FISHERIES MONITORING OF THE RIBBLE CATCHMENT 2020

The Ribble Rivers Trust

ABSTRACT

2020 marks the 13th year of the Ribble Trusts inter-annual fisheries monitoring programme. Results and observations from this work helps inform the trust on the productivity of sub-catchment fisheries and where to direct conservation efforts.

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The Ribble Trust is grateful to all involved landowners for their permission to land-access and look forward to continued cooperation for future work. In addition, RRT wishes to thank the staff for their continued hard work and contributions to this year's fisheries programme, which has proved invaluable during this difficult year.

A thanks to all the volunteers that would normally contribute to our survey efforts. We look forward to welcoming you back, hopefully next year.

Executive Summary

Despite 2020 being a very difficult and unprecedented year the Ribble Rivers Trust (RRT) concluded its 13th year of electric fishing surveys on the Calder, Hodder and Ribble catchments. Whilst the COVID-19 pandemic limited working, strict government guidance was observed to carry out surveys, and additional protective measures were implemented by Ribble Rivers Trust to guarantee the health, safety and wellbeing of their staff. The start of the survey season was also delayed until July 7th when restrictions were reduced, and it was deemed safe to proceed. To ensure that all survey work was completed before Environment Agency consents to survey expired, sites were prioritised by their long-term data series and sites that have higher conservational importance. Overall, 198 sites were surveyed.

The methodologies applied to the Ribble Rivers Trust fisheries programme are adapted from Crozier and Kennedy's – 'Application of Semi-quantitative Electrofishing to Juvenile Salmonid Stock Surveys' (1994) and Zippin's – 'Removal Method of Population Estimation' (1958). National Fisheries Classification Scheme (NFCS) grades are then used as a metric for the standardisation of results which are comparable to national datasets. Outputs are used to support and identify future works on the catchment as well as monitoring the long-term impacts of river restoration schemes.

With anthropogenically driven climate change, we are seeing more extreme weather patterns, increased probability of high intensity rainfall events and longer dry periods. This winter (December, January, February) has been the 5th wettest winter on record (data back to 1862) for the UK as a whole and some of the highest river levels recorded since December 2015 and March 2019 (Figure i). Following on from this 2020 has also given us the driest May on record with just 17% of the average rainfall. With observation on long term trends, these extreme weather events in addition to unresolved habitat and water quality issues, are having a cumulative effect on the Ribble's salmonid (Atlantic salmon and brown trout) productivity

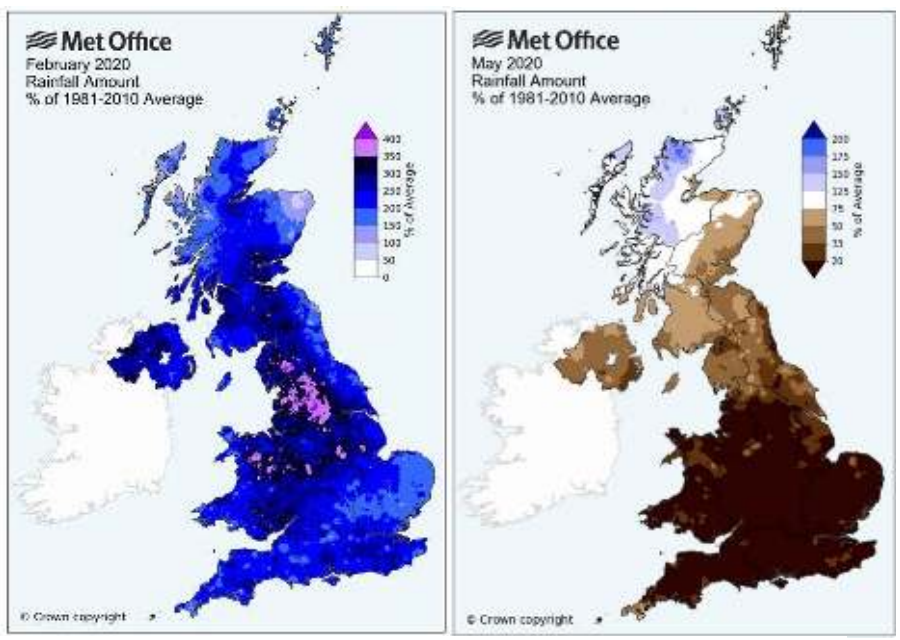


Figure i. February and May 2020 Met office rainfall data as % of 1981 – 2010 average www.metoffice.gov.uk

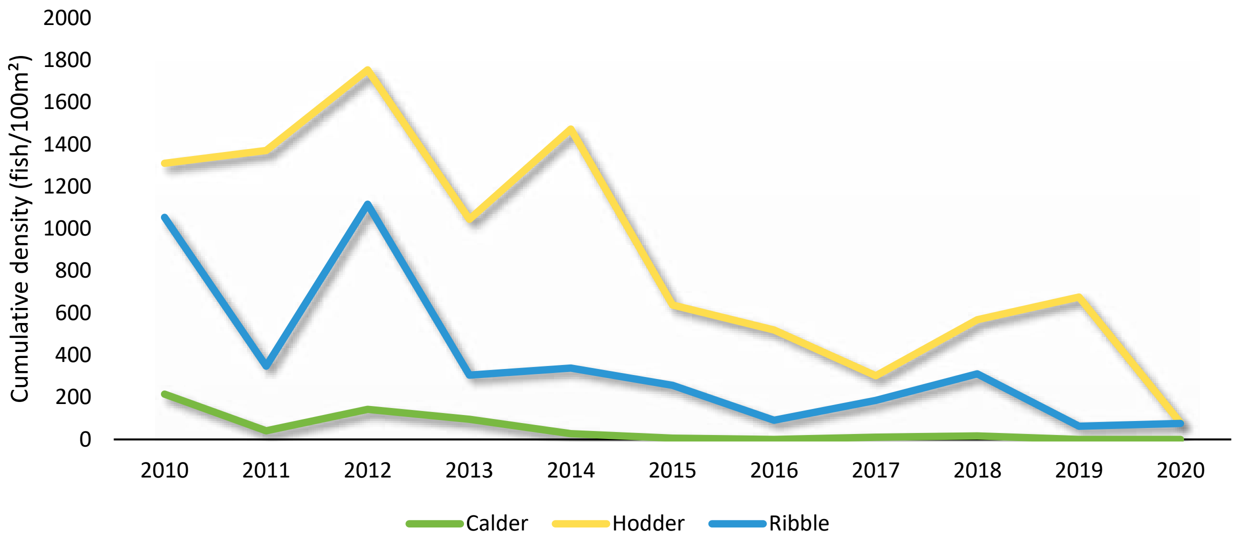


Figure ii. Cumulative densities of Atlantic salmon fry recorded on the Calder (50 sites), Ribble (44 sites) and Hodder (44 sites) sub-catchments from 2010 - 2020.

Fish communities have evolved to live in dynamic river habitats and populations have been adaptable to temporal variation. However, the increasing rate of environmental change is far exceeding the capacity of many populations to adapt to new conditions. In particular, cold-water freshwater fish species are predicted to experience strong selective pressures from a wide range of interacting human stressors as well as severe hydrological events and the impacts of warming river habitat. A stark comparison of long-term sites show that this year's Atlantic salmon fry are at their lowest recorded densities on the Ribble and Hodder with less than 100 fry per 100m^2 recorded over the 44 long term sites on each sub-catchment (figure ii). Degradation of Atlantic salmon populations at this rate may lead to unrecoverable numbers by the end of the next decade with local extinction on the Ribble and its sub-catchments.

