed to ascend the weir face at a high energy expense, however long delays were incurred as high flows were required for ascent. After fish pass construction in 2018 this location has been the most successful fish easement this year with 5 out of 20 radio tagged trout ascending in the first 24 hours and a further 11 fish by the end of the study. Up and downstream movements have also been recorded from 8 individuals; from the 4 trout not recorded above the structure 2 tags have been reported missing from the start of the study with the other 2 residing downstream.

4.2 Length-Weight Relationships and Biomass

The Ribble Rivers Trust's electric fishing programme is a primary tool in the long-term assessment of sustainable catchment restoration. This method maps the distribution and abundance of keystone salmonid species which are indicators of the ecological status and connectivity of the riverine system. To improve the ability to direct and evaluate management strategies, the condition of developing salmonids can be observed via length-weight relationships. During the Ribble Rivers Trust's electric fishing surveys, fork length distribution is used to differentiate between the young of year, parr and adult age classes. To further understand the condition of Ribble salmonids the wetted weights of individuals were recorded in 2018's quantitative surveys, along with the total mass of each bycatch species. It is advised not to include the juvenile population in the analysis of length-weight, however the young of year will be included in the total weight described in this report. Ideally, surveys would be carried out in the same locations over sequential months to monitor dispersal, survival and growth patterns. Single point analysis can provide a snapshot into the condition of salmonids and the other species that inhabit the reach.

Figure 4.4. Measured standard length, fork length and maximum total length of fish (brown trout pictured).

Condition Factor

Considering that the number of salmon parr recorded within quantitative surveys are minimal, the focus of condition will be on brown trout only. As the majority of individuals spend their lifecycle residing in the river system, they are also the best keystone indicators for the catchment. For this analysis, condition must not be considered as the health of an individual but as the relationship between length and weight, which is traditionally characterised by Fultons condition factor (1904):

Fulton condition factor

$$K = 100 \times \mathrm{W}/L^3$$

Where: W = actual weight (g), L = total fork length (cm)

This equation assumes isometric growth; however, it has been shown that fish often grow allometrically which increases the scatter around the mean condition (K) of a population. To reduce the effects of allometry from the estimation of fish condition, the Ricker (1951) modified condition factor K' is used:

Ricker modified condition factor

$$K' = 100 \times W/L^b$$

Where: b is a constant determined from the length-weight relationship (Figure 4.4):

$$Y = aX^b$$

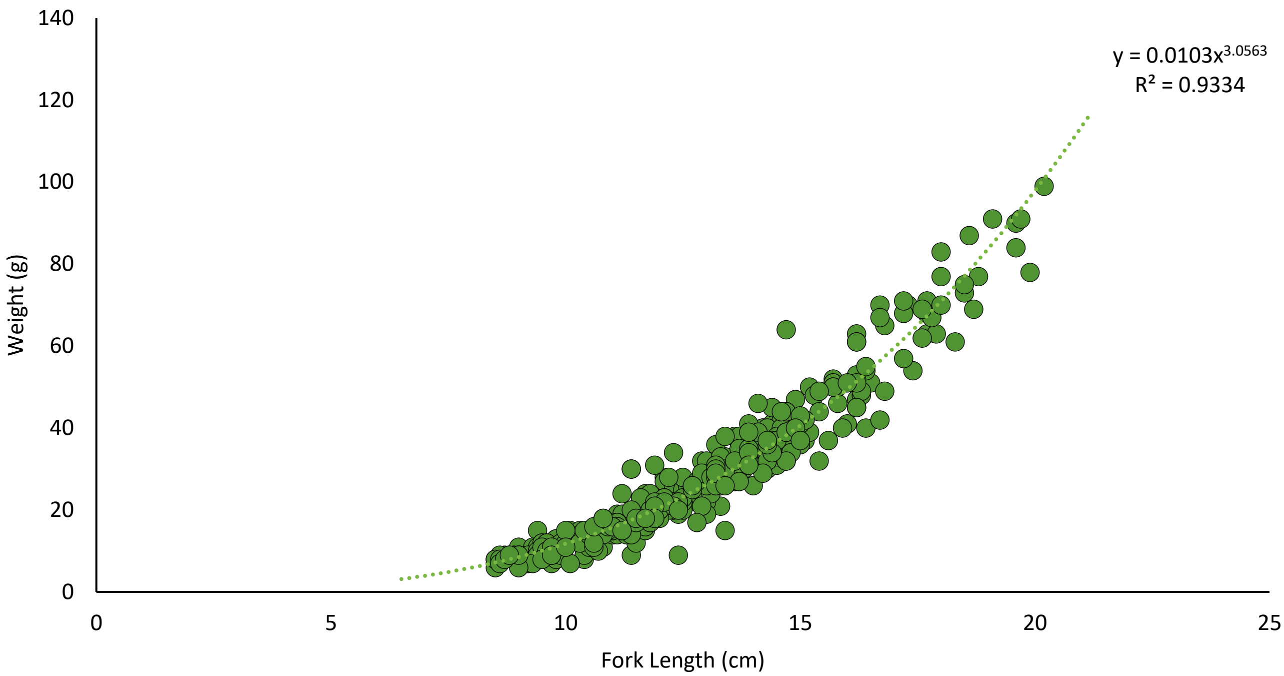


Figure 4.5. Length-weight relationship of +1-year brown trout caught in quantitative surveys on the Ribble catchments 2018.

With the use of a scaling factor, the results of K and K' normal condition is expressed as 1, for K' this result shows that an individual falls within the expected condition defined by trout from the Ribble catchment (Figure 4.5). Where condition is >1 fish have a higher expected mass to fork length and <1 fish have a lower expected mass to fork length. By compiling results, we can visually identify catchments that have outliers of poor condition and identify sites where the carrying capacity and condition of individuals might be affected by lack of resources and habitat complexity (Figure 4.6).

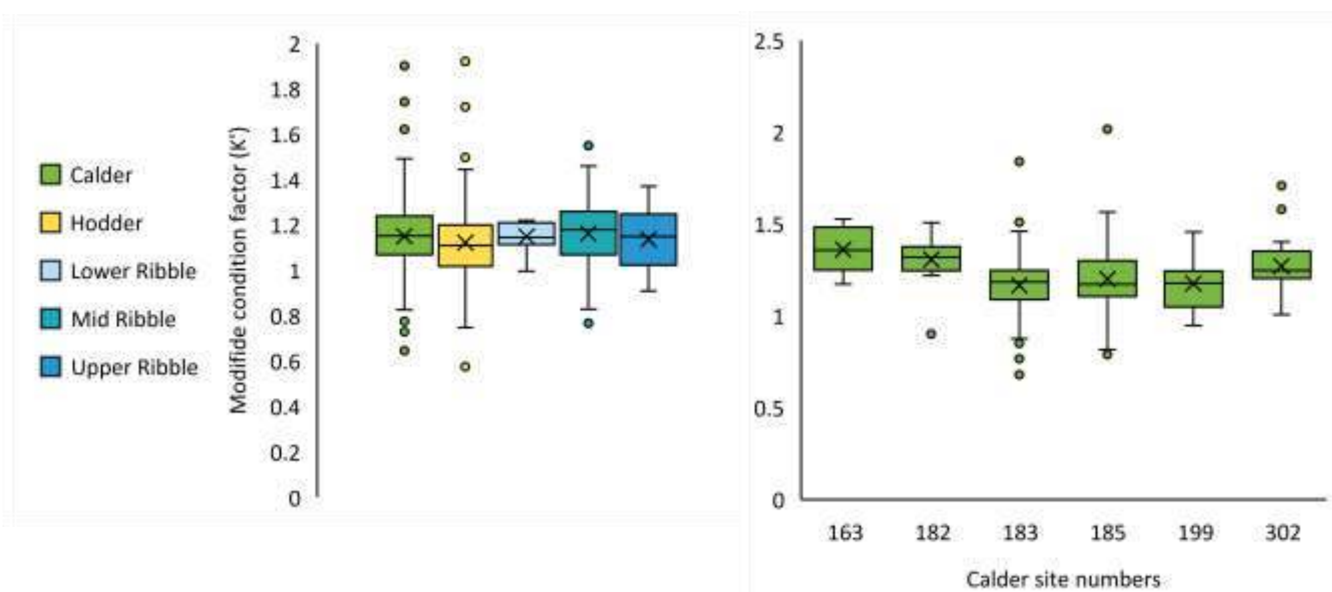


Figure 4.6. Rickers modified condition factor (K') for the sub-catchments of the Ribble and for quantitative sites on the Calder catchment. The plot shows the range of condition, lower and upper quartiles and median. The mean condition is marked as X.

From the length-weight relationship of Ribble brown trout we can create an equation to give an expected weight based on an individual's length. Expected weight and actual weight can be compared to identify individuals that are outside the catchment trend (Figure 4.7).

