Fisheries Monitoring of the Ribble Catchment 2017

Ribble Rivers Trust

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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Executive Summary

The River Ribble Trust concluded its tenth year of its inter-annual fisheries assessment of the Calder, Hodder and main Ribble Catchments. In addition, sites on the River Darwen have been included in 2017's fisheries programme to monitor capital works for Ribble Life Together. Results of these surveys are used to support the identification for future work as well as monitoring the long-term impacts of habitat and migration restoration schemes.

Quantitative and semi-quantitative surveys are performed to assess catchment productivity using an adapted Crozier and Kennedy (1994) electrofishing method. A total of 326 sites were surveyed in 2017 covering 37km² of river. 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. Salmonids are a keystone species within a 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 allows for the standardisation of results by grading sites based on the densities of these fry. Delays were suffered during 2017's fisheries programme as higher than average rainfall (September-October) resulted in sites above Gisburn being surveyed later than usual. Surveys commenced on the 19th of Jun and ended on the 16th of October.

Brown trout (*Salmo trutta*) populations have remained relatively consistent over the past eight years (Figure 1). During this time, the most recent impact to recruitment was observed in 2016 after high flow events of the previous winter caused major spawning disruption and reduced survival of ova. Results of 2017 show better survival rates and after last year's depression with the Calder catchment seeing a 63% increase in grade scores. The Hodder has seen a positive increase in grade score with 36% of its sites improving in comparison to last year's results. And the main Ribble remains consistent for 2017. This year a total of 3421 individuals were caught from 250 of the 326 sites surveyed.

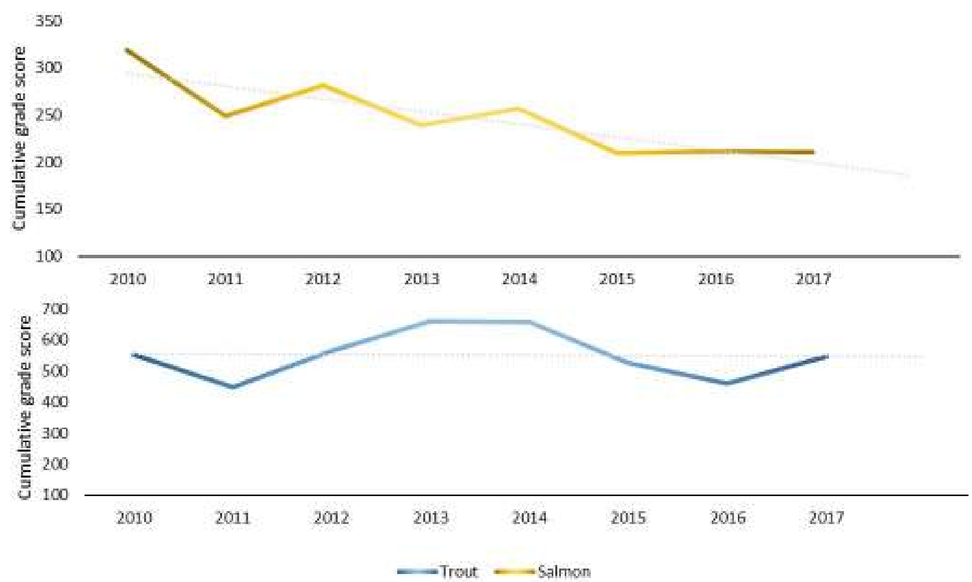


Figure 1. Total grade score for the catchments 155 electrofishing sites with 8 years of consecutive data. Salmon and trout from 2010 to 2017.

Atlantic salmon (*Salmo salar*) have seen the best fry densities on the main Ribble catchment for the past 3 years with 18% of sites increasing in their grade score (Figure 2). However, overall populations across the catchment continued to decline (Figure 1). Minimal recruitment was achieved on the Calder with only three individuals being detected. On the Hodder catchment, sites on the main stem rivers are producing salmon fry but overall densities are down from last year's peaked performance. This year a total of 563 individuals were caught over 79 of the 326 sites surveyed, which is 11 less sites than 2016.

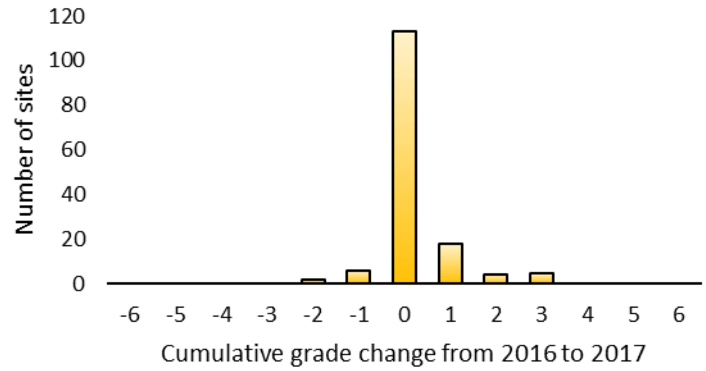


Figure 2. NFCS grade change comparison of Atlantic salmon on the main Ribble catchment from 2016 to 2017.

Electrofishing engagement events have been carried out via the Ribble Life Together programme with Burnley College and the very popular volunteer event of "Fish Friday". Fish Friday has provided an excellent opportunity for additional help during surveying, but events towards the end of the season were unfortunately cancelled due to poor weather. During the Burnley College engagement event at Oakenshaw Weir on the River Hyndburn, salmon fry were discovered below the structure (Figure 3). This find is a positive result as the newly constructed bypass channel was opened in October 2017 connecting the upper reaches for migrating salmonids and hopes are high for detecting salmon above this barrier in 2018.

Figure 3. Salmon fry on the River Hyndburn below Oakenshaw Weir during electrofishing demonstration.

American signal crayfish (*Pacifastacus leniusculus*) cause continued concern for Trawden Brook and Long Preston Beck as they increase their range within these waterbodies. Sites on Trawden Brook have seen no salmonid recruitment and +1-year fish have severe caudal fin damage which will impede swimming performance. On Long Preston Beck the downstream limit of signal crayfish is unknown as the ability to detect this species at low abundance remains problematic. Their continued dispersal will result in the disruption of the main stem Ribble which is designated as a Site of Special Scientific Interest (SSSI).

Figure 4. River lamprey caught during fish rescue at Cuerdale, main stem Ribble, above tidal limit.

River lamprey (*Lampetra fluviatilis*) have been recorded for the first time by the Trust on the main stem Ribble at Cuerdale (Figure 4), bringing the total number of Annex II fish species within the catchment to 6; European eel (*Anguilla anguilla*), brook (*Lampetra planeri*) and sea lamprey (*Petromyzon marinus*), Atlantic salmon and bullhead (*Cottus gobio*). The Environment Agency (EA) have also located river lamprey in the Ribble estuary in 2010 and 2013 as part of “otter trawling” surveys. Designation of ‘Special Area of Conservation’ (SAC) in the lower reaches of the catchment could be applied for following investigation into this discovery. EA records also show the presence of river lamprey in upper parts of the Ribble catchment, we suspect that these may be brook lamprey owing to their location, and that a misidentification was made due to the similarities between these species during juvenile stages.

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 these anadromous and catadromous species and the work that the Ribble Trust has carried out over the past ten years has significantly increased the connectivity of the river to migration and reconnected 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.

Going forward there are 261 sites with five years of consecutive data (inclusive of the core sites) which will be designated as high priority sites for 2018 fisheries programme.

Introduction

The Ribble Rivers Trust (RRT) has been conducting habitat restoration schemes and improving land management within the Ribble catchment since 1999, 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.

October 2017 concluded the trusts tenth year of its annual fisheries programme, covering 37km² of river over 326 selected sites, 155 of which hold 8 years of consecutive data. This year the Ribble Rivers Trust has also launched the 'Ribble Life Together' programme (http://ribblelife.org) which has introduced additional electrofishing locations on the River Darwen and will assess the effects of river management activities funded by the Heritage Lottery Fund (HLF) and other partners and funders. Cooperative electrofishing surveys have also been conducted by the Environments Agency (EA) as part of their monitoring of sustainable abstraction as well as Water Framework Directive (WFD) status monitoring on the River Calder and Pendle Water. Under a data sharing agreement, the EA results are included in the analysis of this report as the methodology applied is synonymous.

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.

The ecological and chemical status of the River Ribble and its tributaries has seen a positive shift between 2009 and 2016 (Figure 5) with over half of its waterbodies receiving and maintaining 'Good' status by 2013 (Environmental.data.gov.uk, 2017) this has been retained at 64% for the past two years. The ecological status of surface waters is assessed according to the biological, hydromorphological and physicochemical qualities. The general pressures on surface water includes urbanisation, the intensification of agriculture, abstraction and extractive industries. As 90% of the catchment is predominantly rural and agricultural activity is extensive, projects such as the Catchment Restoration Fund (CRF) 'Diffusing the Issue' have been helping to enhance the ecological status.

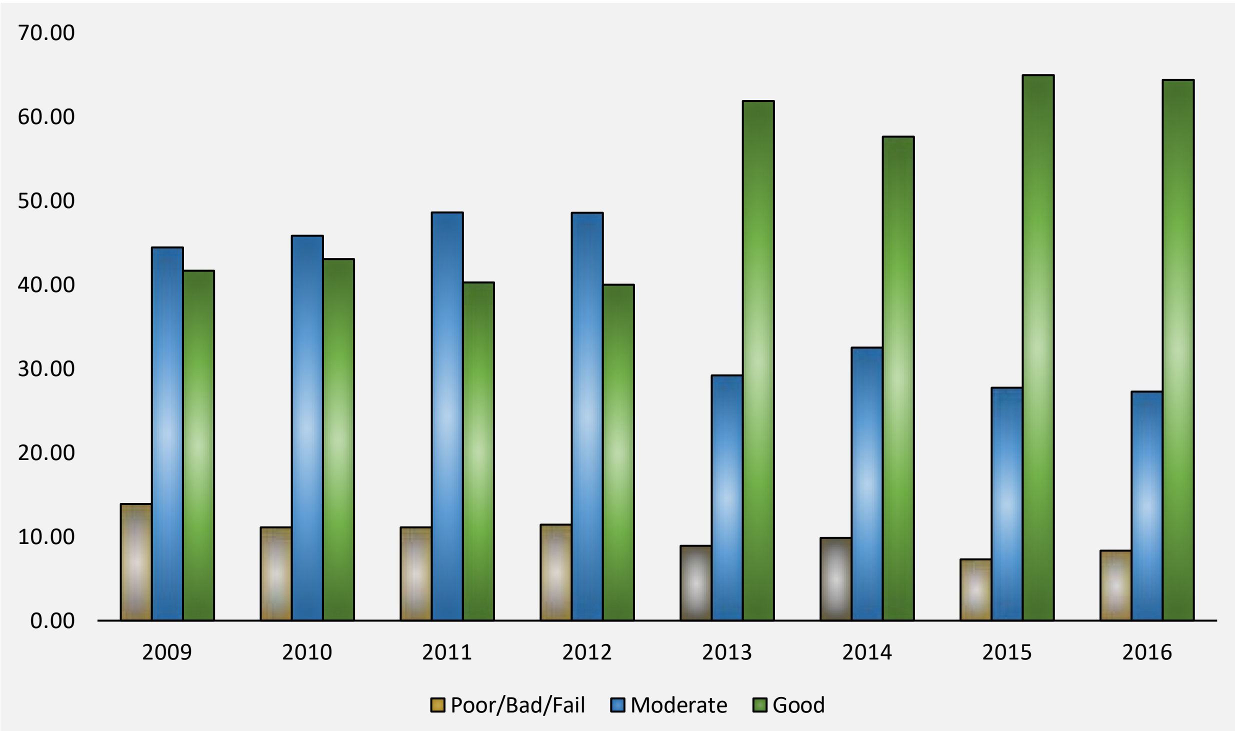


Figure 5. Water Framework Directive classification status of the waterbodies within the Ribble catchment.

The Ribble catchment is a major recreational fishery for both coarse and game fishing with a number of targeted species within the river system recognised as keystone species or holding high conservational interest. To increase population number in relation to angling interests, the habitat in which they reside must have the ability to provision resources to match the needs of its inhabitants. Improvements in habitat quality and quantity will naturally increase the population abundance but the more complex an ecosystem the greater the diversity it can support. When habitats become simplified or disconnected there is a decrease in resources and increased competition which results in the loss of niche species and species richness, affecting each trophic level.