While normally the catchment reports A and B grade sites, this is the first year where there have been no A or B grades found. Further, this year only one site has been classified as Fair (C-grade), a site is on the main stem Hodder in a location that regularly returns 100s of fry per 100m2. The remaining sites on the catchment have all returned D grade or below indicating poor to very-poor fry densities. From the 198 sites surveyed in 2020 the distribution of salmon fry across the catchment is at 30% of the known distribution recorded between 2008 and 2020 by the Ribble Trust. Salmon have a highly complex life cycle that is impacted at every stage by resource competition, environmental stochasticity, and anthropogenic pressures. There is no golden bullet to solve these issues and to have a chance of improving stock of salmon on the Ribble catchment, more needs to be done to reverse negative effects. With such low densities of salmon and trout fry recorded in 2019 and 2020 community composition is being altered and there are concerns to be had over how these cohorts will affect the future adult spawning population. The effective management of freshwater habitat is essential to maintain and enhance salmon and sea trout populations, particularly as there are more unknown and uncontrolled impacts once they reach the saltwater feeding stage of their lifecycle.

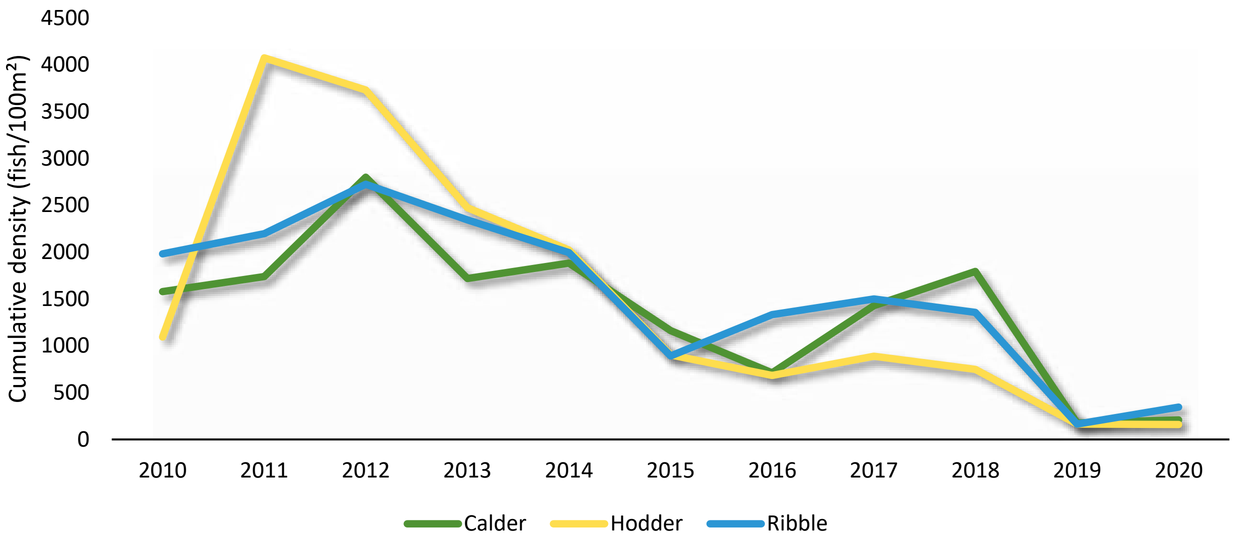


Figure iii. Cumulative densities of brown trout fry recorded on the Calder (50 sites), Ribble (44 sites) and Hodder (44 sites) sub-catchments from 2010 - 2020.

Brown trout on the catchment have also struggled with egg to fry survival with 2019 and 2020 producing some of the worst densities recorded by the trust in 13 years (Figure iii). From data collected and seasonal observation it is thought that high flows between spawning and fry emergence have had a marked effect on 0+ salmonid densities. Spate evets are important for cleaning gravels and allow the migration of fish to spawning ground. However, extreme events, especially at critical lifecycle stages, can have a large impact on spawning success and the survival of egg to fry. With lower fry densities recorded in 2019-2020, it is hoped that with more resource availability and reduced competition that these cohorts will have a greater chance of surviving to maturity.

1.0 Introduction

The Ribble Rivers Trust (RRT) has been conducting habitat restoration schemes and facilitating improved land management for over twenty years in the Ribble Catchment. With more than 6,000 miles of watercourses the ultimate aim of the RRT is to preserve a resilient system in which there will be resources and habitat to support and sustain fish and wider animal populations and increase biodiversity.

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 young of year 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

Despite 2020 being a very difficult and unprecedented year The Ribble Rivers Trust (RRT) concluded its 13th year of electric fishing surveys on the Calder, Hodder and Ribble (Figure 1.1). Whilst the COVID-19 pandemic did limit working, a reduced programme was planned and 195 sites were surveyed with priority given to those with a long-term data series or where considered to have higher conservational importance.

1.1 Sub-Catchment Map

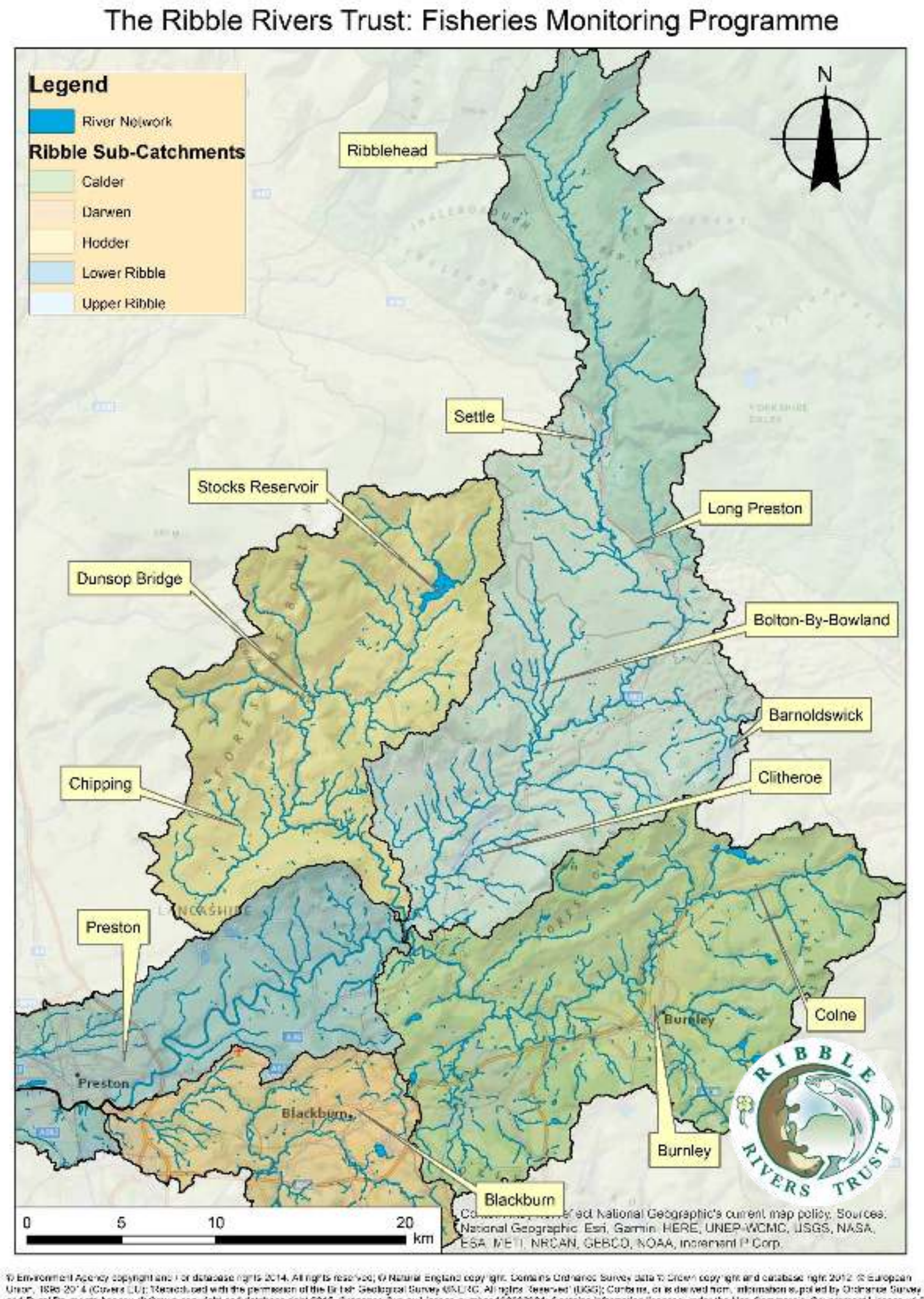


Figure 1.1. River Ribble catchment map displaying sub-catchment boundaries and reference locations.