Expected weight from length

$$\hat{}w = aL^b$$

Where: L = total fork length (cm), a and b are derived from Figure 4.4

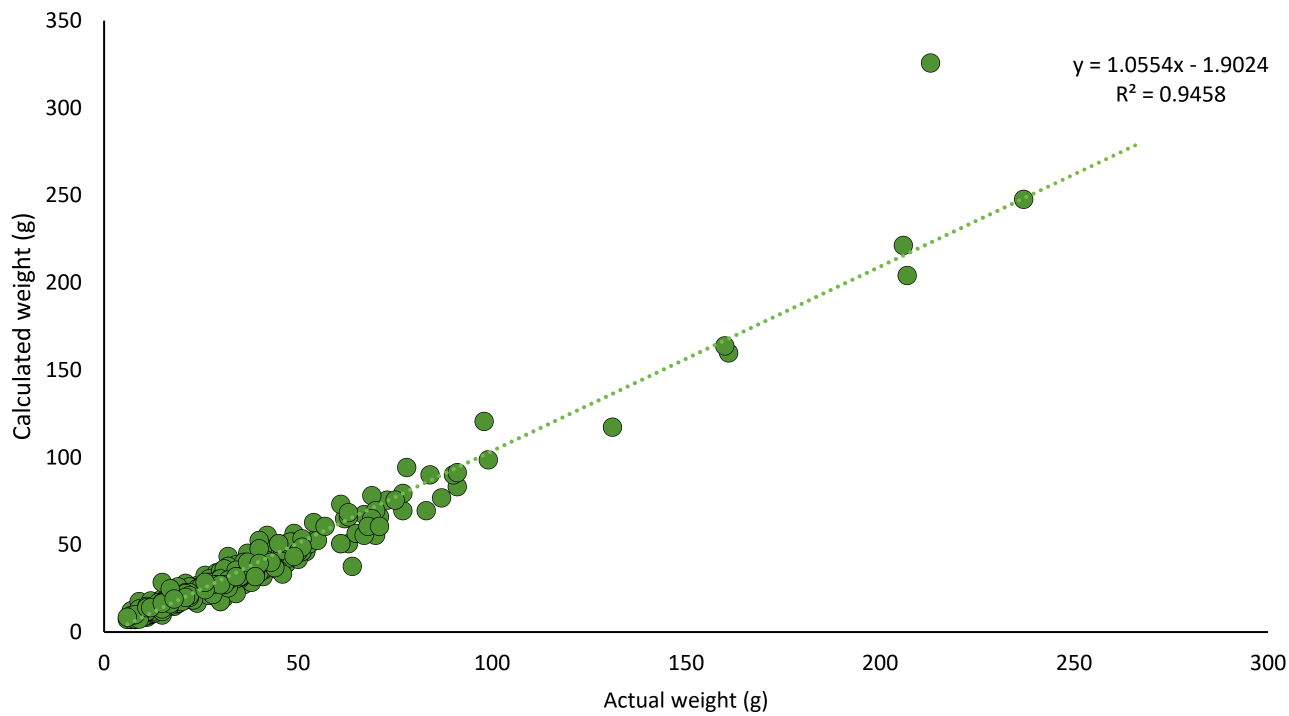


Figure 4.7. Actual weight vs calculated expected weight derived from fork length.

Biomass

The total biomass of fish in a stream is influenced by physical, chemical and biological characteristics of a waterbody (Warren, et al., 2010). Decreases in fish biomass have been linked to limited in-stream productivity of macro-invertebrate abundance and a reduction in terrestrial subsidies (Thomas, et al., 2015). By plotting biomass per unit area for each species areas of species richness and productivity can be ascertained (Figure 4.8).

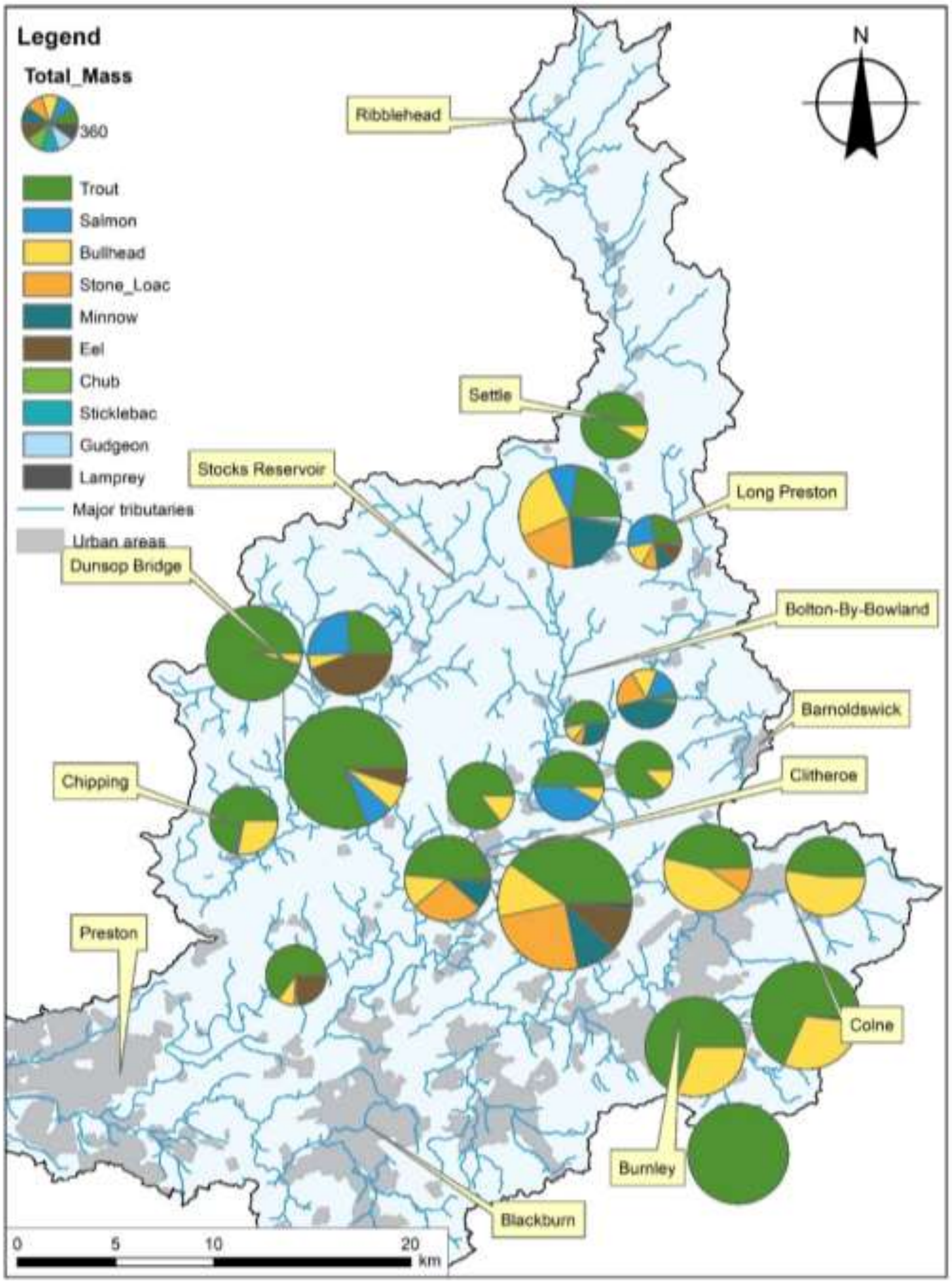


Figure 4.8. Percentage of species in quantitative surveys where the area of the chart is equal to the total biomass per 100m² ranging from 263.15 - 1641.32 g/100m²

5.0 Discussion

5.1 Summer temperatures and drought conditions

The timing and patterns of emergence and the size of emerging fish has high importance on their subsequent establishment of feeding territory, further dispersal and survival potential (Nika, 2013). Mortality bottlenecks for many species occur in juvenile stages and are thought to result from limitations of food or foraging habitat during a "critical period" for growth and survival. (Kennedy, et al., 2008). For salmonids the largest proportion of mortalities occur during the first weeks of fry emergence after depletion of yolk reserves and exogenous feeding begins. Temperature is another factor affecting the survival of young salmonids stages as development can increase metabolic cost due to a rise in temperature and in case of food availability can lead to lower performances. (Arevalo, et al., 2018).