Methodology

Electrofishing surveys

This year, the Ribble catchment's fish population was monitored by the Environments Agency (EA) in fulfilment of its obligations under the Water Framework Directive (2000). Prior to the survey programme the Ribble Rivers Trust co-ordinated with the EA to avoid a duplication of effort with three key sites identified. The applied methodologies are adapted from Crozier and Kennedy (1994) and have been employed by the Trust since 2008. Each site was fished in a zig-zag pattern moving up river. During this process the anode was swept through the water column, approximately half depth, matching the flow towards the netter. Riffle/pool habitat was targeted to capture both the young of year and the adult populous using an E-fish 500W electrofishing backpack system.

A review was conducted and 325 survey sites were identified and assigned an index value based on the number of consecutive years they had been sampled. Sites assigned priority 1 held the greatest priority, with five years of continuous data now available for 270 sample sites and 8 years' data for 155. 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.

Typically, two types of survey were undertaken: semi-quantitative, where the river is actively fished for five minutes covering a measured un-isolated area without using stop-nets; and quantitative, where a netted area of river is sampled as sequential runs, with the catch from each run detained separately for processing. Quantitative surveys allow for the identification of capture efficiencies of each electro-fisher, thus allowing standardised results from semi-quantitative surveys to be presented.

Commencing from the 19th June and closing on the 16nd October, 7 quantitative sites (8 in 2016) were fished on the Calder, 9 on the Hodder (8 in 2016), and 10 completed on the Ribble (12 in 2016). It was suggested that subsequent quantitative sites be assessed prior to surveying using the relative abundance of salmonids caught in neighbouring semi-quantitative sites. A total of 299 (289 in 2016) semi quantitative sites were surveyed, this included 10 quantitative sites that were fished as semi-quants due to time constraints imposed by higher than average rainfall.

The densities of trout and salmon from the above activities were calibrated and allocated a grade score (Table 1). The grades standardise the Trust's field observations with those of the National Fisheries Classification System (NFCS; National Rivers Authority (now EA), 1994). The system is species related and based upon the number of fry captured. Fry were distinguished by establishing a maximum fork length (Appendix B. 1 toAppendix ***B. 5***) discerned by the two-peaked shape of the frequency-length distribution for all captures of that species for each major catchment. Grades A – F are assigned by extrapolating the density of fry per 100m^2 using the number of fry captured over a minimum of five minutes. The capture efficiency of the electrofishing team is calculated through quantitative surveys by comparing the number of captures in the primary run compared with the total present (Appendix C. 1 and Appendix C. 2) The quantitative calibration applied to semi-quantitative analysis must reflect the variation in fishing results based on the constant effort of the electrofishing team for each site surveyed. This calibration summarises all quantitative data collected as well as the addition of a zero, zero point to represent a total absence of salmonids. The resulting equation can be applied to semi-quant data to give a calibrated number of total fry per 100 m^2.

Table 1. National Fisheries Classification System for fry density

Grade	**Fish Density**
A	Excellent
B	Good
C	Fair
D	Poor
E	Very Poor
F	No Fish Present

Once graded the results were transferred to a map layer using ArcGIS 10.3.1 to display catchment scale results. Inter-annual comparisons of data featured in the results section are based on sites holding 8 years of consecutive data. This ensures those of a similar habitat type are being compared year on year. Grade results have been averaged and organised within the analysis of this report according to geographical coverage determined by sub-catchment. Use of pre-selected spot surveys provides us with a useful overview of the Ribble's overall population health, particularly when combined with additional tools (e.g. fish counter data).

Sub-catchment map

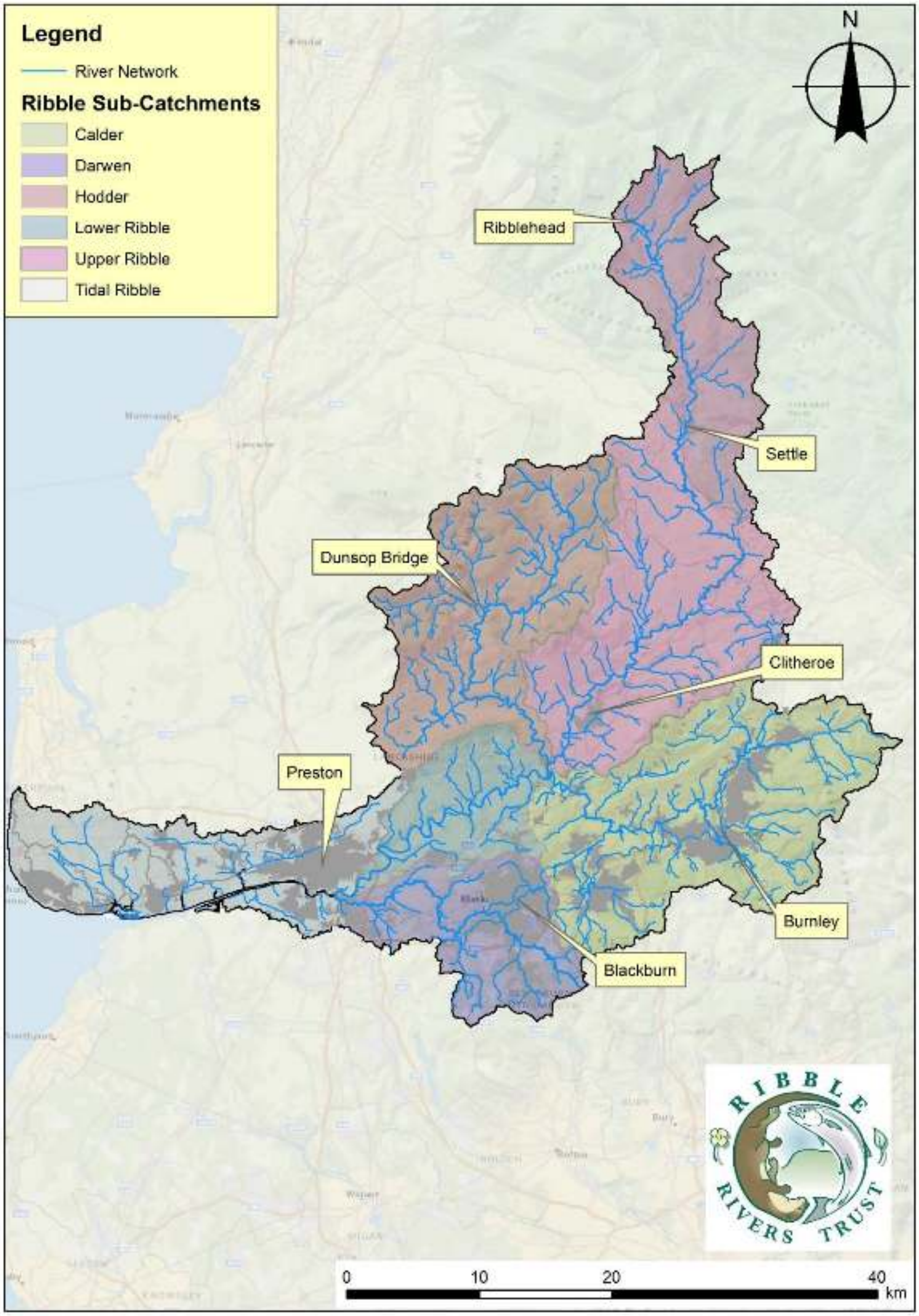


Figure 6. Map of the Ribble catchment outlining the sub-catchments areas discussed in this report.

Data Analysis

The diversity of each major catchment was characterised by calculating the exponential of Shannon-Wiener Diversity Index (below) 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. Fish communities were assessed (without the consideration of other aquatic species i.e. invertebrates) and results describe richness and evenness of the sample.

$$H' = -\sum_{i=1}^{R} P_i \ln P_i$$

$$H_1 = expH'$$

H' = Shannon-Weiner diversity index

H_1 = Exponential Shannon-Weiner diversity index

P_i = The proportion of individuals found in the ith species

R = The richness of the sample

Results

Brown trout

Brown trout have seen a positive recovery from last year's depression (Figure 7) with a total of 3421 fry, parr and adult fish captured over 250/326 electrofishing sites. This is an increase of 800 individuals in comparison with 2016 surveying results, the most notable change being on the Calder catchment. In 2016 it produced the lowest extreme of fry after high fluvial events whereas 2017 sees the Calder become the most productive sub-catchment of the Ribble. The Hodder has also seen a recruitment boost with the main Ribble remaining relatively consistent to the preceding year's results. All 3 sub catchments are yielding a similar degree of young when comparing cumulative grade scores. 2017 has seen a reduction in the number of sites with poor status or an absence of brown trout (E – F). The number of F grade sites (absence of trout) will always be of concern but there has been a positive shift in fair to excellent (C – A) grades over the past three years ().

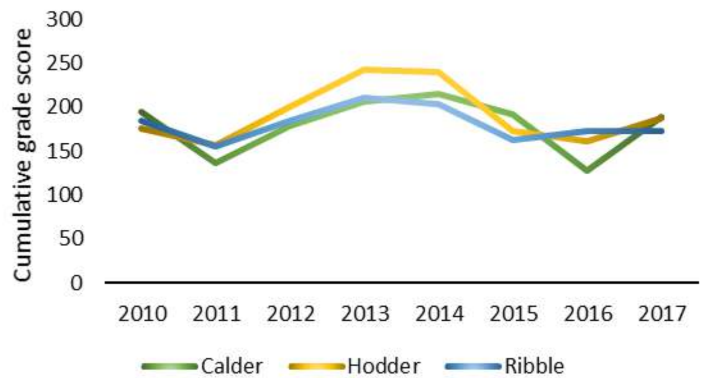


Figure 7. Cumulative brown trout fry grades of sub-catchments of the Ribble 2010 to 2017.

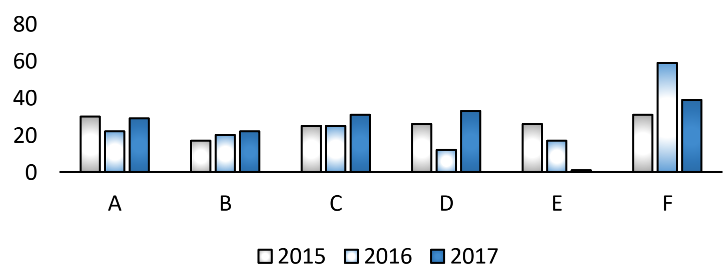


Figure 8. Frequency comparison of brown trout NFCS grades in the Ribble catchment 2015 to 2017.