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 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. Salmonid fork lengths are recorded in millimeters at each site and the abundance of other species is noted.

For 2020, 220 survey sites were identified for assessment with priority given to sites that hold the most significant data set, with eight or more years of continuous data or in key locations for monitoring restoration works. Additional sites were selected on the River Brennand, Dunsop and Whitendale as a conservationally important area for salmon spawning. Due to COVID restrictions and delays the survey team maned 35 days field work between 7th July until 30th of September, with a total of 195 sites were completed.

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.7). Quantitative surveys provide fry densities per 100m² from the depletion of a known measured area, these densities are generated from Zippin's (1956,1958) K-Pass Removal method using the FSA package in R version 3.1.0 (R core Team, 2019), whereas, semi-quantitative results are calculated from the number of fry captured in an active five minutes. The equation applied to the semi-quantitative results 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 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 2.1) 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 is based on sites which hold 11 years of consecutive data and the grade change evaluation is the comparison of all sites fished in both 2019 and 2020. 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*)

Brown trout, as an indicator species, can provide the best insight into a catchment's health. This is due to the majority of the population spending their complete lifecycle residing within the river system. In the past fluctuations in brown trout numbers have been observed, however, there has been a noted decline in the densities of fry captured in surveys (Figure 3.1.1). Previous reports have focused on the cumulative grade score of the data series in order to highlight long-term trends, however the loss of salmonids in the high-grade classes are not always accounted for. For example, a site can be classed as an A grade if it has more than 38 fry/100m^2, yet within the catchment there are sites that can produce fry densities in excess of several hundred. This means that a site can still retain its A grade status despite a high percentage loss in productivity, providing it remains above 38 fry/100m^2 threshold.

From the 11-year dataset, calculating an average at specific intervals set smooths out the data by reducing the impact of fluctuations in short term data. This makes it easier to see overall trends, and with a five-year moving average this downward trend in fry densities is concerning. Given the average lifespan of a river trout is 5 years, then a 5 year moving average gives an indication of the potential health of the entire population, not just the spawning population

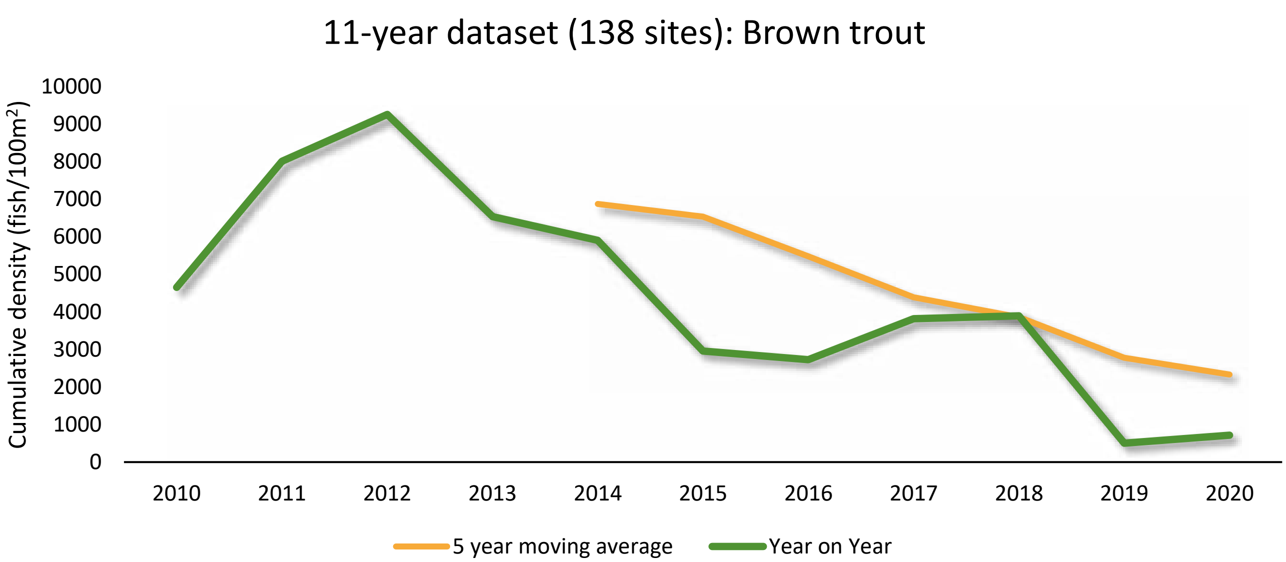


Figure 3.1.1. Cumulative brown trout fry densities on the Ribble catchment for 138 sites fish 2010 – 2020 including 5 year moving average.

One major impact on fry densities is thought to be the cumulative effect of extreme flow events at critical lifecycle stages. With such low densities of trout fry, there are concerns to be had over how 2019 and 2020 fry populations will affect the future adult populations on the catchment; especially when mortality rates in the first year of life are typically approaching 90% or greater. However, with lower fry densities recorded in 2019-2020, resource availability and reduced competition may allow for these cohorts to have a greater chance of surviving to maturity as survivorship in subsequent years is greatly improved with mortality rates between 40-60% (Jensen, et al., 2008).