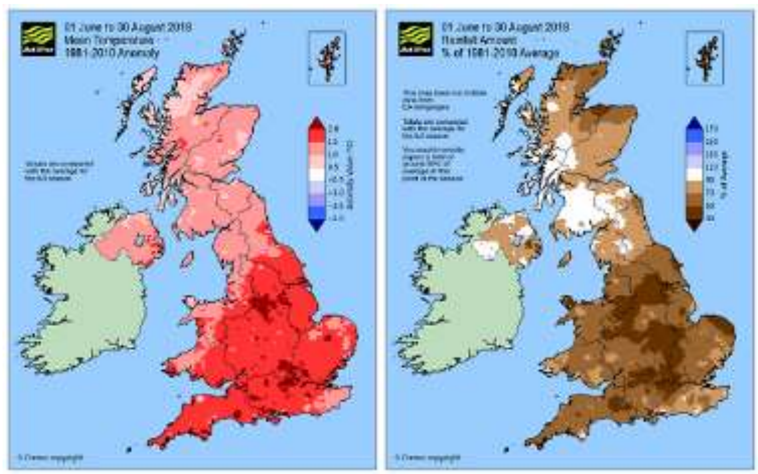


Figure 5.1. Met Office records for summer 2018, % of 1981-2010 averages. Online: www.metoffice.gov.uk/news/releases/2018/end-of-summer-stats

With 2018s summer dominated by warm weather with mean temperatures of 17.2°C and below average rainfall, drought conditions were seen across the Ribble catchment during the survey season. 70 out of the 333 electric fishing sites were revisited due to unfishable water levels or completely dry riverbeds, raising concerns for the +0 salmonids targeted during the survey season. Fry are more sensitive to extremely low flow because of poor mobility and capability to seek refuge (Elliott & Elliott, 2006). During moderate flow decreases, salmon parr may remain in riffle habitats, but during severe droughts they tend to move to deep pools. Also, trout parr of can escape by moving to deep pools or into brackish water in periods of drought (Armstrong, et al., 1998; Landergren, 2004). As more extreme weather events are been recorded in the UK there are fears that there will be a reduction in the thermal suitability of river environments for a range of species. Water temperatures sustained above 18°C severely reduce the oxygen saturation by 2% per 1°C rise, with acclimation to warm water, the 1000-minute lethal temperature for salmonids is 26.7°C, and a 7-day value of 24.7°C (Solomon & Lightfoot, 2008). The cumulative effect of environmental hypoxia and thermal stress will lead to higher mortalities, in particular, the young-of-the-year. Salmonid fry are more affected by the high-water temperature due to their lack of mobility, parr and adult fish have a higher temperature tolerance and suffer less by seeking refuge (Elliott & Elliott, 2010). In response to elevated water temperatures, salmonids thermoregulate by utilising discreet areas of cooler water in the system such as; inflow from spring fed brooks, confluence plume from cooler tributaries, hyporheic upwellings and riparian shading (Dugdale, et al., 2013) (Caissie, 2006).

Figure 5.2. Water temperature reading taken to make sure that surveys are carried out in temperatures below the threshold for electric fishing to reduce stress to captured species.

During the fisheries programme, the highest in river temperature was recorded by the electric fishing team at 22°C bringing a halt to the days fishing as guidelines state that anything over 18°C causes undue stress to any targeted species. The Ribble Trust also has a long-term temperature monitoring project on Bashall Brook. The brook itself is shaded for most of its length, however, temperature logger data during this summer has shown a 9°C increase over 1km of unshaded section on the lower reaches with a temperature high of 29.5°C. Planting and habitat restoration has been carried out on these lower reaches in 2018 to extend this shaded zone and long-term monitoring and scheme maturation will show a positive change to this exposed reach. The Ribble Trust is working to mitigate the effects of increasing water temperatures and climate change by selective planting of riparian zones. Tributaries are targeted with lower stream orders to increase shading in areas that are influenced by high sun exposure. This work comers off the back of the 'Keeping the Ribble Cool' project and compliments the efforts to reduce diffuse and point pollution from rural sources.

5.2 Targeted conservation

Species richness

Habitat complexity often leads to a greater species diversity and abundance. When habitats become simplified or disconnected there is a decrease in resources and increased competition, resulting in the loss of niche species and species richness. From the 2017's fisheries report, the diversity of each major catchment was characterised by calculating the exponential of Shannon-Wiener Diversity Index (Figure 5.3) based on quantitative survey results. Because the quantitative methodology assumes that depletion is reached over sequential runs and covers a larger range of habitat that is archetypal of the area, then all species are represented within the sample. As fish communities were assessed without the consideration of other aquatic species; i.e. invertebrates, and only limited to quantitative surveys, generalisations can only be inferred from the results. To utilise additional information collected in semi-quantitative surveys, areas of conservational and species importance can be highlighted through the presence/absence of all fish species. Using ArcGIS 10.3.1, point density analysis can be used to produce an average magnitude-per-unit area from site data that fall within a neighborhood defined by a distance from each site (Figure 5.4). Those areas that are highlighted as having a higher fish species richness, coincide with areas that support spawning and nursery habitat of Atlantic salmon. Using data in this way can help direct strategies to protect areas of spawning importance and also highlight areas that are failing to reach their full ecological potential, i.e. the tributaries of the lower Ribble are found to be poor spawning habitat for salmonids and are mainly dominated by other species. The lower reaches on Bezza Brook are a hot spot for species richness and hold nursery habitat for coarse species. With improvements in connectivity for non-salmonid species in the lower reaches there could be further dispersal and utilization of habitat and neighboring tributaries.

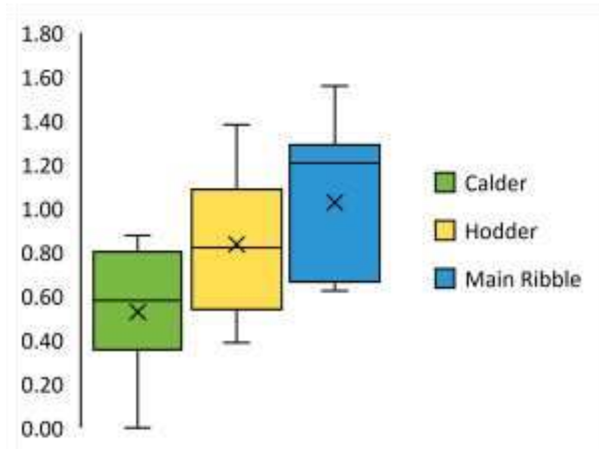


Figure 5.3. Shannon-Wiener Diversity Index results for the Calder, Hodder and main Ribble catchments. The plot shows the range of diversity scores, lower and upper quartiles and median. The mean catchment diversity is marked as X.