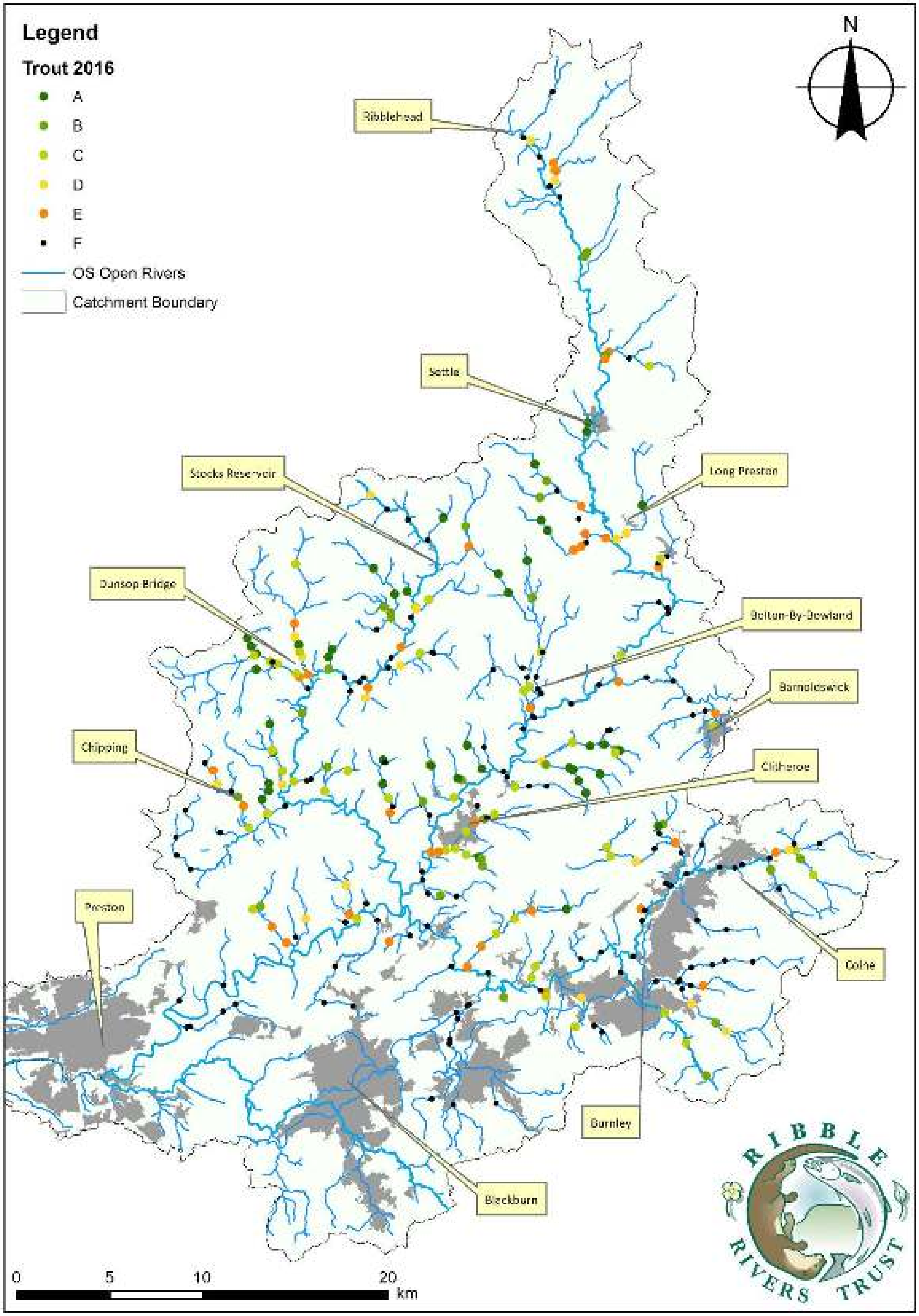


Figure 9. Catchment map (1:250,000) showing brown trout fry NFCS grades from surveys undertaken by RRT and the EA in 2016. Green points indicate higher grades and therefor higher trout densities, decreasing to orange. Black indicates an absence of trout fry.

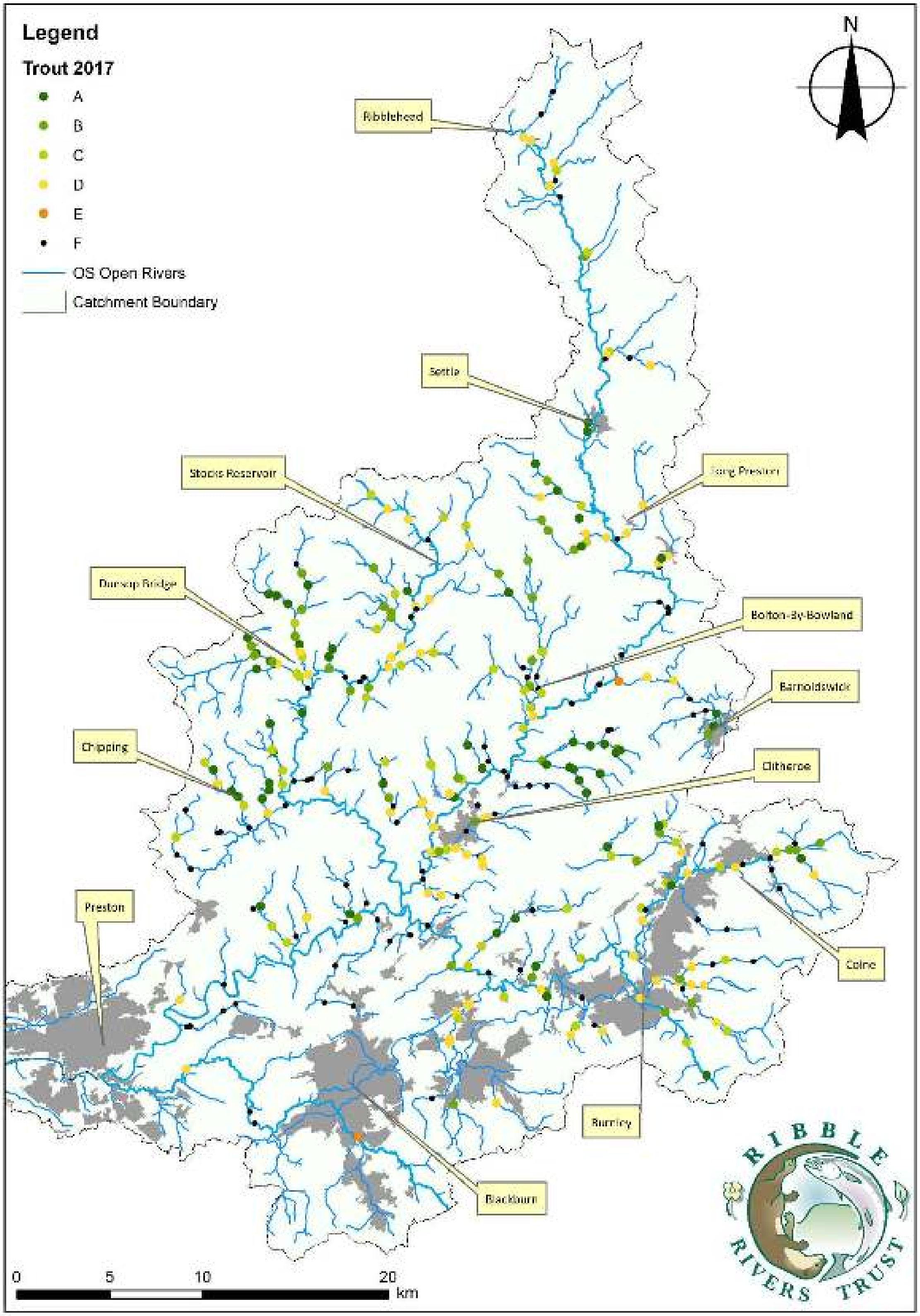


Figure 10.Catchment map (1: 250,000) showing brown trout fry NFCS grades from surveys undertaken by RRT and the EA in 2017. Green points indicate higher grades and therefor higher trout densities, decreasing to orange. Black indicates an absence of trout fry.

Calder

Brown trout (*Salmo trutta*) populations have made a good recovery over each catchment with the best recruitment seen on the Calder with 63% of sites increasing by an average of 2 grades (Figure 11). In 2016 the River Don and Thursden Brook were impacted by fluvial geomorphological change resulting in the loss of juvenile salmonids. The River Don has seen a strong recovery with Thursden Brook showing slower returns with one site achieving a C grade. This higher grade is promising for the rest of the brook and over the coming year dispersing juveniles will re-colonise the reach. There is concern for Trawden Brook since last year's fry deficiency and the further dispersal of signal crayfish (*Pacifastacus leniusculus*) in the area, no young of year were recorded in 2017. With this invasive species thriving, trout fry survival can be impacted and grade scores will be low due to predation of ova and young. Signal crayfish can expand to other tributaries over time forcing similar depletion in salmonid recruitment (Peay, et al., 2009). As well as negatively affecting recruitment, parr caught in 2016 and 2017 exhibit caudal fin damage which will inhibit swimming efficiency and reduce the ability to utilise resources.

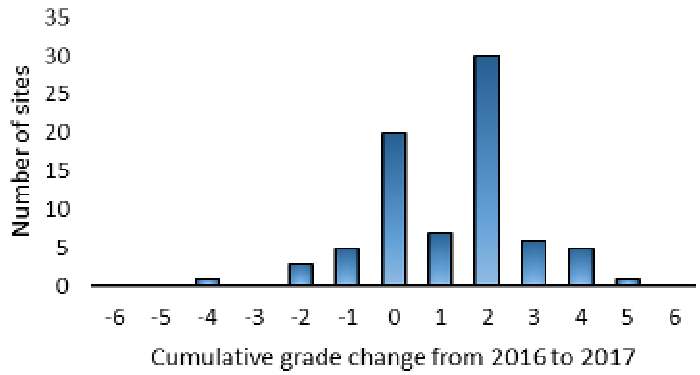


Figure 11. NFSC grade change comparison of sites from 2016 to 2017 for brown trout fry per 100m² in the Calder catchment.

Hodder

Trout distributions follow a similar trend to the Calder with numbers rising after the 2016 low (Figure 12). The most improved site was in a Ribble Trust habitat scheme at the top of Easington Brook, going from a grade F to a grade C, its highest grade-score in 9 years of data. Elsewhere, Chipping Brook has seen a promising improvement this year and despite suffering from a pollution incident all but one site increased in grade score. That site unsurprisingly produced parr and adult fish as the habitat surveyed is less suited to +0 salmonids. The site at Loud Bridge is the only site which has produced trout fry on the River Loud with 2015 seeing the last rise in grade scores following the completion of the Ribble Trust's 'Diffusing the Issue' project. Leagram Brook, a tributary of the River Loud, continues to yield high densities of trout fry. One barrier to improving salmonid recruitment on the Loud is

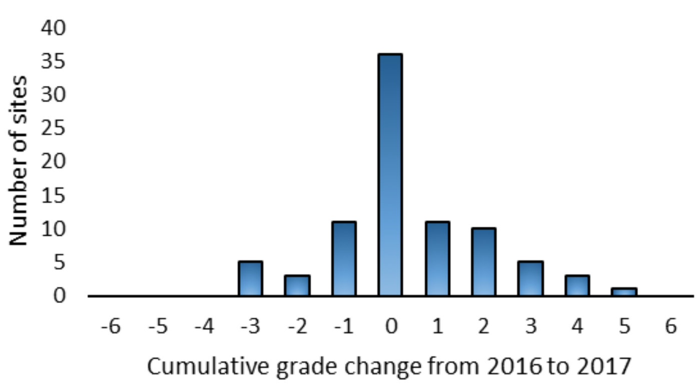


Figure 12. NFSC grade change comparison of sites from 2016 to 2017 for brown trout fry per 100m² in the Hodder catchment.

believed to be the quality of its water, rated 'poor' under the Water Framework Directive. For this reason, the Ribble Trust is targeting this through a number of projects and activities, encouraging water friendly farming, particularly through Ribble Life Together.

On the River Dunsop, spawning channels off the main stem were once considered the best salmon spawning location in the Hodder catchment. Over the past 5 years salmon fry have been absent from the channels and brown trout fry have become the dominant species. Over time the constructed channel has narrowed and substrate levels and composition have evolved (Figure 13).

Figure 13. Spawning channel on the River Dunsop from 2008 (left) to 2016 (middle) and 2017 (right - taken from mouth of channel).

There are sites within the catchment that see yearly variation in population dynamics and many of the sites producing higher grades are believed to be dependent on sea trout spawning. Two adult sea trout were caught in Greystoneley Brook this year which is considered to be a key sea trout spawning tributary and produces consistently high densities of trout fry. One concern is that adult salmonids in this area have been found with net or wrapped line damage, which may be a sign of continued poaching effort.

Lower Ribble

The lower Ribble has consistently produced sparse numbers of trout and the majority of sites are salmonid free. In part, this may be due to unsuitable habitat and as such in future, to evaluate the health of this area more effectively, the Trust would like to undertake a more diverse sampling of the fish community, investigating coarse species and existing community structure as well as focusing on angling interests. On a positive note, trout have been found on Tun Brook where the habitat is highly influenced by unstable clay banks and heavy sediment loading from landslides. Furthermore, the most upstream sites on Duddel Brook have produced fry for the first time in six years (Grade D), with trout having been absent in this area for 4 years.

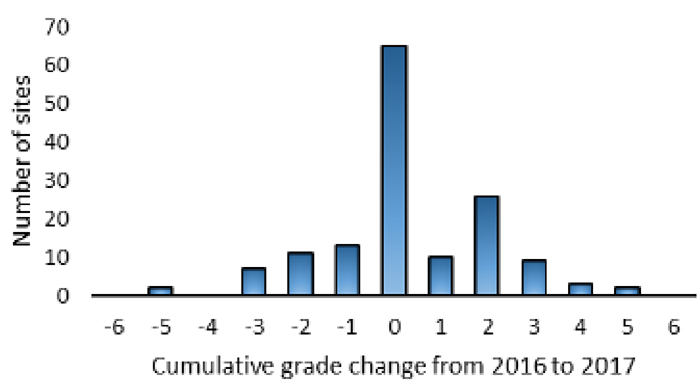


Figure 14. NFCS grade change comparison of sites from 2016 to 2017 for brown trout fry per 100m² in the main Ribble catchment.