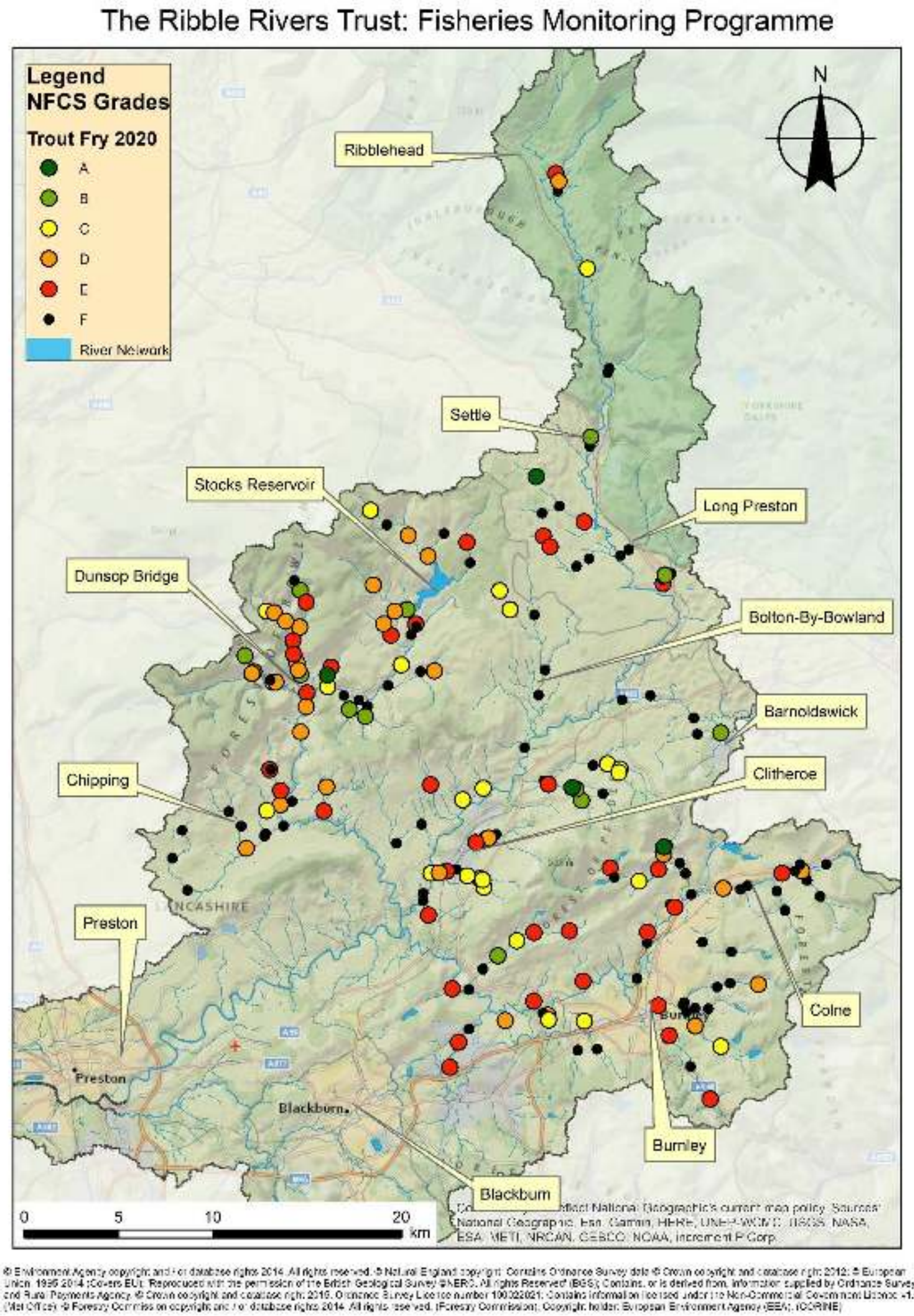


*Figure 3.1.2 Catchment map [1:250,000] showing brown trout fry NFCS grades from **195** surveys undertaken by RRT in 2020. Green to red points indicate higher to low grades. Black indicates an absence of trout fry.*

With all sub-catchments underperforming when compared to historical data, sites that would be expected to produce fry densities in the C to A grade bracket have returned poor fry numbers, such as Wigglesworth Beck, Swanside Beck, the lower reaches of Ings Beck on the Ribble catchment and others in the upper reaches of the River Calder. For instance, sites near the confluence of Ings and Swanside Becks have historically produced excellent numbers of both salmon and brown trout fry with an average of 70 trout fry/100m^2 and 79 salmon fry/100m^2. However, in 2020 only 1.99 trout fry/100m^2 were recorded and no salmon fry were present. Sites that have returned consistently good results appear to be in the upper reaches of the smaller tributaries, where impacts from high spate events are not normally observed.

On a more positive note, fresh run sea trout were recorded on a small spawning tributary of the Hodder catchment after spates in August. These fish can be responsible for a large proportion of young, especially when larger females can produce 1,000-2,000 eggs/kg of bodyweight. Anadromous trout eggs are normally larger than resident brown trout and offspring emerged on average earlier and at a larger body size than the resident fish. This gives fitness benefits to juveniles as larger fry have greater survival, can feed on a wider range of prey, and have better swimming ability.

Figure 3.1.3 Fresh run sea trout captured in surveys on small spawning tributary of the Hodder Catchment

3.2 Atlantic Salmon (*Salmo salar*)

The Ribble, once considered a premium English salmon water, contines to see a downward trend in its fry population. In addition to a narrowing distribution of spawning sites, waterbodies that have previously been classed as 'strongholds' for salmon spawning are also being impacted and returning poor fry numbers. These areas must be protected and an increase in conservational efforts must be applied to improve habitat and water quality for the long-term sustainability of this species. Degradation of Atlantic salmon populations at this rate may lead to unrecoverable numbers by the end of the next decade with local extinction on the Ribble and its sub-catchments. There are many issues that are impacting our native fish and without drastic change they will continue to struggle to fulfil their basic biological needs let alone complex lifecycles.

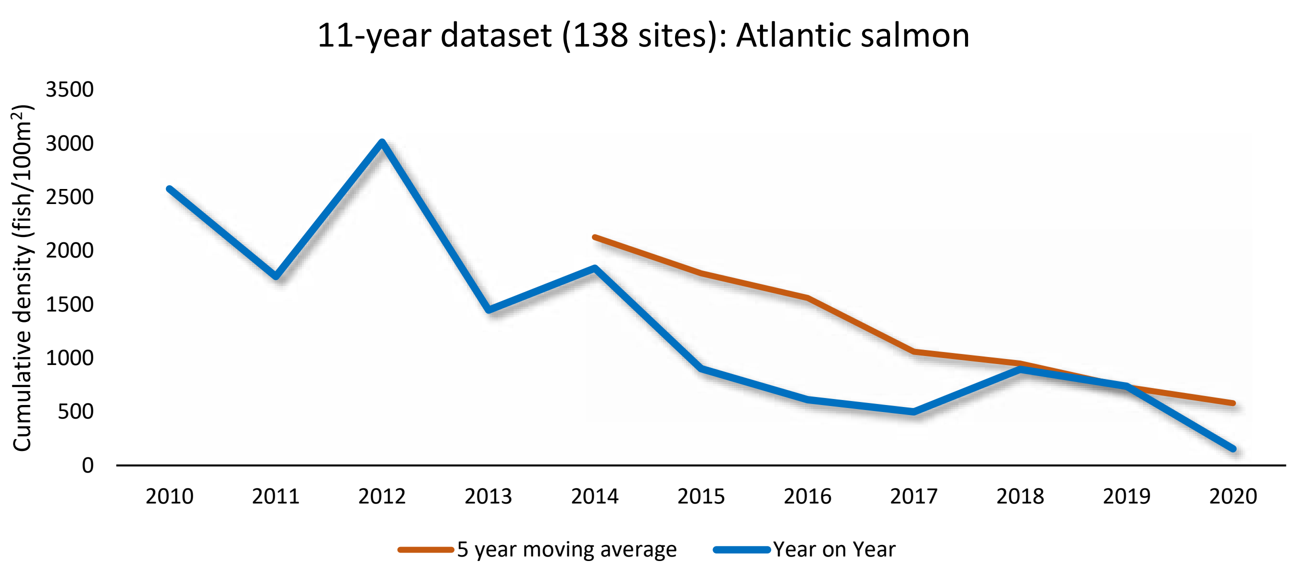


Figure 3.2.1. Total densities of salmon fry for sub-catchments electric fishing sites with 10 years of consecutive data for Atlantic salmon 2010 to 2018.

While normally the catchment reports A and B grade sites, this is the first year where there have been no A or B grades found. Further, this year only one site has been classified as Fair (C-grade), a site on the main stem Hodder in a location that regularly returns 100s of fry per 100m^2. The remaining sites on the catchment have all returned D grade or below indicating poor to very-poor fry densities (Figure 3.2.2). From the 198 sites surveyed in 2020 the distribution of salmon fry across the catchment is at 30% of the known distribution recorded between 2008 and 2020 by the Ribble Trust (Figure 3.2.2 **&** 3.2.3).