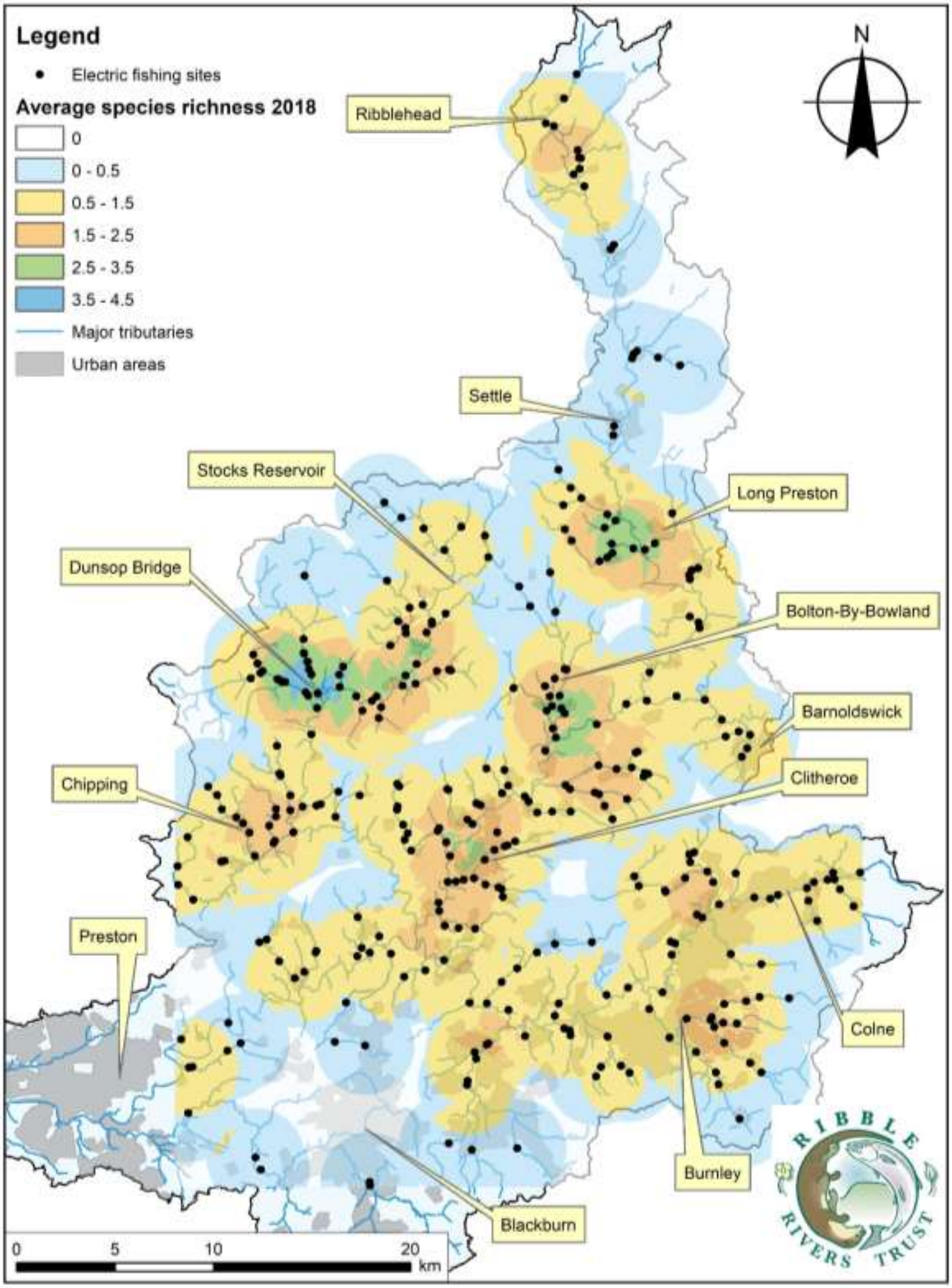
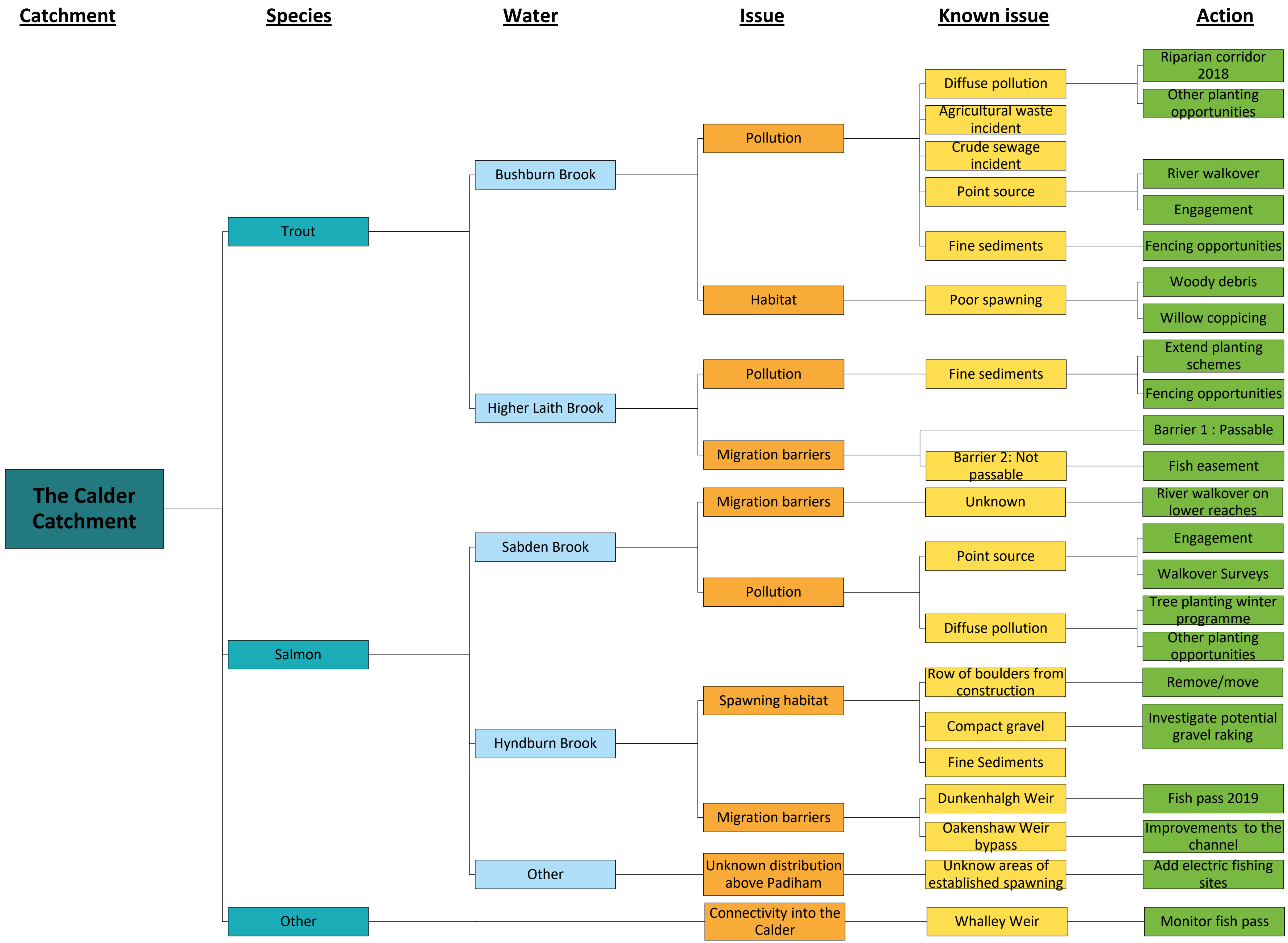


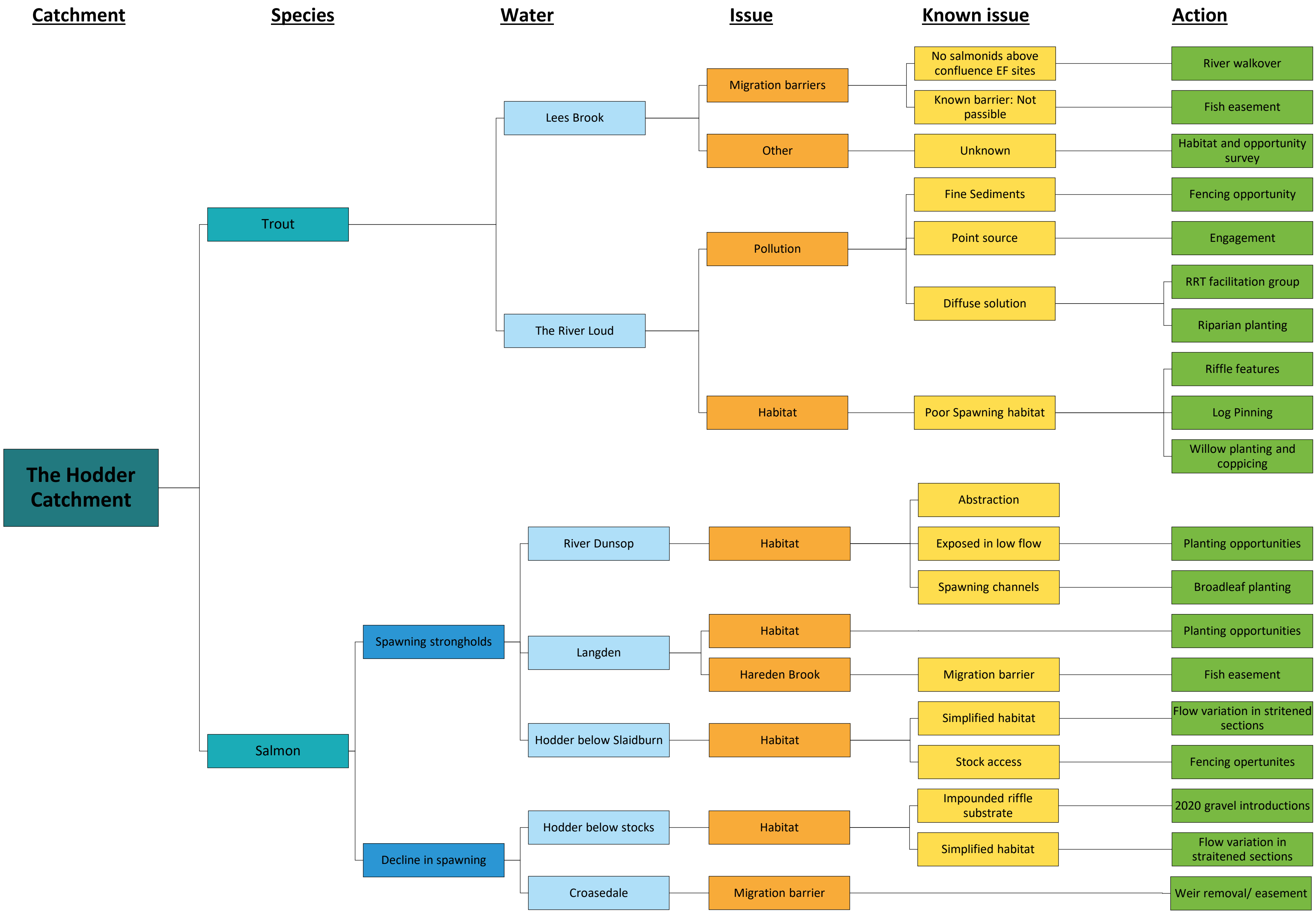
Figure 5.4. Catchment map [1:250,000] showing 2018s electric fishing sites (black) and the average point density calculated from a magnitude-per-unit area based on the total fish species richness of each site that falls within with a neighborhood of 2500m