Main Ribble

In contrast with other sub-catchments, trout populations did well in 2016 in the main Ribble catchment, appearing to be the least affected by the Boxing Day floods. This is the only catchment that saw a marked improvement in grade scores and remained consistent for 2017. There was some variation within waterbodies as Pendleton Brook and Standen did not perform well. These sites are adjacent to the A59 which could be a source of diffuse pollution and a decrease in water quality. Ings Beck remains one of the best brown trout waterbodies for spawning in the mid-Ribble catchment and has produced a four year high in the lower reaches. A very positive find was on Rathmell Beck in the Upper Ribble, seeing fantastic returns and having the highest densities of fry in the catchment after previously being absent.

Salmon

Atlantic salmon (*Salmo salar*) have seen the best fry densities on the main Ribble catchment in the past 3 years with 18% of sites increasing in their grade score. However, overall populations continue to decline (Figure 15) with a total of 469 fry and parr captured over 87/326 electrofishing sites in 2017. This is approximately a third of 2012's maximum abundance where a total of 1533 individuals were processed. The Calder catchment saw minimal improvements where three individuals were caught after the previous year's total absence. The Hodder, once considered the best spawning habitat on the Ribble, continues to decline after last year's rise in fry numbers. This rise could be a buffered outcome of salmon returns from 2012's population high. There has been very little shift over the past 3 years in the number of sites showing an absence of salmon. In 2017, 69% of sites were designated F-grade with less than 10% of sites receiving a fair to excellent rating (Figure 16). There are considerations when looking at the number of F-grade salmon sites in the Ribble catchment. A sizable proportion of returning Atlantic salmon are considered to spawn on the main stem rivers where locations are not suitable for backpack electrofishing analysis, therefore, the majority of Ribble Trust sites are located on smaller tributaries. There are limitations to where salmon will spawn; depth, water velocity and substrate composition are considered the most important contributing factors to site selection (Louhi, et al., 2008). In comparison to brown trout, salmon have more sensitive ova requirements and consequently demand higher water quality for development, with good dissolved oxygen concentrations and low sediment loading. Sites that have a historical absence of salmon may persist as they are naturally inaccessible to migration and the morphology of smaller tributaries may only permit the migration of large adults in ideal flows. Waterbodies that have the potential to sustain salmon ova and fry development are identified through the fisheries programme and are targeted by projects to reinstate migration routes as well as improving spawning habitat and water quality.

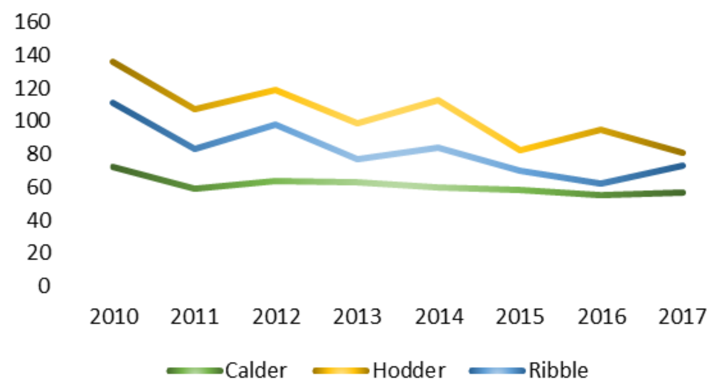


Figure 15. Cumulative Atlantic salmon grade of sub-catchments of the Ribble 2010 to 2017.

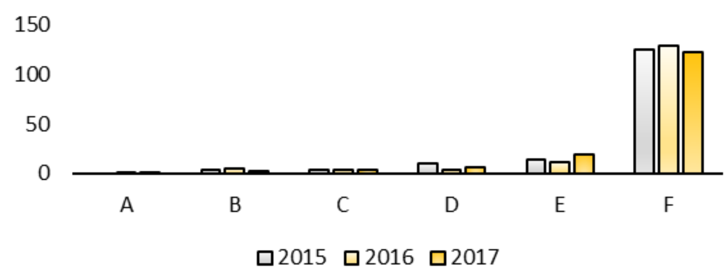


Figure 16. Frequency comparison of Atlantic salmon NFCS grades in the Ribble catchment 2015 to 2017.

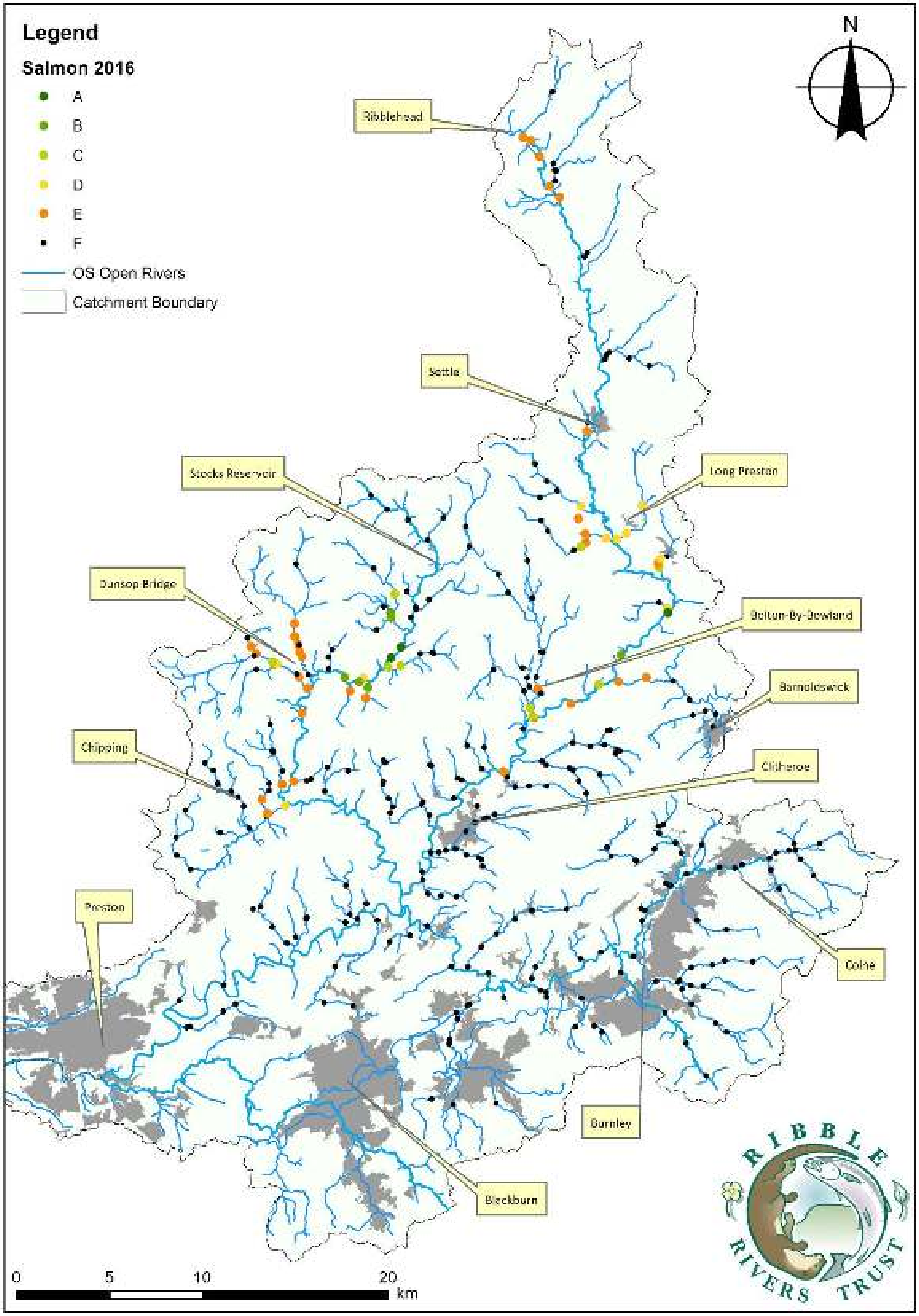


Figure 17.Catchment map (1: 250,000) showing Atlantic salmon fry NFCS grades from surveys undertaken by RRT and the EA in 2016. Green points indicate higher grades and therefor higher trout densities, decreasing to orange. Black indicates an absence of salmon fry.

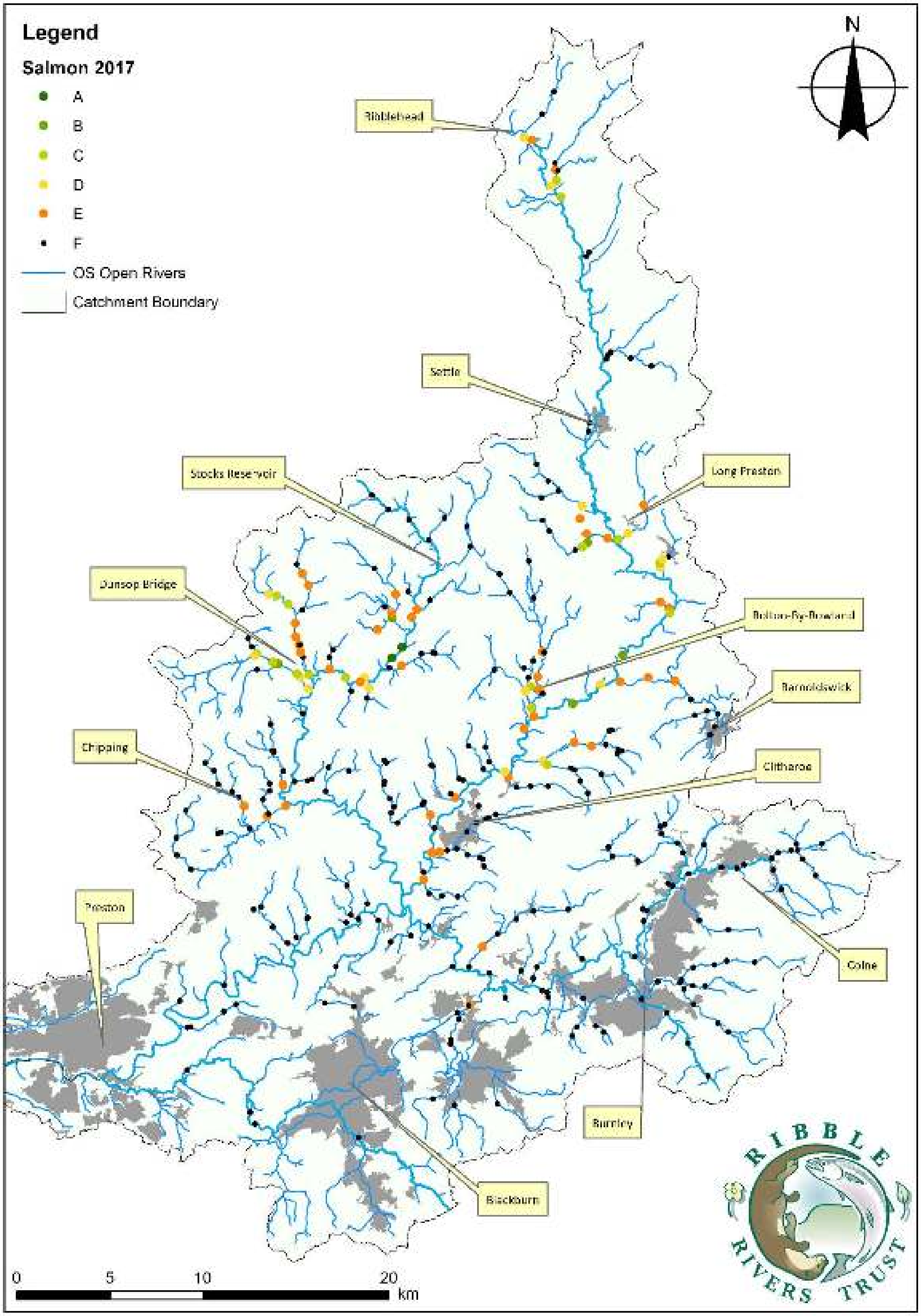


Figure 18. Catchment map (1:250,000) showing Atlantic salmon fry NFCS grades from surveys undertaken by RRT and the EA in 2017. Green points indicate higher grades and therefor higher trout densities, decreasing to orange. Black indicates an absence of salmon fry.