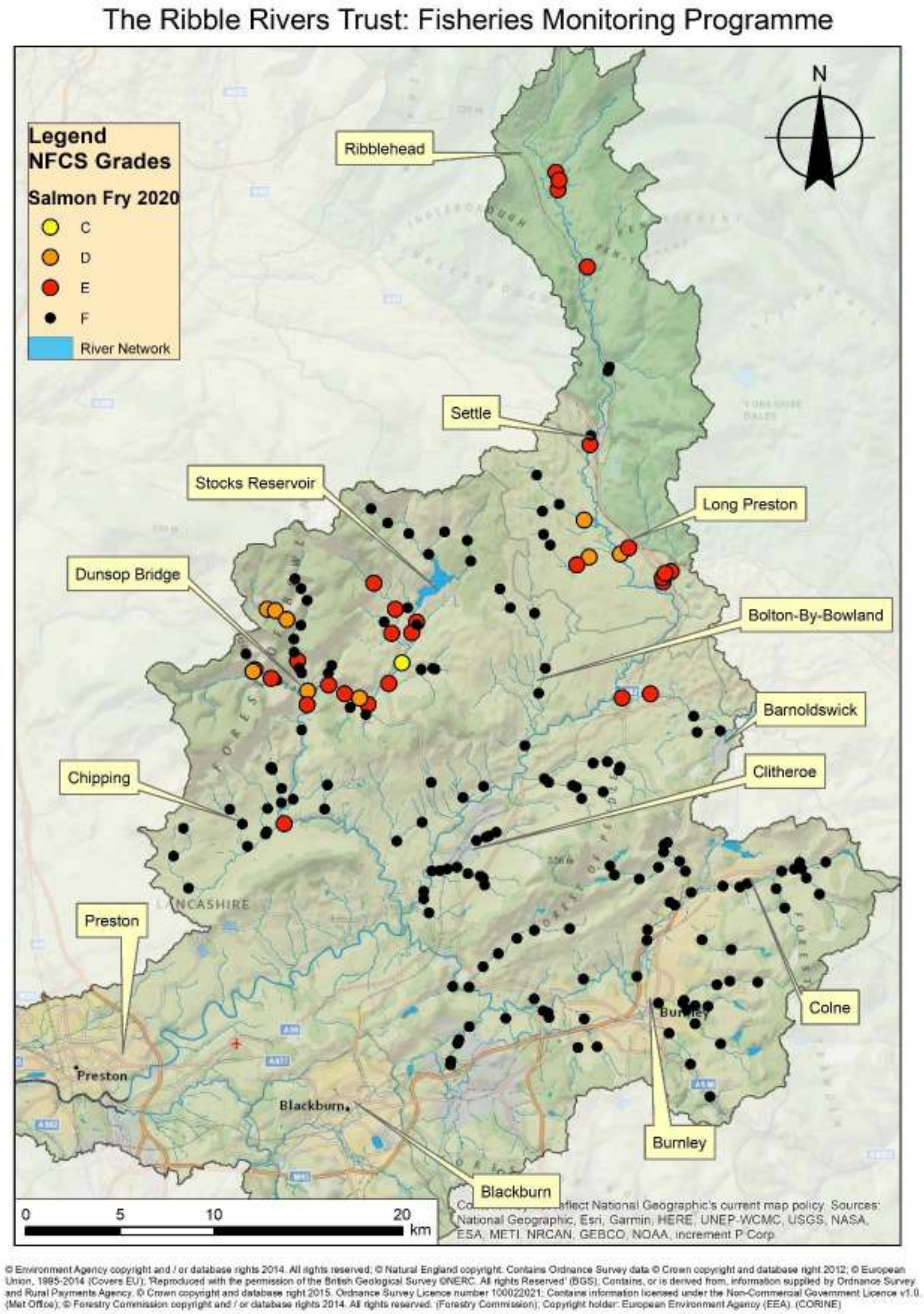


Figure 3.2.2. Catchment map [1:250,000] showing Atlantic salmon fry NFCS grades from 195 surveys undertaken by RRT in 2020. Green – red points indicate higher to low grades. Black indicates an absence of salmon fry.

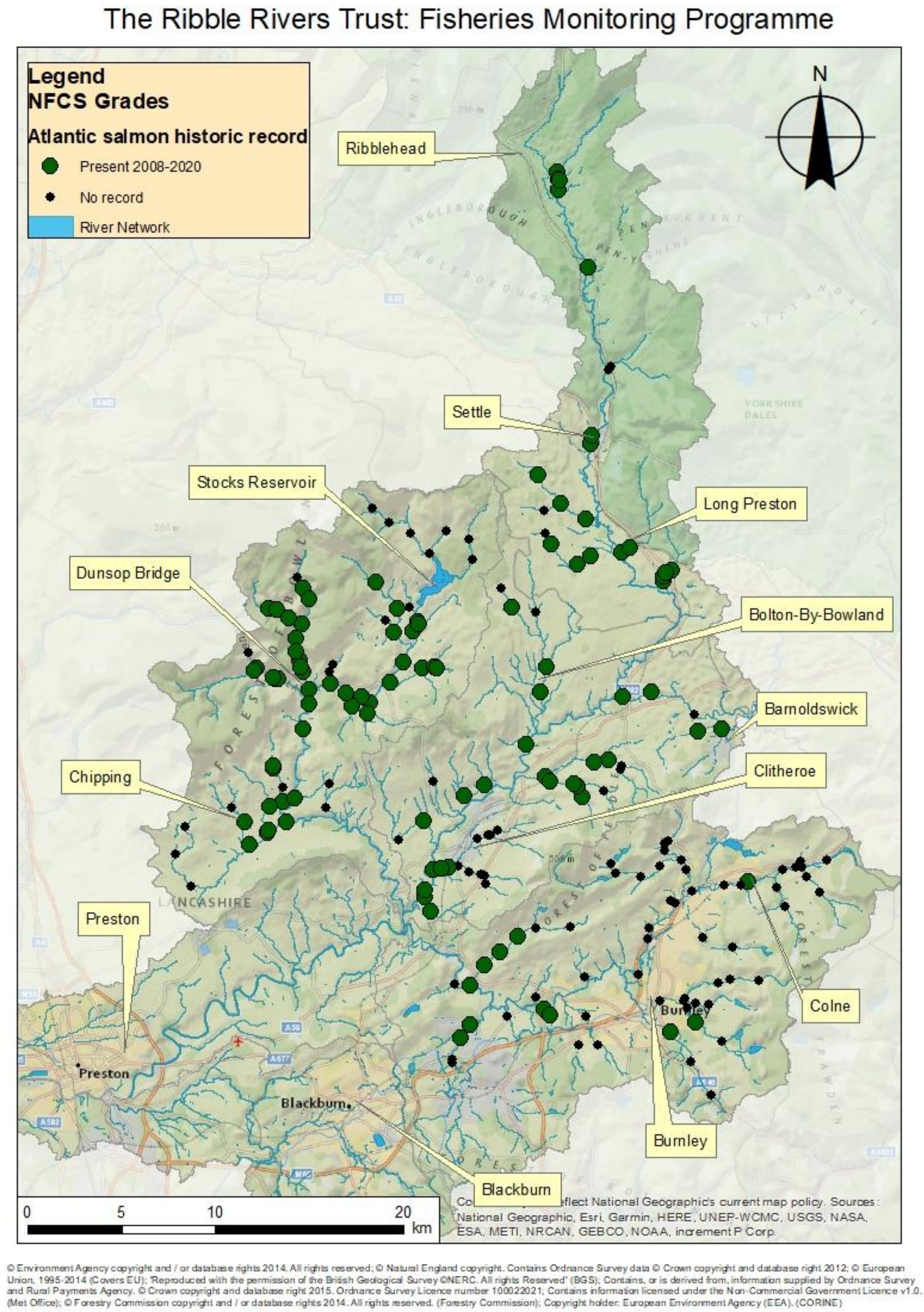


Figure 3.2.3. Catchment map [1:250,000] showing Atlantic salmon fry locations historically recorded by RRT between 2008 and 2020.