Actions and Strategies

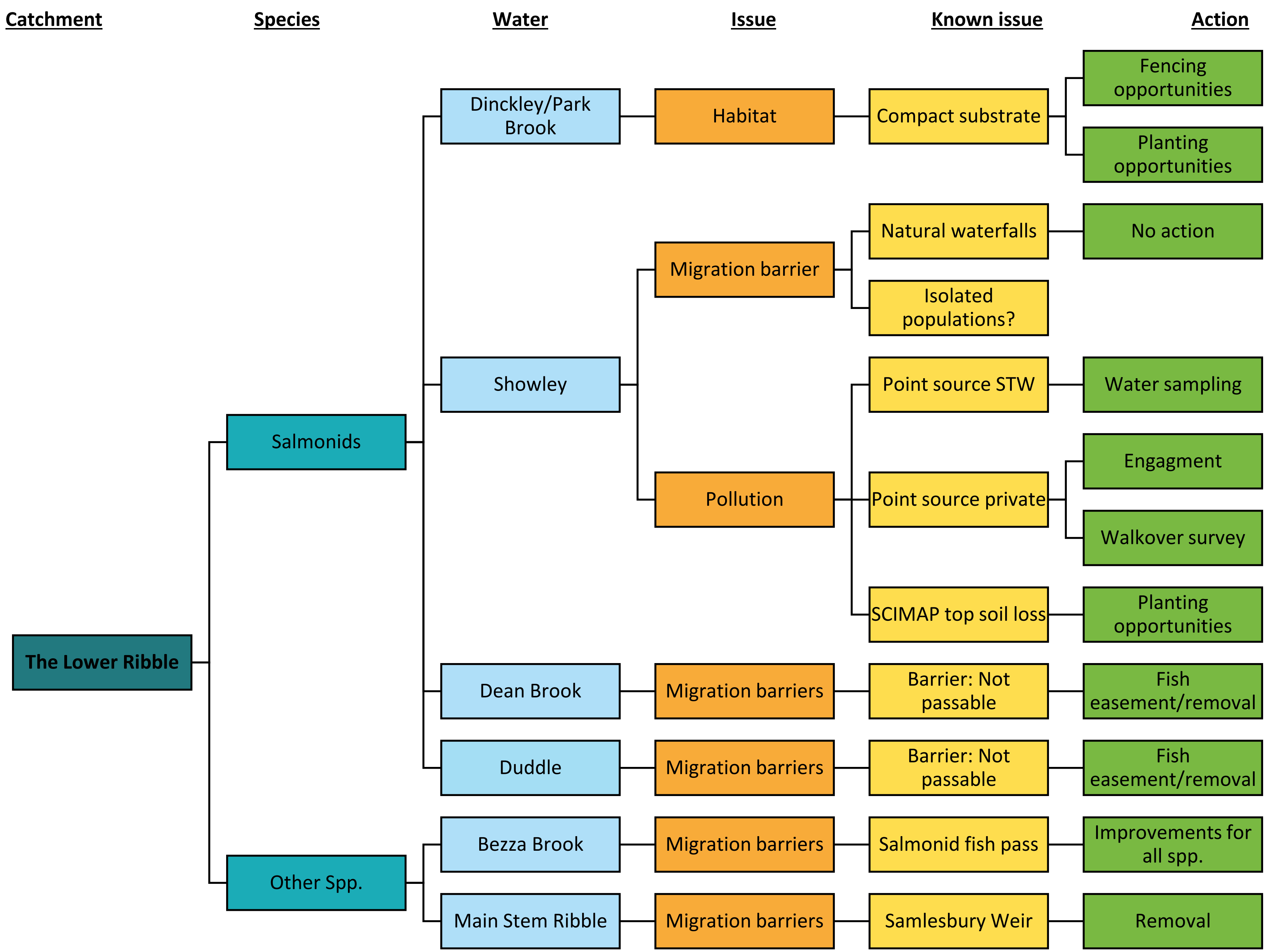
Fisheries Monitoring of the Ribble Catchment



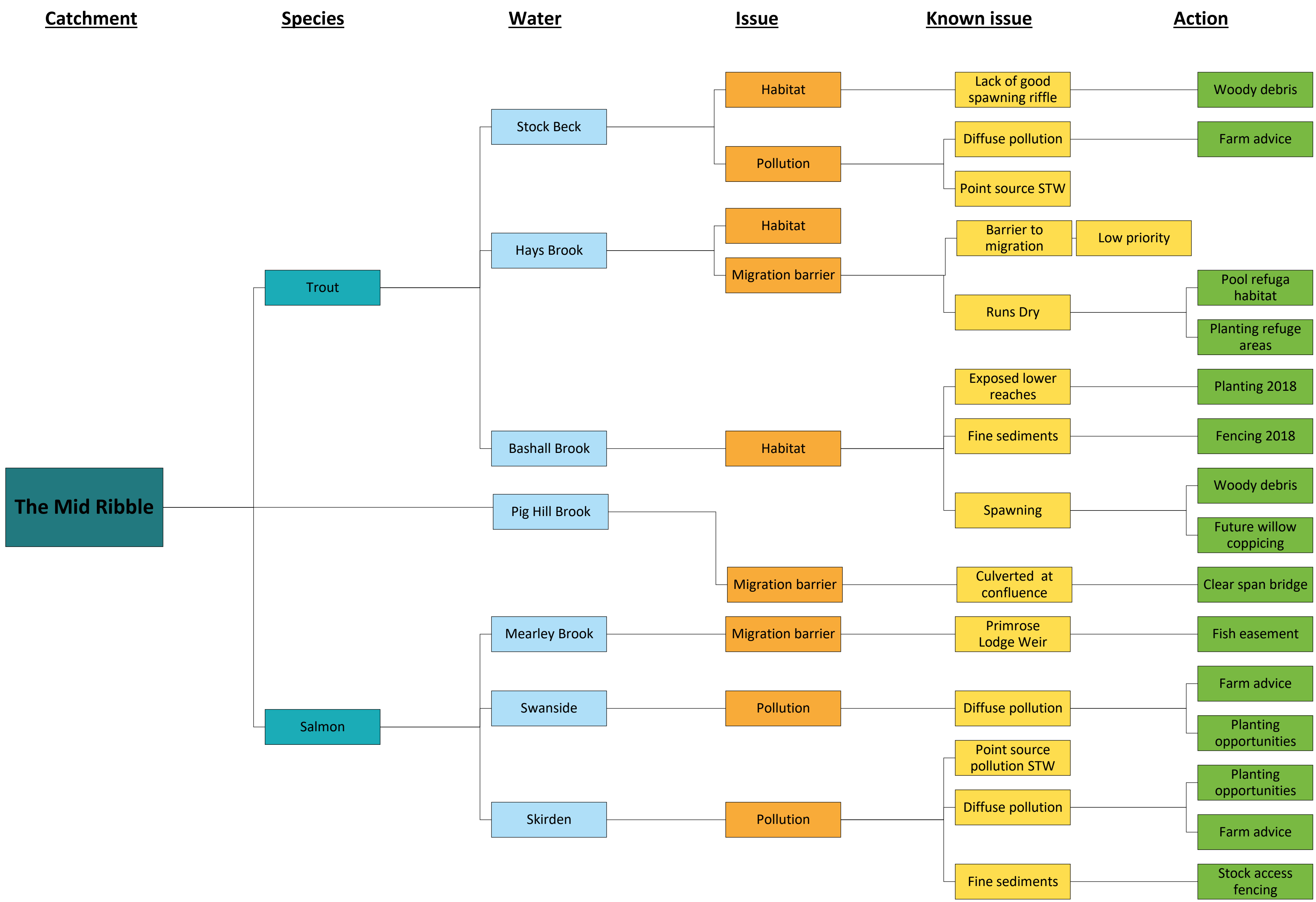
Fisheries Monitoring of the Ribble Catchment