Calder

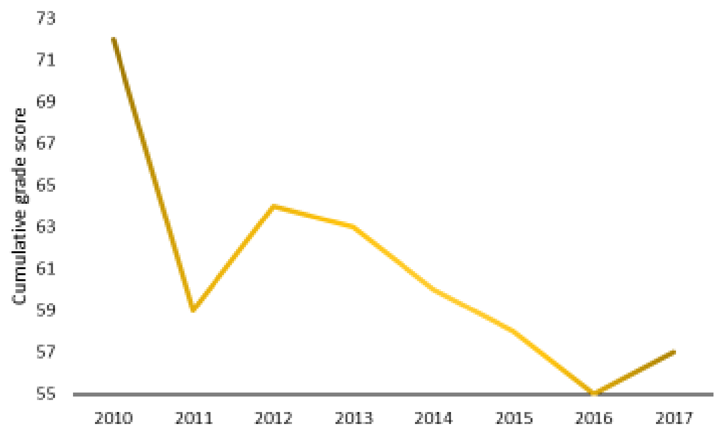


Figure 19. Cumulative NFCS score for Atlantic salmon on the Calder catchments 2010 to 2017 (A = 6, F = 1).

Salmon within the Calder catchment were absent in 2016 and fry returns are minimal for 2017 (Figure 19). Sabden Brook was historically considered one of the most important tributaries for salmon spawning in the catchment from Ribble Trust surveys, but this year only a single fry was identified on the lower reaches of the brook. With the installation of the fish pass at Sabden Weir in May 2017, 14km of river has been reconnected and hopes are high for salmon to return during this year's migration. During the monitoring of the easement a sea trout was captured above the newly constructed fish pass during a mark-recapture exercise. This study has shown fish movements both upstream and downstream of the easement. Salmon fry have also been found on the River Hyndburn with two individuals being caught during the electrofishing season. Several fry were also caught as part of an engagement day with Burnley College downstream of Oakenshaw Weir (Figure 20). With the construction of the bypass channel in October 2017 the Trust is hoping to observe salmon fry above this structure in 2018 and potential spawning sites will be identified before survey work begins.

Figure 20. Oakenshaw Weir on the River Hynburn 2017. Construction of fish bypass channel can be seen on the left-hand bank. Electrofishing site location 20m downstream of the structure.

Hodder

2016 saw the first increase in salmon recruitment on the Hodder in four years which could be a buffered result with fry from the 2012 peak population of salmon returning to spawn. 2017 continues to follow the general downward trend in numbers (Figure 21) but the most productive spawning sites have been located on the main stems of Langden and Dunsop. Salmon have previously used artificial spawning channels on these rivers with high grade scores during 2008 - 2010 but the change in morphology of the channels has affected the hydrology, potentially making them unsuitable for salmon. Salmon are successful on the main stem as they can excavate larger substrate to create redds, but this is leaves them vulnerable to redd washout during high fluvial events.

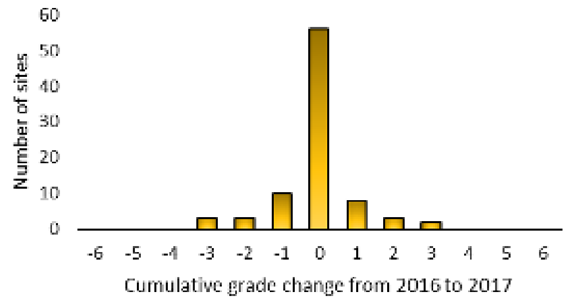


Figure 21. NFCS grade change comparison of sites from 2016 to 2017 for Atlantic salmon fry per 100m² in the main Hodder catchment.

Lower Ribble

The tributaries of the lower Ribble remain consistently absent of salmon fry.

Figure 22. Ribble Trust planting scheme on Cam Beck – Upper Ribble.

Main Ribble

The Ribble is the only catchment that has seen an increase in salmon fry numbers which is particularly evident in the upper Ribble (above Gisburn and Stock Beck) (Figure 23). The main Ribble has remained relatively stable for the last five years and the overall decline is less steep than elsewhere. Delays were suffered during the survey season due to higher than average rainfall which resulted in sites above Gisburn being surveyed later than usual. This temporal shift resulted in the maximum fork length of juvenile salmon being above that of previous years. After a two-year absence salmon have spawned on lower Ings and Swanside Becks, with fry located in all sites downriver of Rimington.

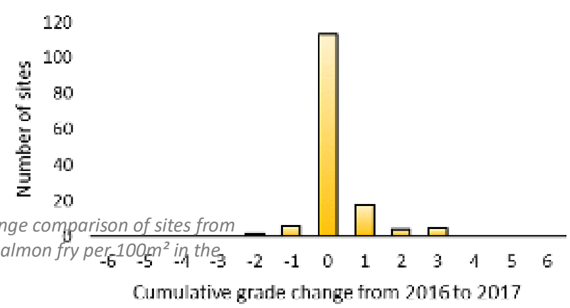


Figure 23. NFCS grade change comparison of sites from 2016 to 2017 for Atlantic salmon fry per 100m² in the main Ribble catchment.

Biodiversity

Increase in habitat complexity often leads to a greater abundance and species diversity. When habitats become simplified or disconnected there is a decrease in resources and increased competition which results in the loss of niche species and species richness. In the case of salmonids, this ecosystem shift will have a negative effect on lifecycle stages and impact the populous. The Ribble catchment holds the highest diversity due to high species richness and abundance of each in comparison to other catchments (Figure 24). It is known from previous surveying efforts that this area is key for coarse fish which are not seen in other areas. The Calder, even though it has the highest abundance of brown trout, suffers from the lack of other salmonids and coarse species thus reducing richness. The Calder holds the lowest diversity score of 0 but this site (River Calder at Holme Chapel) is a NFCS 'A Grade' site due to the number of brown trout fry but holds no other fish species. This could be an indication of a simplified habitat and an area that needs management to increase diversity. Stronger conclusions can be inferred if all aquatic organisms were considered when comparing quantitative sites.

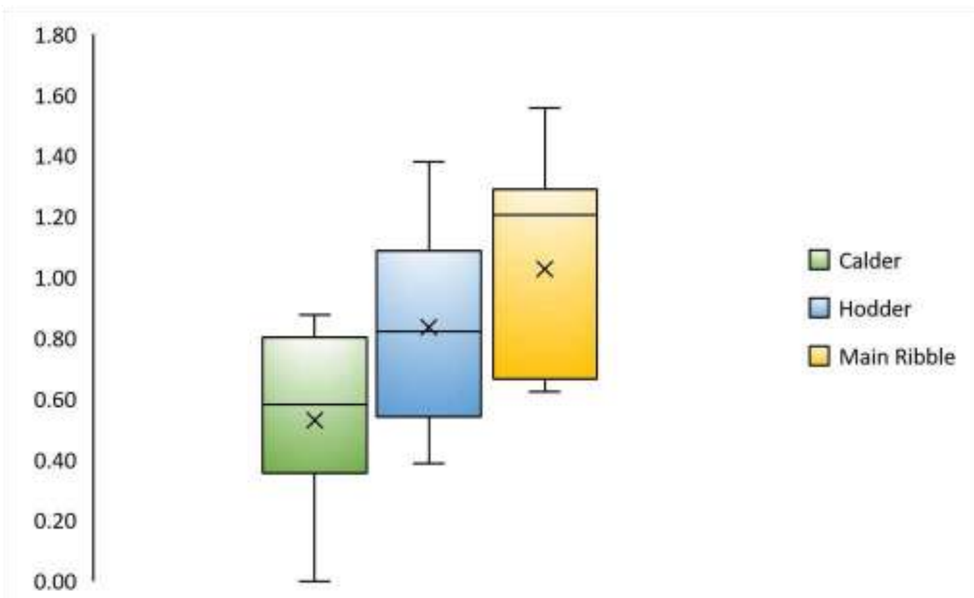


Figure 24. Shannon-Wiener Diversity Index results for the Calder, Hodder and main Ribble catchments. The plot shows the range of diversity scores, lower and upper quartiles and median. The mean catchment diversity is marked as X.

Other Species

Bycatch

Bullheads (*Cottus gobio*) and Stone loach (*Barbatula barbatula*) remain the dominant species in the catchment (Figure 25) with 80% of sites containing bullheads and 50% stone loach. Yearly records of minnow (Phoxinus phoxinus) are variable depending on conditions but also habitat type. If sites contain a pool feature a greater number of minnows are likely to be detected, as the species is less abundant in faster flows and large numbers can be caught due to their shoaling behavior. Numbers of chub (*Squalius cephalus*), gudgeon (*Gobio gobio*) and grayling (*Thymallus thymallus*) were down from 2016 (Figure 26) but were present in key areas around Long Preston Deeps and surrounding tributaries; Wigglesworth Beck, Rathmell, Long Preston and Hellifield highlight the Deeps as an important rearing site for coarse fish likely due to morphology. 2016's "year of the grayling" has not seen a repeat trend, but on Colne water catch-return data shows a good head of grayling moving into the area. This is a fantastic indicator that the fish easements are optimised for fish passage as grayling do not have the burst capacity for swimming against fast flows in comparison to other salmonids, and their response to flow patterns will determine their success in traversing barriers or utilising fishways (Lucas & Bubb, 2005). Also, Chipping Brook has seen grayling move up from the River Loud.

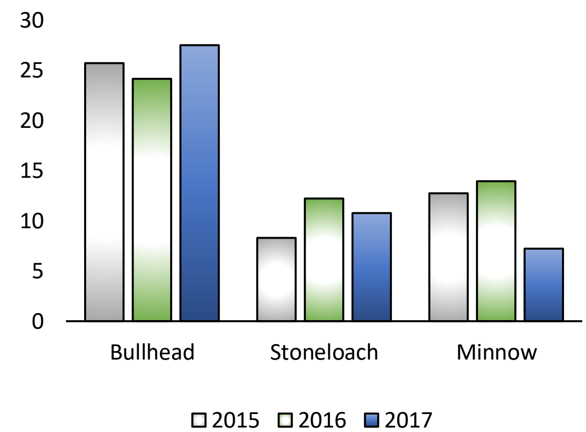


Figure 25. The average abundance of dominant bycatch species per site 2015 to 2017.

River lamprey have been recorded for the first time by the Trust at Cuerdale, bringing the total number of Annex II fish species within the catchment to 6 (eel, brook lamprey, sea lamprey, Atlantic salmon and bullhead). Investigation into this finding could allow for the application for the designation of 'special area of conservation' (SAC) in the lower reaches of the catchment. The EA have also located river lamprey in the estuary in 2010 and 2013 as part of otter trawling surveys. Another species to note at Cuerdale was a juvenile barbel (*barbus barbus*) found in the tidal limit of the Ribble.

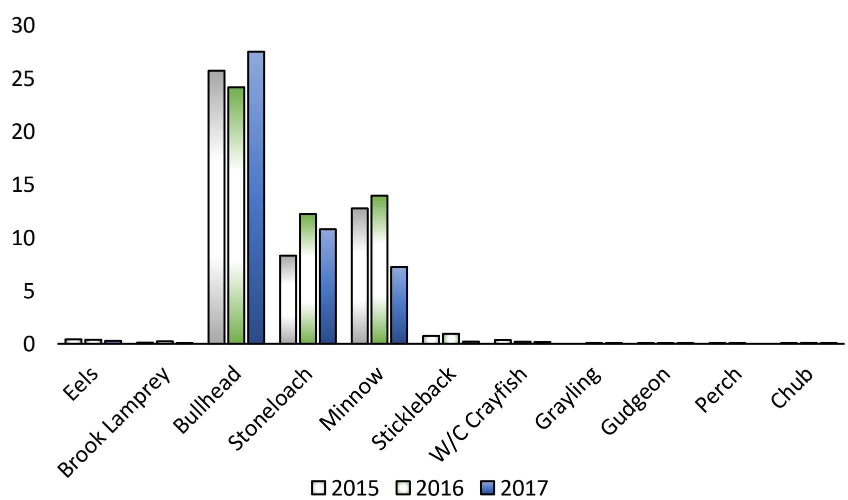


Figure 26. The average abundance of accompanying bycatch species per site 2015 to 2017.

Annex II Species

Figure 30. Bullhead (Cottus gobio): Benthic species that feeds on a variety of invertebrates and fish eggs. Spawns in March-April with the male guarding the egg cluster.   6 – 8cm in length.

Figure 29. Atlantic salmo (salmo salar): Large parr (180mm) S2 captured in August 2017 on the Hodder catchment.

Figure 31. European eel (Anguilla anguilla): Yellow eel growth stage – caught on the main stem Ribble at Cuerdale, above tidal limit.

Figure 28. Brook lamprey (Lampetra planeri): Ammocoetes larva stage (left) spending four years blind, filter feeding before metamorphosing into adult (right) creating eyes, suction discs and gonads during the process.

Figure 27. River lamprey (Lampetra fluviatilis): Parasitic species which feed by boring into the flesh of other fish to suck their blood.