3.3 Other Species

Bullhead (*Cottus gobio*) remain the dominant non-targeted species on the catchment found within 86.7% of sites (Figure 3.3.1 and 3.3.2). Stone loach (*Barbatula barbatula*) have been recorded in 51.8% of sites and common minnow (*Phoxinus phoxinus*) in 32.8% of sites. The number of European eel (*Anguilla anguilla*) caught as by-catch by the Ribble Trust has seen an annual decrease over the past six years. As a non-targeted species this reduction does not truly reflect the population, but as this species is classed as critically endangered, the reduction is worth noting.

One observation that was made during this electric fishing season was that stone loach and bullhead were noticeably smaller than in previous years and the more mature adults were lacking within sample sites.

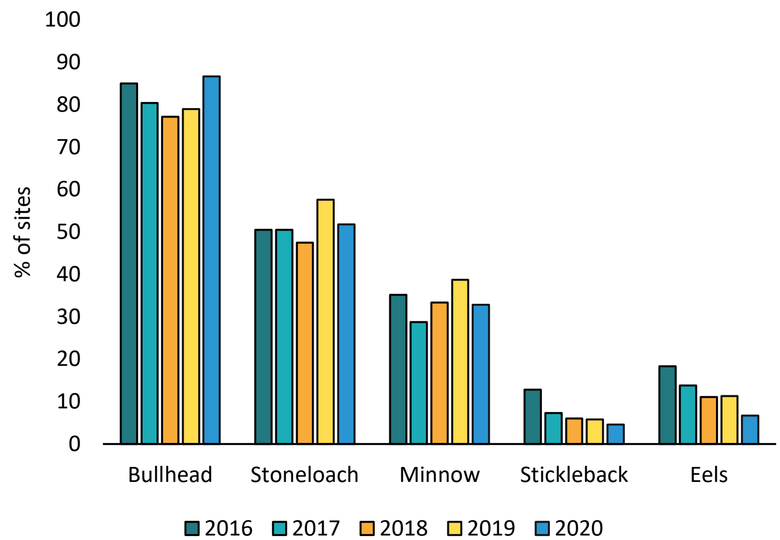


Figure 3.3.1. Dominant by-catch by species % presence of sites from 2016 to 2020.

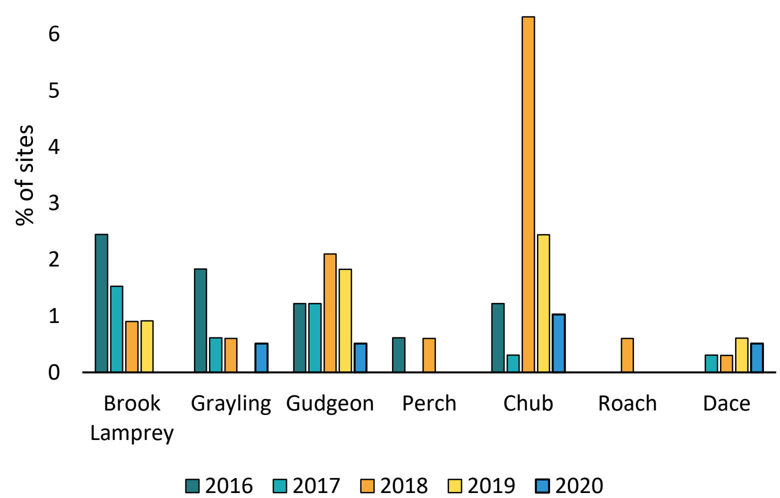


Figure 3.3.2. Accompanying by-catch by species % presence of sites from 2016 to 2020.

4.0 Discussion

Fish communities have evolved to live in dynamic river habitats and populations have been adaptable to temporal variation. However, the increasing rate of environmental change is far exceeding the capacity of many populations to adapt to new conditions. In particular, cold-water freshwater fish species are predicted to experience strong selective pressures from a wide range of interacting human stressors as well as severe hydrological events and the impacts of warming river habitat.

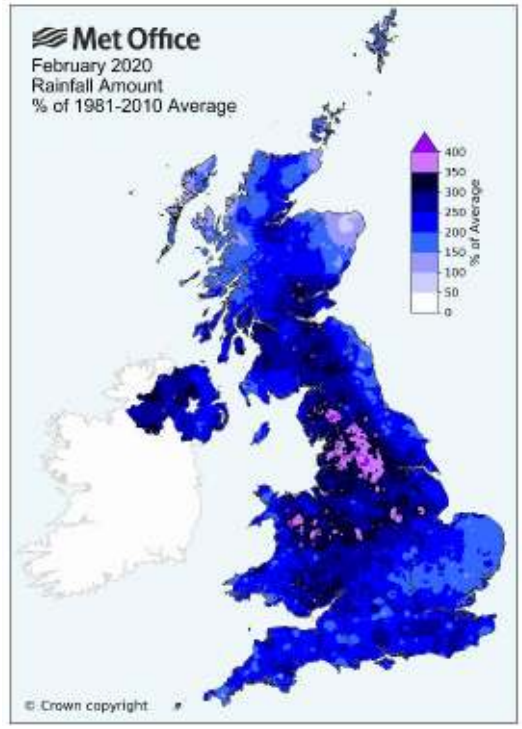


Figure 4.0.1. February May 2020 Met office rainfall data as % of 1981 – 2010 average www.metoffice.gov.uk

A growing body of evidence suggests that high flows between spawning and fry emergence have a marked effect on 0+ salmonid densities (Gillson, et al., 2020), which may be positive or negative. Salmonids use spate events to migrate upstream to spawning grounds, however, beyond an optimum discharge fish migration becomes impeded. Pre-spawning high flow events can provide clean gravel free of organic sediments for spawning, improving oxygen levels and egg survival. After spawning, riverbed scour or fine sediment loading can increase egg mortalities, eggs can also be displaced away from optimal habitat for development. Timing of these events can also be critical to different species; high discharges might increase spawning site availability for salmon and decrease egg-to-fry survival for trout.

Extremes, particularly high flow events between spawning and fry emergence, are thought to be impacting the Ribble catchment. Summer 2018's lowest flows coincided with the main run of sea trout in July and in the Autumn months minimal spate events took place from the end of September delaying returning Atlantic salmon. In 2019 rainfall was exceptionally high for the North West in March with Storms Freya, Gareth and Hannah bringing bands of heavy rain fall and high winds (Figure 4.0.1). This resulted in flood warnings being issued and some of the highest river levels recorded since the winter of 2015. By the month-end, half of the hydrological areas in North West England had observed around twice the expected monthly rainfall for March at a time where fry are emerging for their first feed. In 2020 three named storms crossed the UK during February, Ciara, Dennis and Jorge. The heavy rainfall throughout the month resulted in some severe impacts with many areas flooded and the gauging station on the River Ribble at New Jumbles Rock (among other) logging the highest level on record (Figure 4.0.2). At this time of year salmonid fry are still relying on yolk reserves, remaining very immobile within redds. With river levels exceeding all previous records, heavy sediment movement will have washed out redds leading to high mortalities of undeveloped young that have little to poor swimming ability.