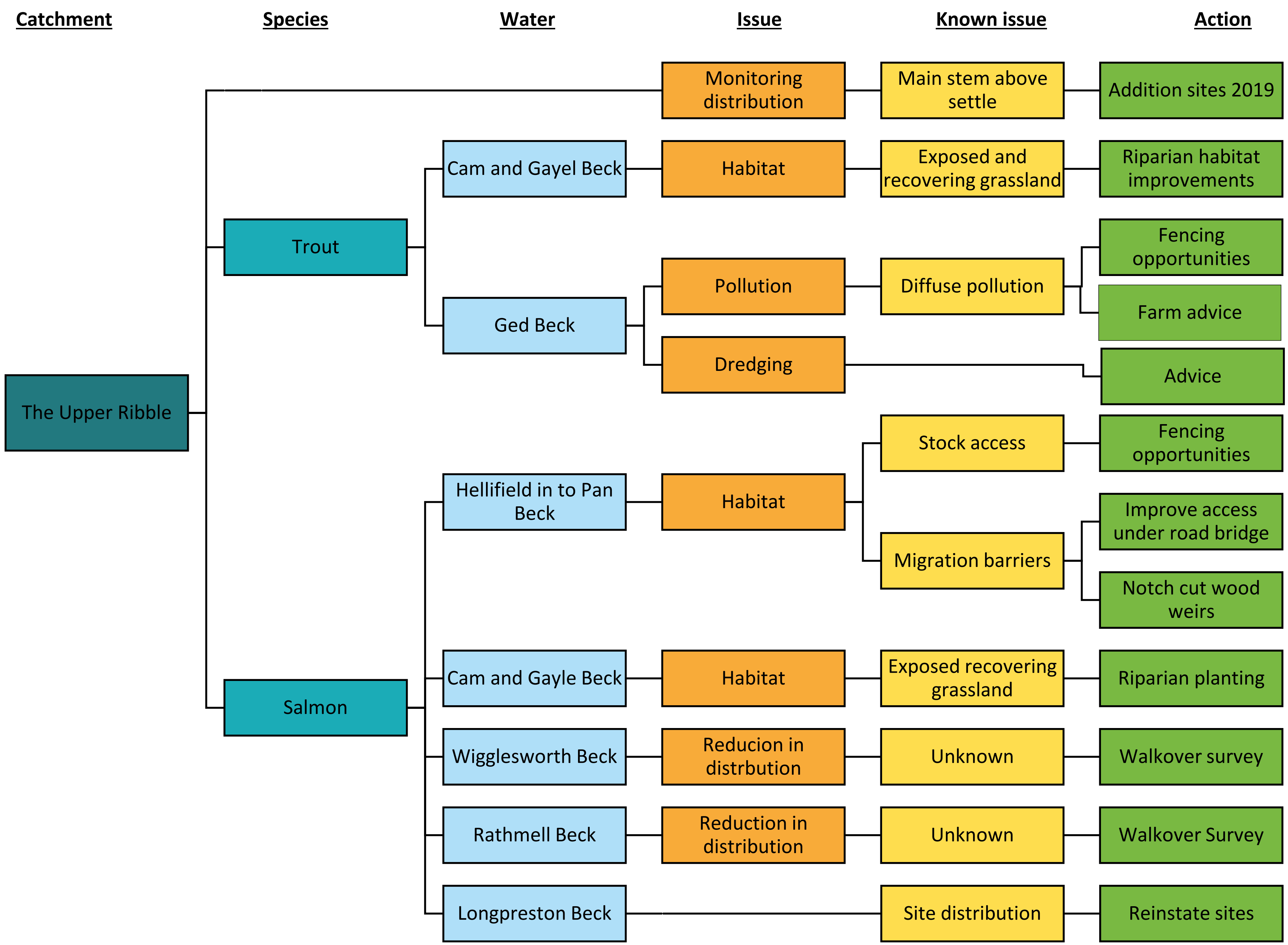
Fisheries Monitoring of the Ribble Catchment



Fisheries Monitoring of the Ribble Catchment



Fisheries Monitoring of the Ribble Catchment



6.0 Recommendations

1. Continue monitoring existing inter-annual electric fishing sites for cost/benefit monitoring purposes of previously completed projects. Priorities must be given to sustain and extend the six-year records of RRT fisheries data held across 256 sites (inclusive of the core eleven-year sites).
2. Investigate the use of depletion statistics in quantitative surveys and how it effects the outputs of semi- quantitative density calculations.
3. Continue looking at weight-length and total weight relationships of salmonids and bycatch to give more understanding to catchment condition and the relationships between bycatch and keystone species.
4. Look into the rotation of quantitative sites on waterbodies retaining key quantitative site for calibration based on Atlantic salmon densities.
5. Continue to monitor the main-stem Ribble, with the possibility of increasing the number of main-stem sites on the upper Ribble to fill in knowledge gaps of spawning locations.
6. Focuses on water friendly farming in areas that have been designated as areas that hold significant spawning importance highlighted in salmon and species richness maps 2018.
7. Expand the initial Actions and Strategies concern into a desktop study of waterbodies that are failing to provide suitable and sustainable habitat for fish populations.
8. Continue to support the voluntary catchment and release of salmonids, encouraging anglers to aim for a rate of at least 90%, with perhaps 100% from September or October.
9. Increase main stem coverage on the Calder catchment to locate key salmon spawning areas for future monitoring.
10. Reduce impacts of invasive species on native crayfish and support strategies and efforts to reduce further movement, and prevent introductions, especially where there are impacts on a designated site and on where there is a risk of interface with key spawning, and juvenile nursery areas.
11. Introduce invertebrate studies alongside fisheries surveys to map the aquatic biodiversity of the catchment in relation to key salmon spawning locations on the Hodder and Ribble catchment. Explore how this can be best used to inform future targeting of work and conservation efforts.
12. Assessment of the lower Ribble to capture more information on coarse species populations alongside continued salmonid monitoring.
13. Increase knowledge of eel populations and movements within the catchment.
14. Focus on improving knowledge on salmonid smolts such as fry to smolt survival and factors effecting downstream migration in the catchment.
15. Support targeted research on river lamprey on the lower Ribble, to identify if this area would support SAC designation and whether this should be sought.
16. Carry out eDNA sampling in waters above Padiham to find any upstream presence of Atlantic salmon on the Calder.

7.0 References

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Thomas, S. M., Griffiths, S. W. & Ormerod, S. J., 2015. Adapting streams for climate change using riparian broadleaf trees and its consequences for stream salmonids.. *Freshwater Biology,* 60(1), pp. 64-77.

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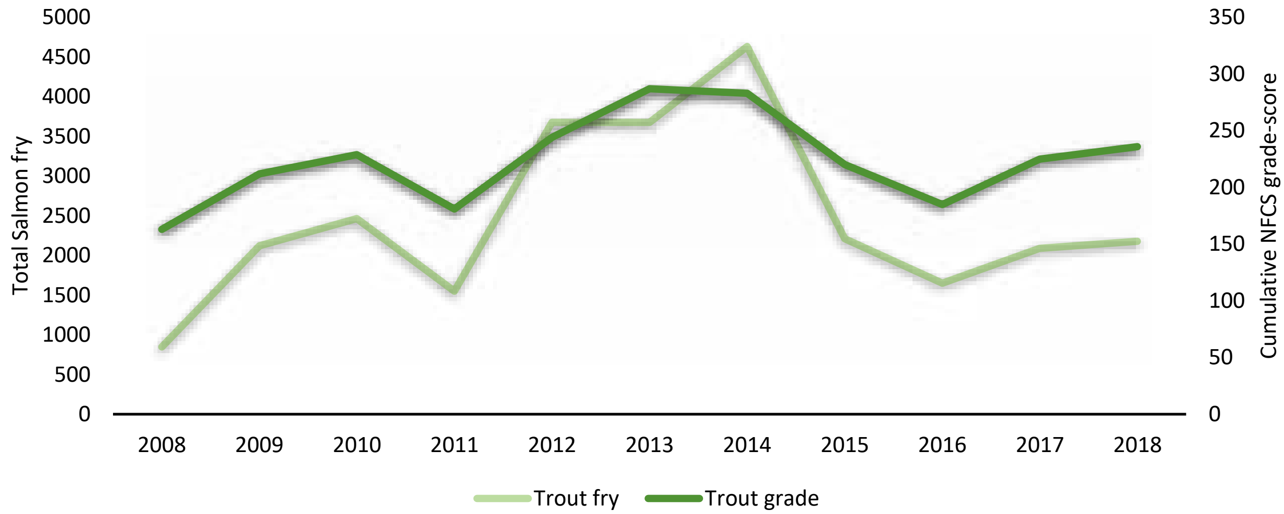
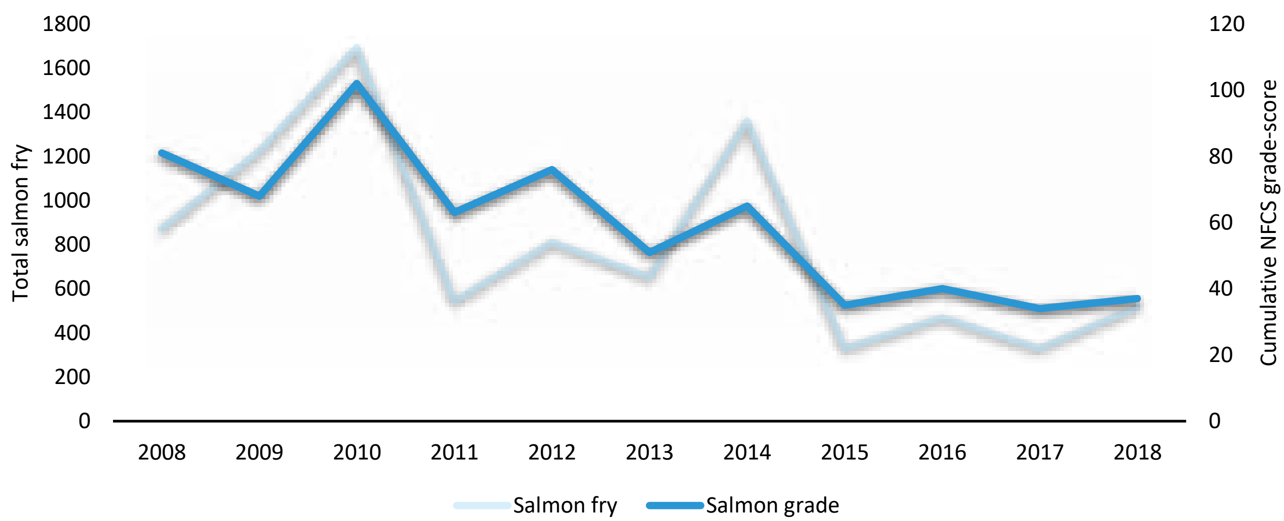
8.0 Appendices