Eel

The European eel is marked as 'critically endangered' by the IUCN red list (IUCN, 2017a) and due to its complex life cycle very little is known about this species. The number of eels caught as bycatch by the Ribble Trust has seen an annual decrease over the past four years. This drop in numbers does not truly reflect the population within the catchment as they are not a targeted species, but the reduction is worth noting. Eel populations are difficult to establish in river systems with their densities decreasing as a function of distance from the tidal limit (Aprahamian & Walker, 2008). In 2017 the highest abundance of anguilliformes was observed during a fish rescue carried out within the tidal limit at Cuerdale. The tidal Ribble is not yet included in the fisheries programme and any site location outside of small tributaries may not be possible to survey due to depth. From past survey work the Trust has observed higher densities of elver and bootstrap eel (Figure 32) (<150mm) within the lower Ribble tributaries compared with other catchments. This highlights the lower Ribble as a key area for juvenile development. As eels age, the dispersal of individuals is influenced by ontogenesis, population loading and environmental parameters (Feunteun, et al., 2017) but movement behaviours are not mutually exclusive between individuals.

Figure 32. Bootstrap eel from 2016 on the lower Ribble

Physical barriers on a river system, like weirs and dams, make it difficult or impossible for elver and eel to travel up-stream. Even with the installation of a fish pass, the burst capacity of a juvenile is insufficient for them to ascend the easement. Yellow eels (Figure 34) are more mobile and can move over structures providing the 'crawling medium' is sufficient and wetted, although highly abrasive surfaces can lead to loss of protective mucous. Yellow eels can also navigate barriers by leaving the waterbody and moving on wetted land using air gulping for respiration during terrestrial migration. Eel ladders are a solution for juvenile and adult migration above physical barriers (Figure 33) in which shallower gradients help with passage and climbing substrate retains water well. Positioning the passes with the entrance alongside the arms of the barrier helps utilise the 'edge effect' in passage route selection of eels (Piper, et al., 2012). Background river discharge can compete with the attraction flow of the eel pass and so the addition of a plunging flow at the entrance of the pass has seen to optimise use. Facilities for passage should ideally be provided at both


Figure 33. Eel ladder pass at Settle Weir with bristle substrate and gravity fed conveyance flow.

banks of the barrier. The Hodder catchment (Figure 35) holds the greatest number of eel sites with 14/33 recorded locations in 2017 providing habitat and resources to growing yellow eel with most individuals' length over 200mm. The Calder catchment has a lower number of sites in which anguilliformes are located as it is a recovering postindustrial catchment with major barriers to migration. The upper head waters of the Ribble have a lower density of eels migrating this distance from the estuary with only a single individual being detected above Settle in 2015.

The likelihood of detecting eels is greater during quantitative electrofishing surveys as individuals are detained within a reach with the use of stop-nets, with detection increasing owed to the disturbance of sequential runs. Lower eel numbers in surveys might be due to them evading capture within semi-quant sites, choosing to conceal themselves within substrate or abscond from the site. If we are to understand more about the habitat, movement and populations of eels on the Ribble catchments a more targeted approach is needed for this species.

Figure 34. Yellow eel caught on the Hodder 2016.

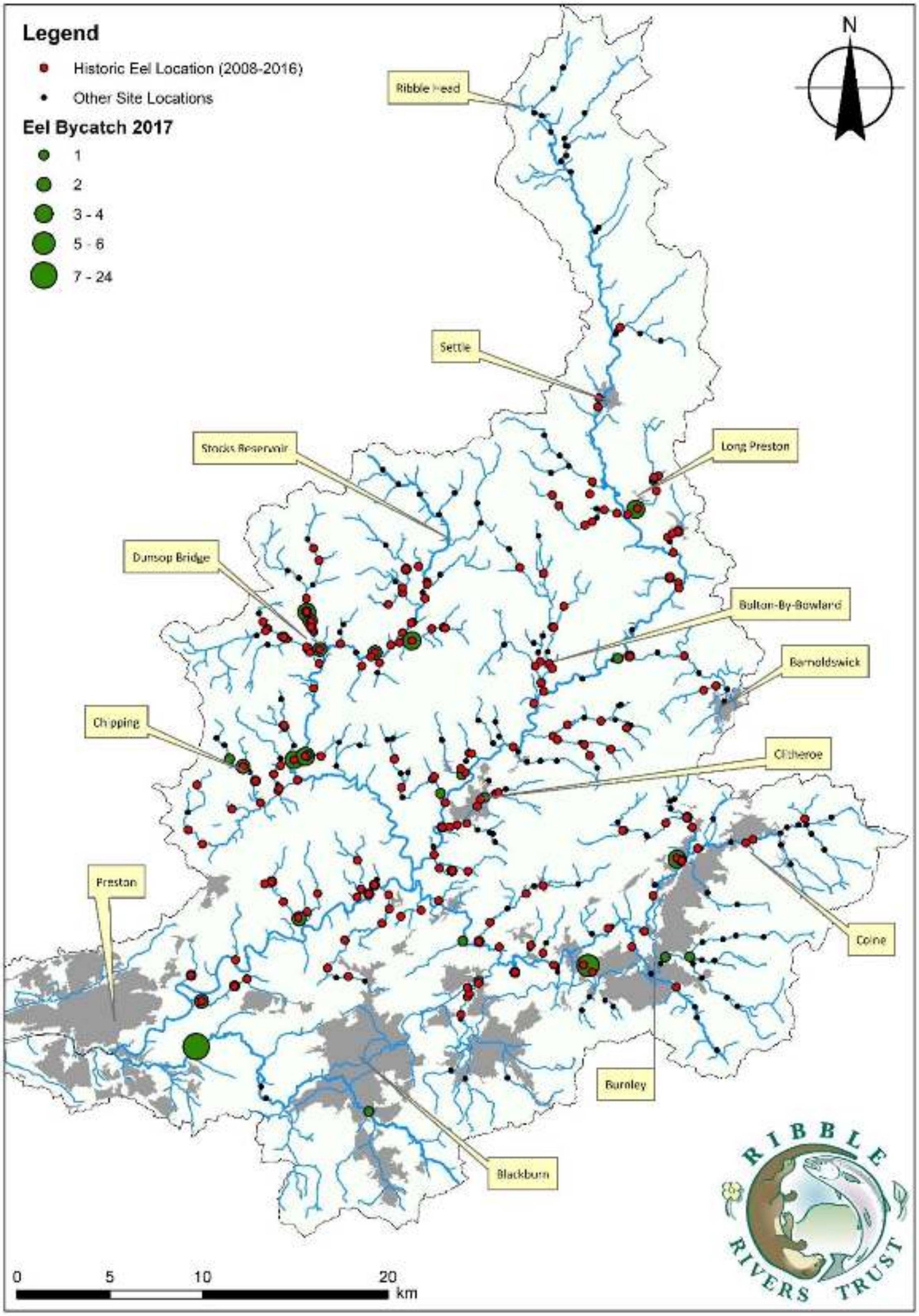


Figure 35. Catchment map outlying the presence and numbers of eel recorded during 2017 fisheries programme and historical site locations (Marked in red) for the past 10 years of Ribble Trust monitoring. Electrofishing sites holding no eel information are marked black.

Crayfish

The white-clawed crayfish (*Austropotamobius pallipes*) has seen a national decline over the past 10 years with losses between 50-80% (IUCN, 2017b). Localised extinction can be attributed to the introduction of American signal crayfish (*Pacifastacus leniusculus*) as they are vectors for the fungal disease *Aphanomyces astaci*. The Ribble Trust gains insight into the distribution of crayfish through the fisheries programme as these species are an unavoidable bycatch of electrofishing. However, this is by no-means and exhaustive method that will allow inferences on the population. With this in mind, the number of sites where white-clawed crayfish were found to be present is at a five-year low (Figure 26). Water contaminants and loss of refuge can be contributing factor (Rosewarne , et al., 2017) but changes have been observed in areas where American signal crayfish are present. From the locations monitored by the Ribble Trust, the abundance and overall distribution of signal crayfish is unknown and the ability to detect this species where numbers are low remains problematic. Observations from 2016 have seen the continued dispersal of signal crayfish within Long Preston Beck. In the long term this downstream movement will result in signals residing in the main stem Ribble and consequently increasing the difficulties of control and putting them in close proximity to a designated Site of Special Scientific Interest (SSSI). EA surveys on the Calder located a single large male signal crayfish in 2011 downstream of Burnley, but non-since. Also on the Calder, illegal introductions of signal crayfish are considered to be impacting salmonid recruitment in Trawden Brook. Musseau, et al. (2014) has shown that introductions of European eel can be used as a biocontrol to reduce population growth and distribution rates. The advantage of encouraging eels into the area is that there is limited competition with salmonids and piscivorous predation is only more common in individuals over 400mm. With the number of structures on the Calder restricting the upstream (and downstream) migration of eels it is seen as a limiting factor to the population size in the catchment. This increases the importance of habitat connectivity in the Calder, but also the wider Ribble Catchment.

Discussion and Conclusions

Results from the Ribble Trusts long term data show that salmonid recruitment was likely affected by the Boxing Day floods of 2015 (**Error! Reference source not found.** and **Error! Reference source not found.**), therefore concerns were high for 2017s young of year as high spates occurred from the 16th to the 20th of March 2017 (Figure 36). This large volume of water arose at a critical time when the alevin have exhausted their yolk reserves and are to emerge for their first feed. Mortalities of Atlantic salmon can increase significantly with high discharge events due to their size affecting swimming ability (Jensen & Johnsen, 1999). As Brown trout emerge earlier than salmon there is opportunity for growth to increase swimming ability and thus increasing survival rate. Events like this also have a negative effect on growth as spate events reduce the abundance of food.

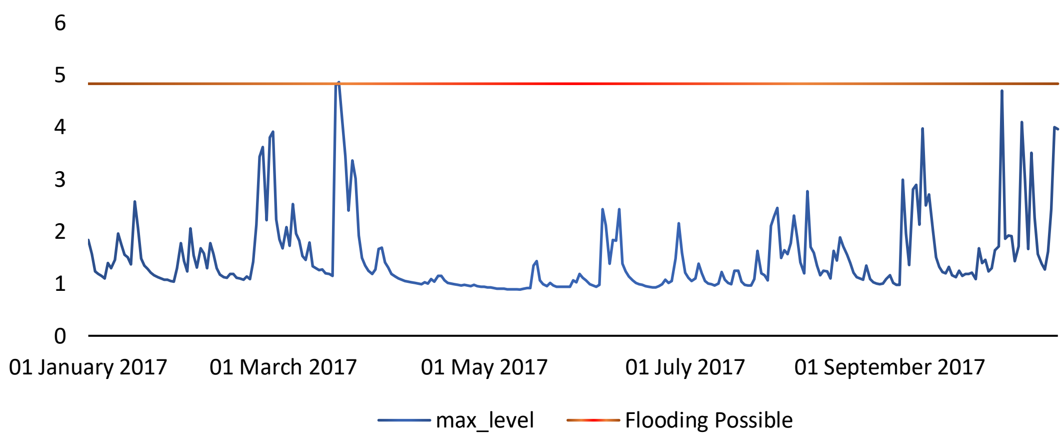


Figure 36. River levels recorded at Samlesbury from 1st January 2017 to 22nd October 2017. Raw data was obtained from the Environment Agency and used under the Open Government License.

Despite the spring spates, survivorship of trout eggs to young was higher for 2017 than the preceding year (Figure 37**Error! Reference source not found.**) however Salmon populations continue to follow a downward trend (Figure 38**Error! Reference source not found.**). This overall decline may not be reflection of habitat quality and quantity within the river system but more so the survivorship and health of the adult population at sea and the number returning to river to spawn. As results are produced through inter-annual surveys specifically targeting fry, the survival rate of fry to smolt within the catchment and the number of outward migrating smolt is unknown.