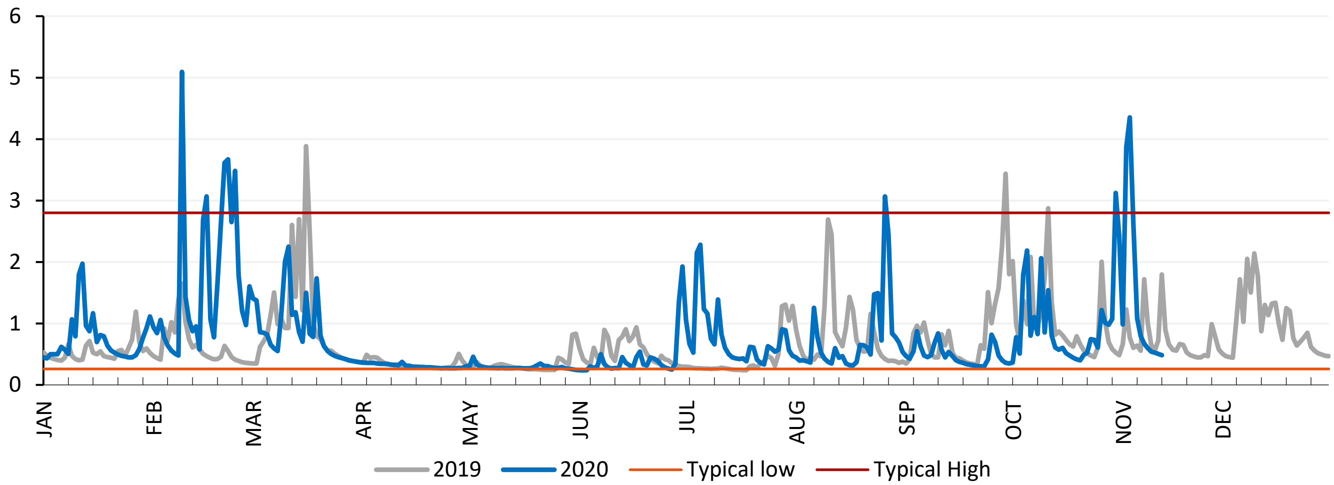


Figure 4.0.2. River level data from River Ribble at New Jumbles Rock 2019 and available data for 2020.

For Atlantic salmon we are seeing a year on year decline in recruitment. Salmon have a highly complex life cycle that is impacted at every stage by resource competition, environmental stochasticity and anthropogenic pressures. There is no golden bullet to solve these issues and to have a chance of improving stock of salmon on the Ribble catchment, more needs to be done to reverse negative effects. With such low densities of salmon and trout fry recorded in 2019 and 2020 community composition is being altered and there are concerns to be had over how these cohorts will affect the future adult spawning population. The effective management of freshwater habitat is essential to maintain and enhance salmon and sea trout populations, particularly as there are more unknown and uncontrolled impacts once they reach the saltwater feeding stage of their lifecycle.

One issue impacting salmon stocks is that of man-made barriers on main stem rivers. Atlantic salmon (Salmo salar), known as ‘the leaper’, are renowned for their ability to clear obstacles during their spawning migration. However, a number of studies have documented the movement of Atlantic salmon to key spawning areas may be delayed up to several weeks by man-made obstacles such as weirs, natural waterfalls and even fish passes (Thorstad, et al., 2008). Newton et al. (2018) recorded mean delays of 47.8h at a low-head weir with delays ranging from 15 min to 31 days. Fish may even abandon their migration and enter neighboring watercourses due to the abundance or size of in-river barriers (Thorstad, et al., 2008). The Ribble Trust and EA spring salmon tracking study (2012-2014) showed delays at Arnford weir of between 1 to 24 days. Out of the 11 salmon tagged, 6 were unsuccessful in migrating above this barrier with a maximum of 22 failed attempts to ascend from one individual. For the salmon that were successful there was still an average delay of 3 days at the structure. The sustained and prolonged swimming performance of Atlantic salmon reduces over time, losing between 50 and 70% of their total energy content during river migration and spawning (Booth, 1998; Jonsson, et al., 1997). Prolonged delays will prevent salmon from reaching suitable resting or spawning areas and as a consequence will reduce their reproductive success.

Figure 4.0.3. Partial weir removal on the River Ribble adjacent to Settle sewage works

Many of the structures on the catchment have associated fish passes which aids upstream migration. However, fish passes rarely achieve 100% efficiency and ascent success decreases with increased slope (Dodd, et al., 2017). Another major consideration is that downstream migrants can also be impacted by weirs and their upstream impounded reaches as Salmon smolts , when encountering a velocity gradient such as accelerating flow over a weir, causing delays to their migration in comparison with open stream sections. Aarestrup and Koed (2003) showed an average delay of 7 days for smolts negotiating weirs with a 0.6 - 2.5 m head drop during emigration. 53% mortality rates were recorded in Atlantic salmon smolts and 18 to 71% documented in brown trout. Delays can result in desmoltification due to a narrow migration window in which to reach the estuary (Leaniz, 2008). These effects are further compounded by unfavorable climatic conditions resulting in low flows during the smolt migration (Gauld et. al., 2013).

Figure 4.0.4. Partial weir removal on the river Ribble in the Upper Ribble near Horton-in-Ribblesdale

Weirs are recognised as predator hotspots and can facilitate excessive predation in a number of ways. Firstly, they offer a vantage point for predators as migrants are forced to swim over shallow crests which are exposed in lower flows. Leaniz (2008) indicated the distribution of cormorants (Phalacrocorax carbo) along river courses can be closely related to the location of weirs as these structures cause crowding of fish downstream of the structure. Also, otters (Lutra lutra) and cormorants can use the homogenous flow in the upstream reaches to their advantage as prey can be targeted with less energy expenditure. Weir removal will reinstate pool/riffle features, reducing predation success though increased habitat complexity, as variation in flow and depth allows for increased prey evasion. Overcrowding of fish downstream of impoundments have also been shown to facilitate the spread of parasites and infectious diseases, magnifying the impact of pollution incidents and increasing the risk of mass mortalities in low flows (Leaniz, 2008).

Figure 4.0.5. Samlesbury Weir removal on the River Ribble, Samlesbury. Today, the widest weir removal in England

This year the trust has completed 3 weir removals including one of the widest in England, bringing the total to 17. More structures need to be offered up for full or partial removal. Our catchment is suffering from the effect of anthropogenic pressures and climate change. The Ribble Trust will continue to improve the water environments of the catchment, by restoring and protecting the river to make sure that future generations can enjoy the beauty of its flora and fauna. This work will give our fish populations the best opportunity to recover and flourish into the future.

5.0 References

Arevalo, E. et al., 2018. Effect of food shortage and temperature on age 0+salmonids: a contribution to predict the effects of climatechange. *Journal of Fish Biology,* pp. 642-652.

Armstrong, J. D., Braithwaite, V. A. & Fox, M., 1998. The response of wild Atlantic salmonparr to acute reductions in water flow.. *Journal of Animal Ecology,* Volume 67, pp. 292-297.

Baldigo, B. P. & Warren, D. R., 2008. Detecting the Response of Fish Assemblages to Stream Restoration: Effects of Different Sampling Designs. *North American Journal of Fisheries Management,* 28(3), pp. 919-934.

Caissie, D., 2006. The thermal regime of rivers: A review. *Freshwater Biology,* 51(8), pp. 1389-1406.

Crozier, W. W. & Kennedy, G. J. A., 1994. Application of semi-quantitative electrofishing to juvenile salmonid stock surveys. *Journal of Fish Biology,* 45(1), pp. 159-164.

Dugdale, S. J., Bergeron, N. E. & St-Hilaire, A., 2013. Temporal variability of thermal refuges and water temperature patterns in an Atlantic salmon river. *Remote Sensing of Environment,* Volume 136, pp. 358-373.

Elliott, J. M. & Elliott, J. A., 2006. A 35-year study of stock-recruitment relationships in asmall population of sea trout: assumptions, implications and limitations for predicting targets. In: G. Harris & N. Milner, eds. *Sea Trout: Biology, Conservation and Management.* Oxford: Blackwell Publishing, pp. 257-278.