8.1 Appendix A

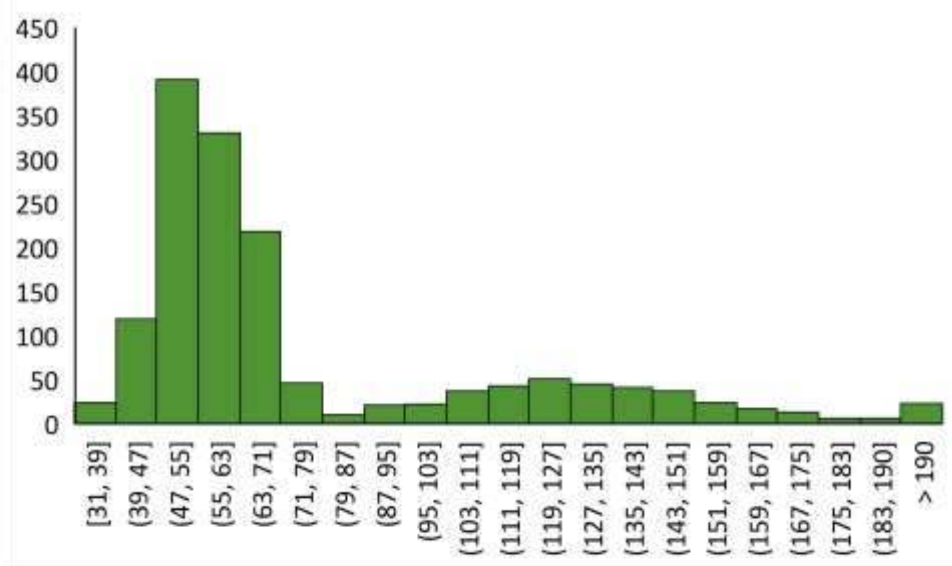


Appendix A. 1. Cumulative NFCS grade-score and total calculated fry/100m² for the catchments core 88 electric fishing sites for brown trout 2008 - 2018.

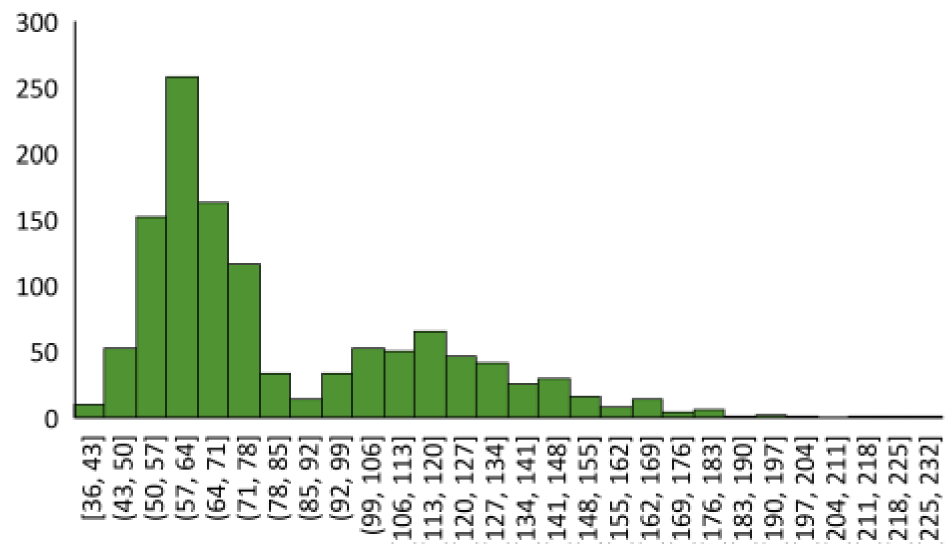


Appendix A. 2. Cumulative NFCS grade-score and total calculated fry/100m² for the catchments core 88 electric fishing sites for Atlantic salmon 2008 - 2018.

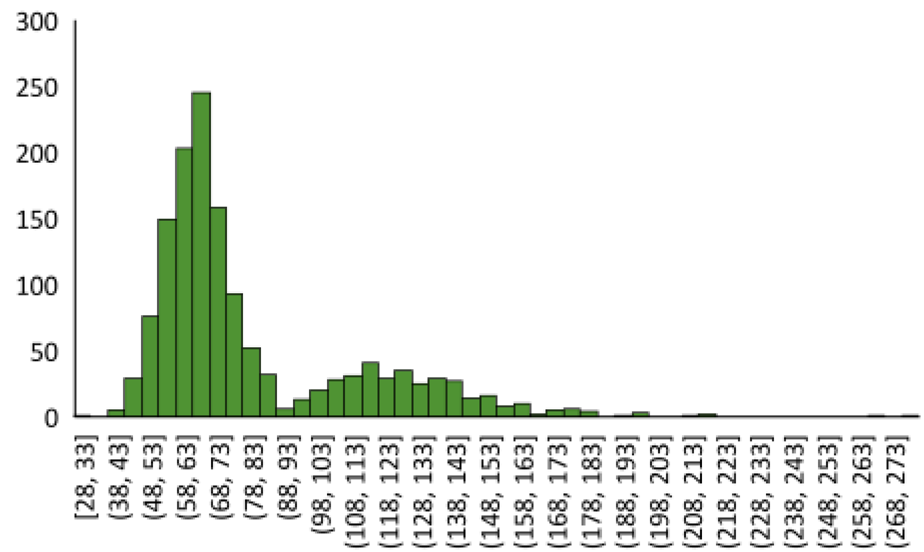
8.2 Appendix B



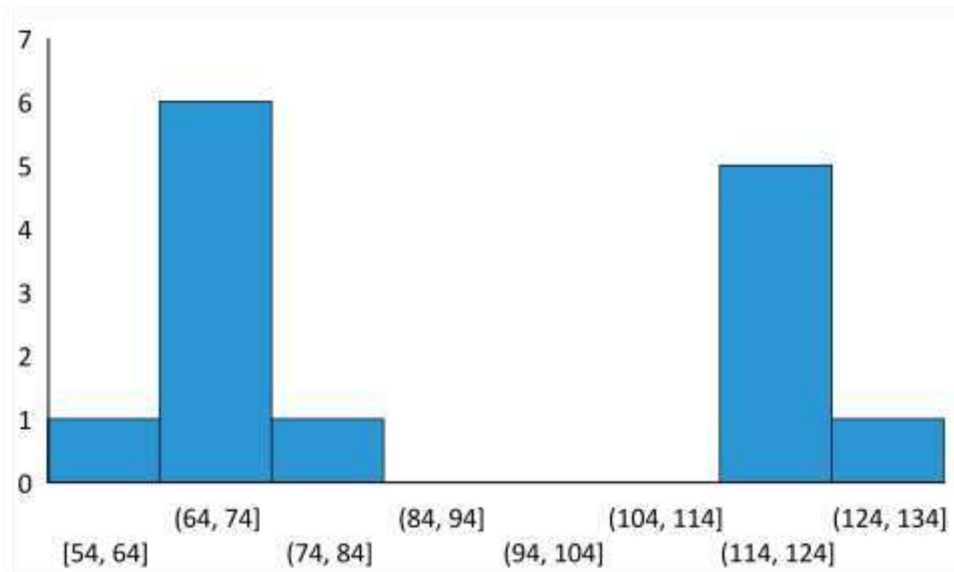
Appendix B. 1. Fork length histogram of all brown trout captured on the Calder catchment 2018. Maximum fork length for 0-year trout = 88 mm at time of survey.