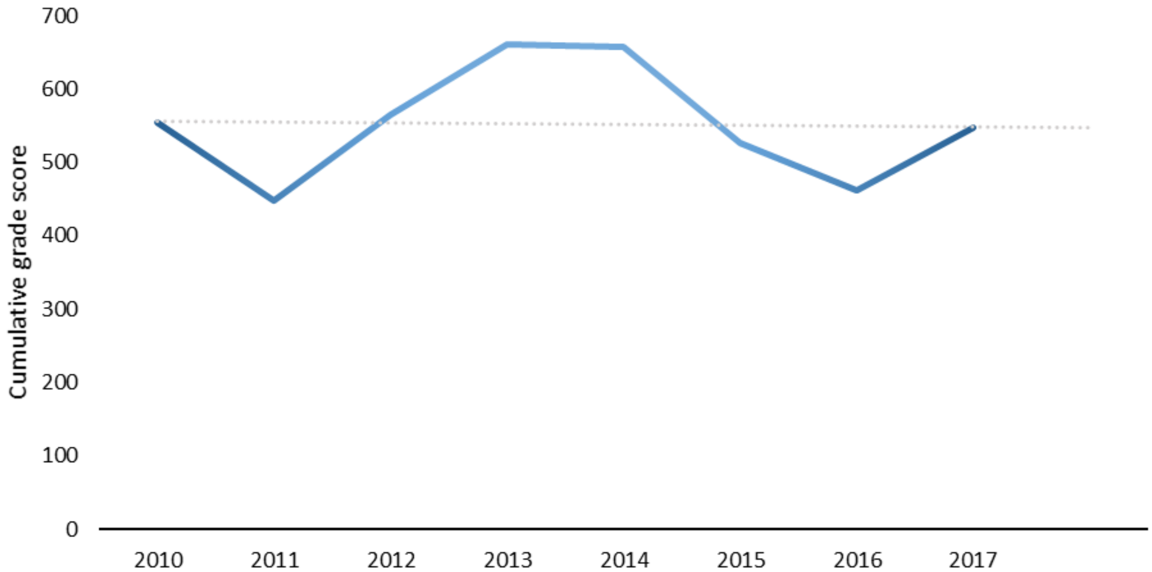
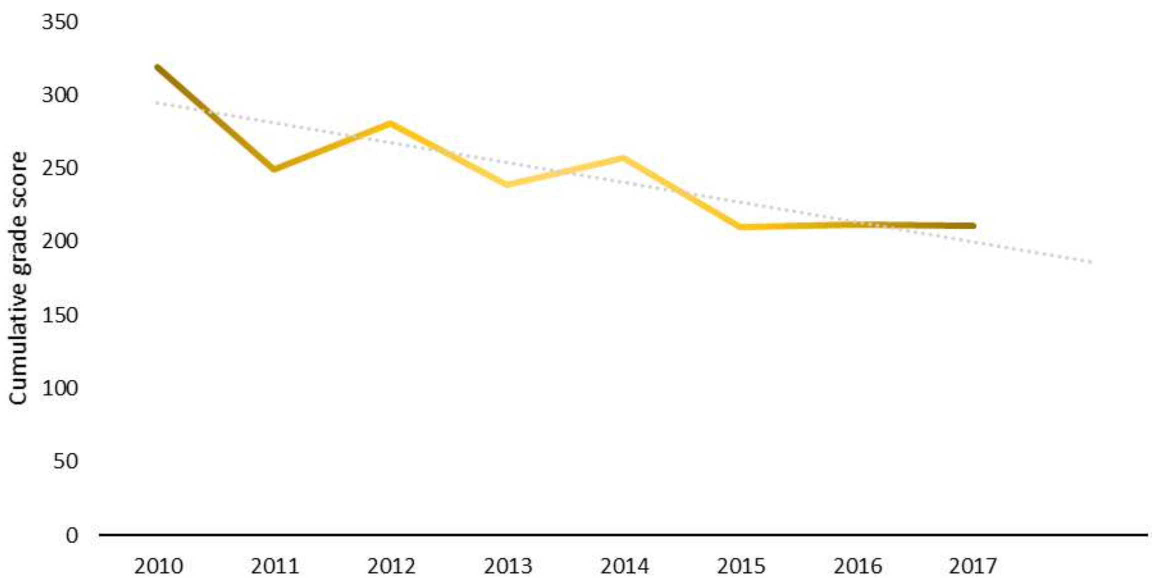


Figure 37. Cumulative grade score for brown trout for sites holding 8 years of consecutive data. Ribble catchment 2010 to 2017.



Figure
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With an increased number of sites (155) holding eight years of continuous data, more accurate trends can be inferred in comparison with the core 87 sites retaining ten years of annual assessment. Going forward there are 261 sites with five years of continuous results which will have priority during the field season to increase the value of the Ribble Rivers Trust dataset.

The work the Ribble Trust has carried out over the past ten years has opened rivers to migration and reconnected them to the Ribble estuary. By 2020 a further 8 structures deemed to be barriers to migration will be removed or have easements installed. Connectivity of a river system is highly important for the lifecycle of anadromous and catadromous species, allowing access to feeding grounds and optimal spawning areas. Reinstated migration routes allow areas devoid of salmon to be repopulated through migration straying from neighboring natal areas (Keefer & Caudill, 2014) and increasing genetic diversity of other protandrous species previously isolated by barriers. Providing sites have relative ecological stability and quality of spawning and rearing habitat then homing rates and site fidelity will increase over time.

Recommendations

1. Continue monitoring existing inter-annual electrofishing sites for cost/benefit monitoring purposes of previously completed projects. Priorities must be given to sustain and extend the five-year records of RRT fisheries data held across 261 sites (inclusive of the core ten-year sites).
2. Reduce the number of quantitative surveys to be able to focus resources on providing a wider coverage of the catchment with the introduction of taking weights of individual salmonids and total biomass of bycatch species to give more understanding to fish health and relationships between bycatch and keystone species.
3. Introduce new electrofishing sites above Oakenshaw Weir to identify salmon spawning areas after locating salmon fry below the structure and the opening of the new by-pass structure.
4. Continue to monitor the main-stem Ribble, with the possibility of increasing the number of main-stem sites, including an efficiency evaluation of single anode backpack fishing on main stem sites.
5. Designation of areas that hold significant spawning importance and increase education efforts on water friendly farming.
6. Continue to support the voluntary catchment and release of salmonids, encouraging anglers to aim for a rate of at least 90%, with perhaps 100% in September and October.
7. Undertake a high-resolution study to map the distribution of American signal crayfish.
8. 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.
9. Introduce invertebrate studies alongside quantitative fisheries surveys to map the aquatic biodiversity of the catchment, and explore how this can be best used to inform future targeting of work.
10. Assessment of the lower Ribble to capture more information on coarse species populations alongside continued salmonid monitoring.
11. Increase knowledge of eel populations and movements within the catchment. Consider possible projects with eel in the classroom.
12. Focus on improving knowledge on salmonid smolts such as fry to smolt survival.
13. 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.
14. Consider how we may assess sites to determine if use of the NCFS grading is an appropriate measure of population health.

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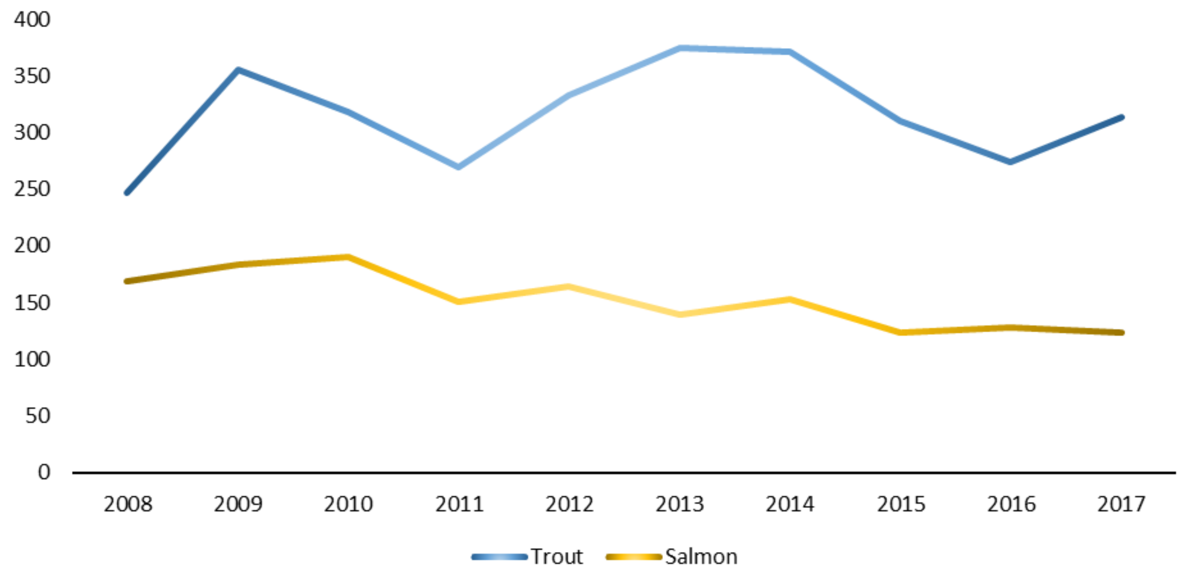
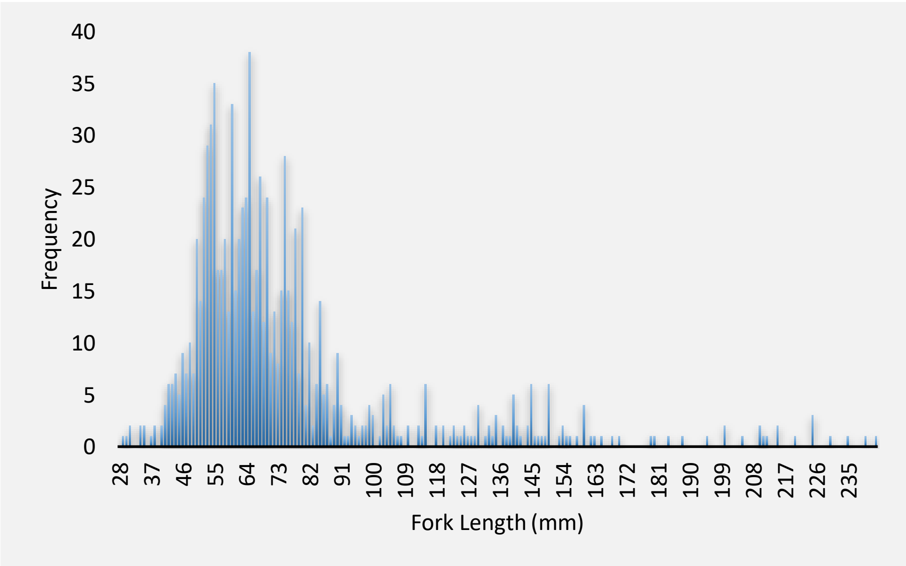
Appendices

Appendix A

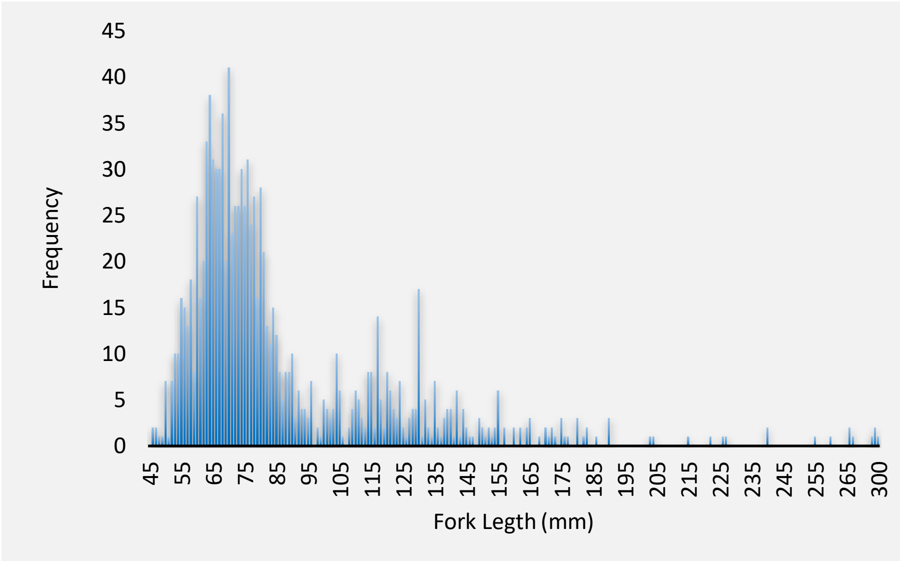


Appendix A. 1. Total grade score for the catchments core 87 electrofishing sites for salmon and trout 2008 - 2017.