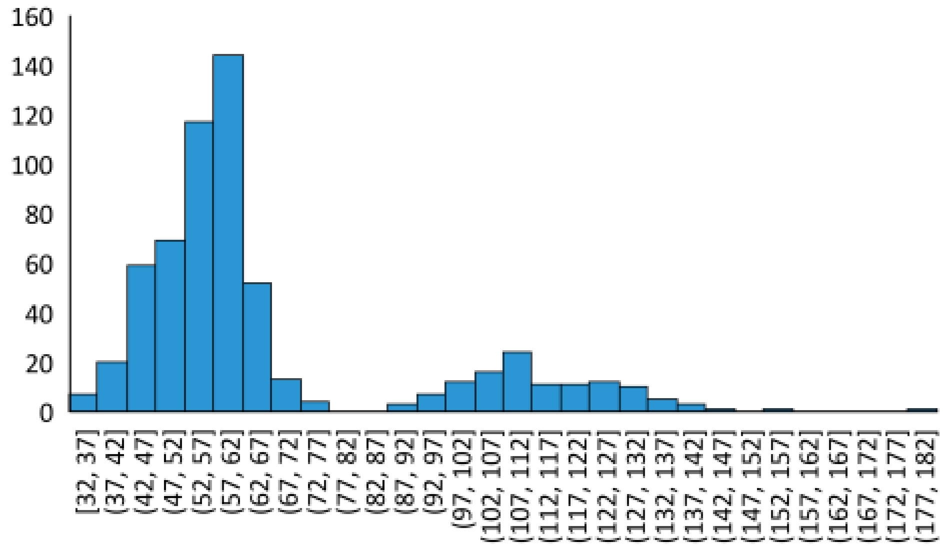
Appendix B. 2. Fork length histogram of all brown trout captured on the Hodder catchment 2018. Maximum fork length for 0-year trout = 87 mm at time of survey.



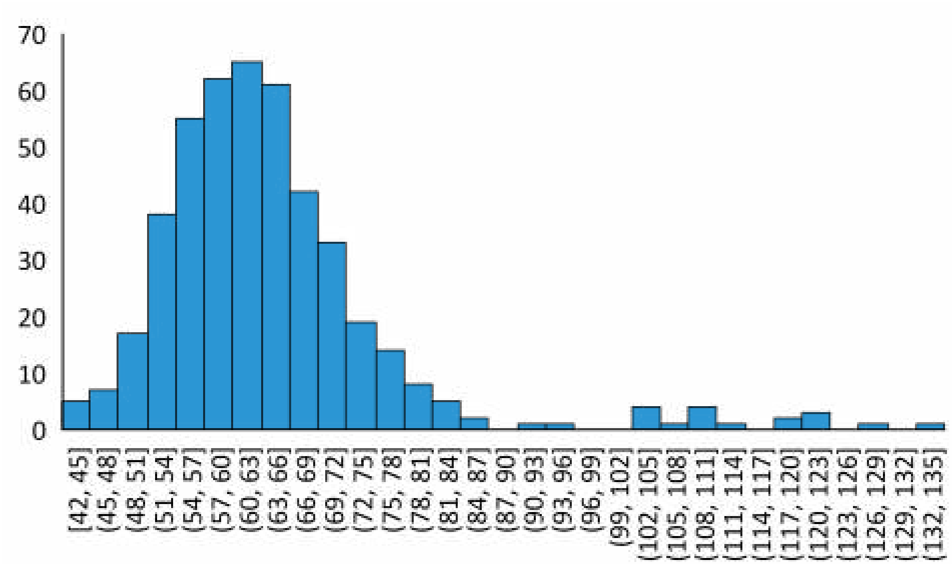
Appendix B. 3. Fork length histogram of all brown trout captured on the Ribble catchment 2018. Maximum fork length for 0-year trout = 93 mm at time of survey.



Appendix B.4. Fork length histogram of all Atlantic salmon captured on the Calder catchment 2018. Maximum fork length for 0-year salmon = 83 mm at time of survey

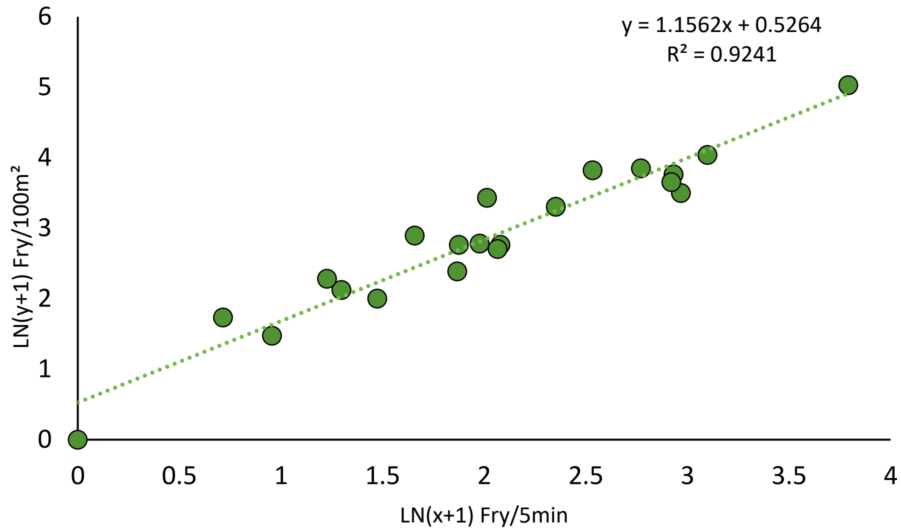


Appendix B. 5. Fork length histogram of all Atlantic salmon captured on the Hodder catchment 2018. Maximum fork length for 0-year salmon = 87 mm at time of survey

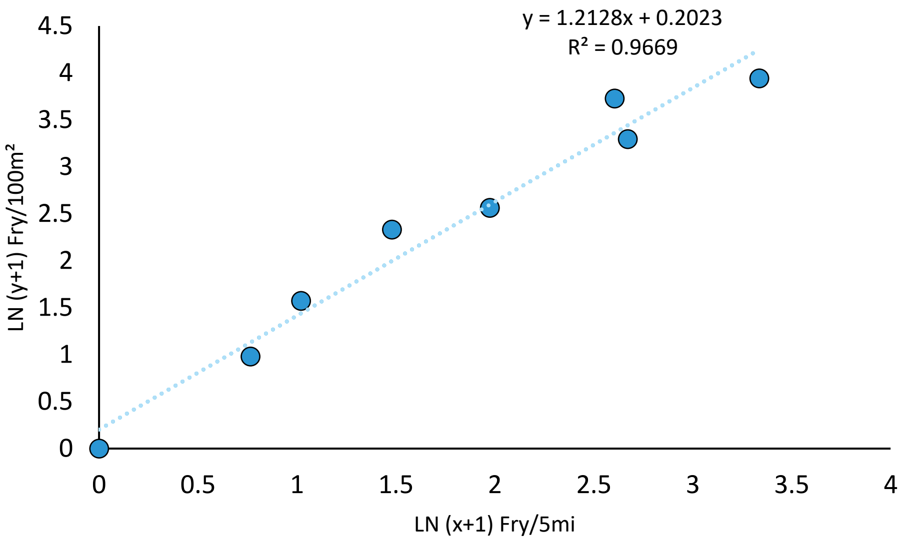


Appendix B.6. Fork length histogram of all Atlantic salmon captured on the Hodder catchment 2018. Maximum fork length for 0-year salmon = 79 mm at time of survey

8.3 Appendix C



Appendix C. 1 Brown trout quantitative fry population relationship between semi-quantitative (5 minutes fry capture) and quantitative electric fishing results (Fry per 100 square) that is LN+1 transformed. Fitted linear regression for 0 + salmonids is produced where Ln (y + 1) = 0.5264 + 1.1562 Ln (x + 1)



Appendix C. 2. Atlantic salmon quantitative fry population relationship between semi-quantitative (5 minutes fry capture) and quantitative electric fishing results (Fry per 100 square) that is LN+1 transformed. Fitted linear regression for 0 + salmonids is produced where Ln (y + 1) = 0.2023 + 1.2128 Ln (x + 1)