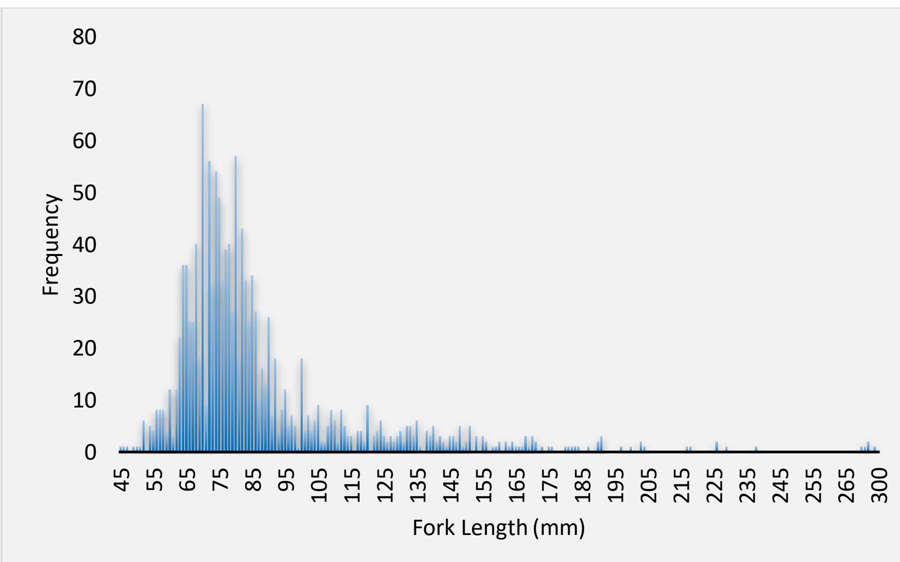
Appendix B



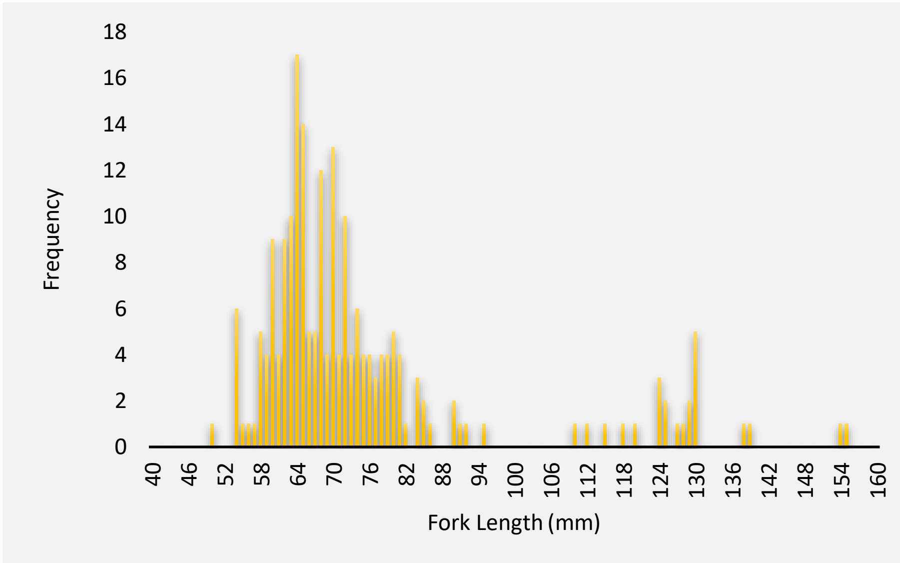
Appendix B. 1. Fork length chart of brown trout caught on the Calder catchment 2017. Age class distinguished by distribution. 0 year max = 92mm



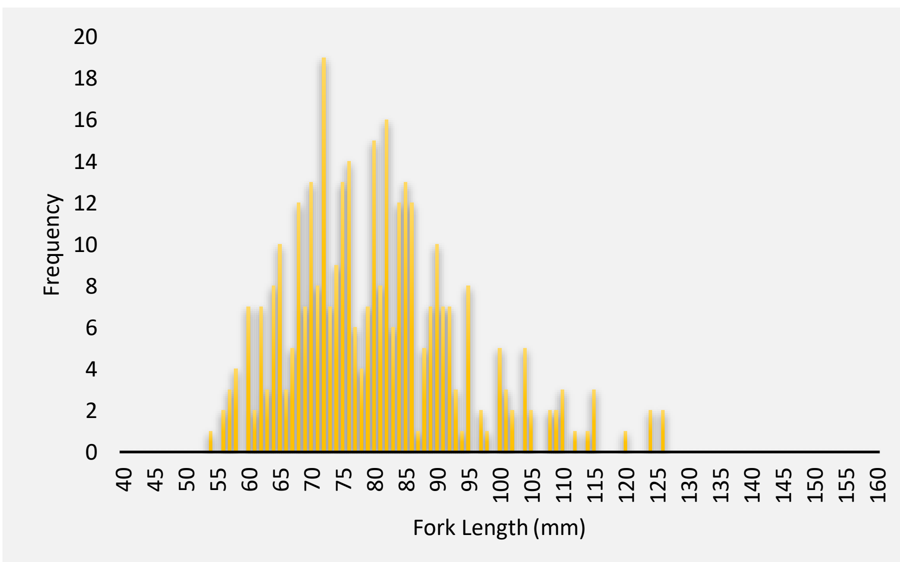
Appendix B. 2. Fork length chart of brown trout caught on the Hodder catchment 2017. Age class distinguished by distribution. 0-year max = 99mm



Appendix B. 3. Fork length chart of brown trout caught on the main Ribble catchment 2017. Age class distinguished by distribution. 0-year max = 106mm

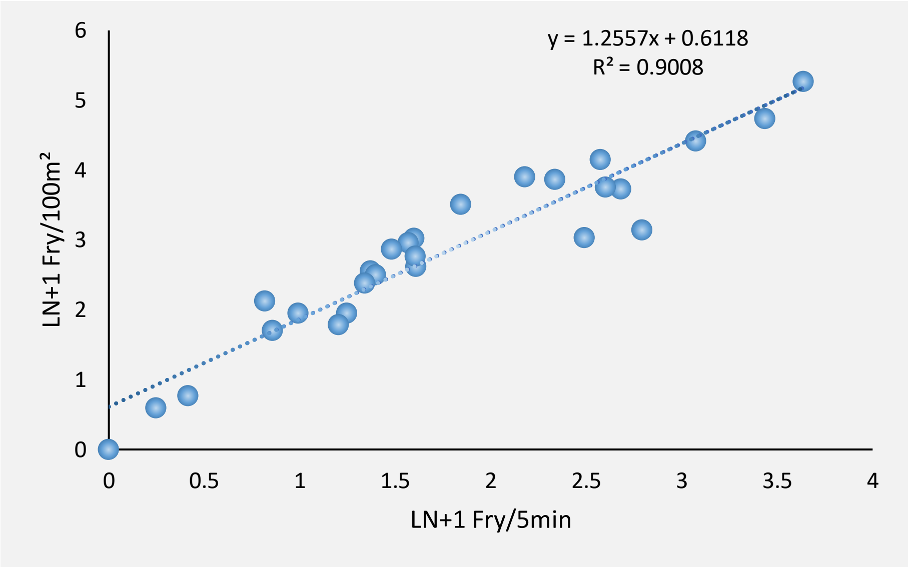


Appendix B. 4. Fork length chart of Atlantic salmon caught on the Hodder catchment 2017. Age class distinguished by distribution. 0-year max = 95mm

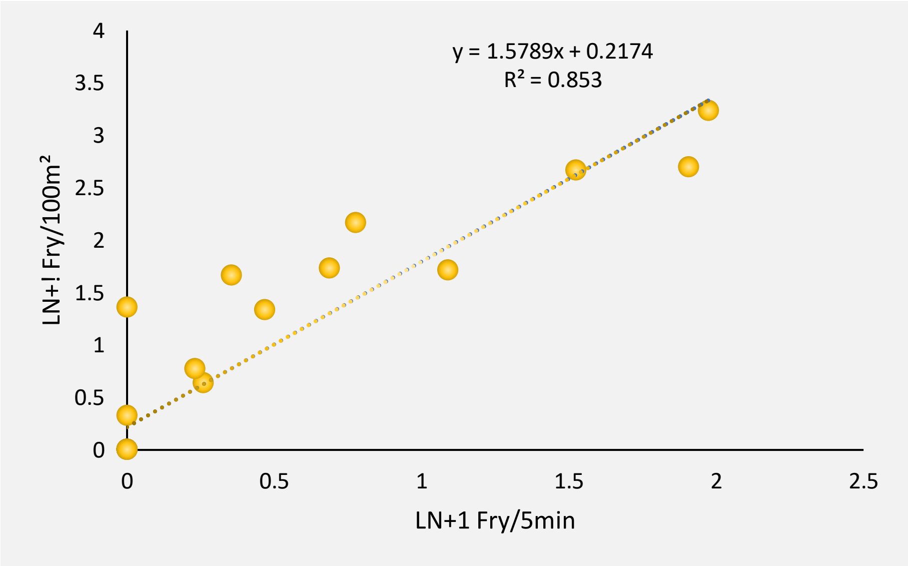


Appendix B. 5. Fork length chart of Atlantic salmon caught on the main Ribble catchment 2017. Age class distinguished by distribution. 0-year max = 115mm

Appendix C



Appendix C. 1. Brown trout quantitative fry population relationship between semi-quantitative (5 minutes fry capture) and quantitative electrofishing results (Fry per 100 square) that is LN+1 transformed. Fitted linear regression for 0 + salmonids is produced where Ln (y + 1) = 0.6118 + 1.2557 Ln (x + 1)

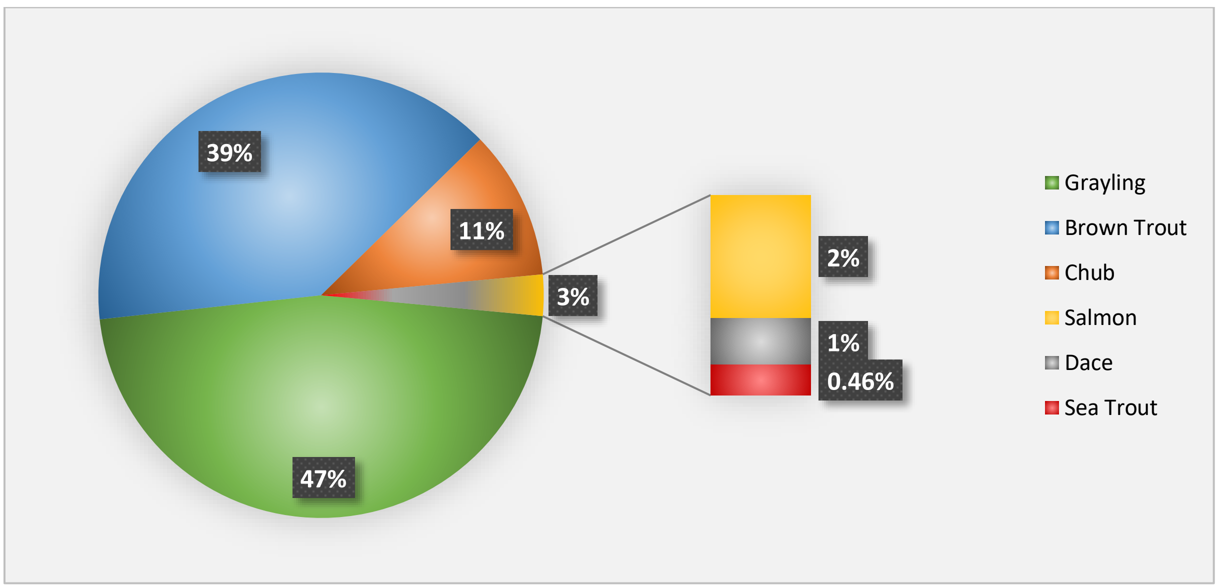


Appendix C. 2. Atlantic salmon quantitative fry population relationship between semi-quantitative (5 minutes fry capture) and quantitative electrofishing results (Fry per 100 square) that is LN+1 transformed. Fitted linear regression for 0 + salmonids is produced where Ln (y + 1) = 0.2174 + 1.5789 Ln (x + 1)

Appendix D

Appendix D. 1. Table of Ribble Trust angling passport scheme ticket returns. Catch reports for November 2016 to October 2017.

Token type	Brown Trout	Sea Trout	Chub	Grayling	Salmon	Roach	Dace	Other	Incomplete	Non-caught	Totals
Angling Passport	62	2	38	84	3	0	2	0	116	28	191
Mitton Trout & Coarse	105	0	8	118	1	0	1	0	18	71	233
Mitton Salmon	4	0	1	1	4	0	0	0	13	31	10
Total Catch	171	2	47	203	8	0	3	0	147	130	434



Appendix D. 2. Species captured across 9 Ribble Trust angling beats November 2016 to October 2017.

“Improving rivers for people and wildlife”