Elliott, J. M. & Elliott, J. A., 2010. Temperature requirements of Atlantic salmon Salmo salar, brown trout Salmo trutta and Arctic charr Salvelinus alpinus: Predicting the effects of climate change. *Journal of Fish Biology,* 77(8), pp. 1793-1817.

Fredrich, F., Ohmann, S., Curio, B. & Kirschbaum, F., 2003. Spawning migrations of chub in the River Spree, Germany. *Journal of FishBiology,* Volume 63, pp. 710-723.

Fulton, T. W., 1904. The rate of growth of fishes.. *22nd Annual Report of the Fishery Board of Scotland,* Issue 3, pp. 141-241.

Gillson, J. P. et al., 2020. Can aspects of the discharge regime associated with juvenile Atlantic salmon (Salmo salar L.) and trout (S. trutta L.) densities be identified using historical monitoring data from five UK rivers?. *Fisheries Management and Ecology,* Volume 27, pp. 567-579.

Jacoby, D. & Gollock, M., 2014. *Anguilla anguilla. The IUCN Red List of Threatened Species 2014.* [Online]
Available at: https://www.iucnredlist.org/species/60344/45833138
[Accessed 20 November 2019].

Jensen, L. F. et al., 2008. Local adaptation in brown trout early life-history traits: implications for climate change adaptability. *Proceedings of The Royal Society B,* 275(1653), p. 2859–2868.

Kennedy, B. P., Nislow, K. H. & Folt, C. L., 2008. Habitat-Mediated foraging limitations Drive Survival Bottlenecks For Juvenile Salmom. *Ecology,* 89(9), pp. 2529-2541.

Landergren, P., 2004. Factors affecting early migration of sea trout Salmo trutta parr tobrackish water.. *Fisheries Research,* Volume 67, p. 283–294.

Le Cren, E. D., 1951. The length – weight relationship and seasonalcycle in gonad weight and condition in the perch (Percafluviatilis). *Journal of Animal Ecology,* Volume 20, pp. 2-19.

R core Team, 2019. *R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/..* s.l.:s.n.

Ricker, W. E., 1951. Chapter 9. Growth in Length and in Weight. In: W. E. Ricker, ed. *Computation and interpretation of the biological statistics of fish populations..* Ottawa : Fisheries Research Board of Canada, pp. 1-382.

Solomon, D. J. & Lightfoot, G. W., 2008. *The thermal biology of brown trout and Atlantic salmon,* Bristol: Environment Agency.

Team, R. C., 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria..

Team, R. C., n.d. *R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.URL https://www.R-project.org/..* s.l.:s.n.

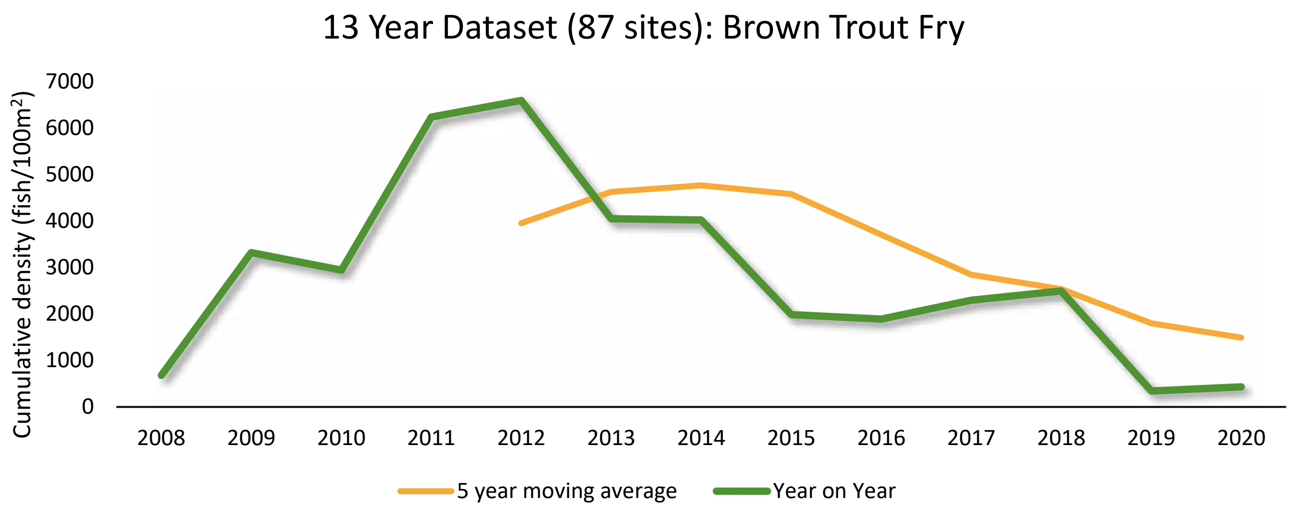
Thomas, S. M., Griffiths, S. W. & Ormerod, S. J., 2015. Adapting streams for climate change using riparian broadleaf trees and its consequences for stream salmonids. *Freshwater Biology,* 61(1), pp. 64-77.

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.

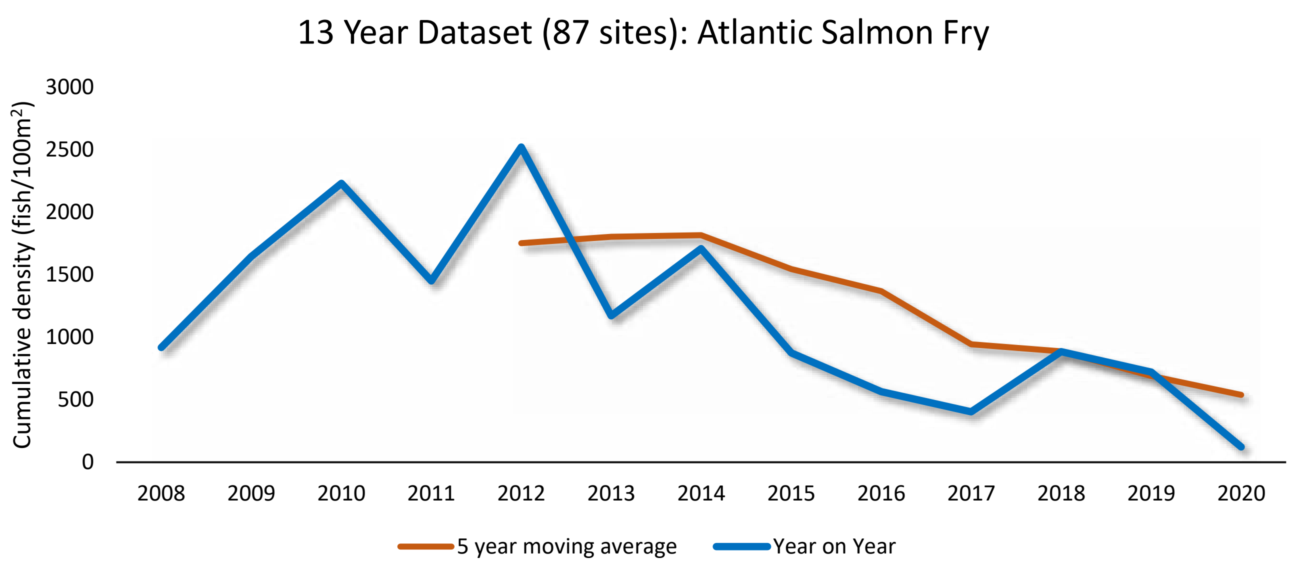
Warren, D. R., Mineau, M. M., Ward, E. J. & Kraft, C. E., 2010. Relating fish biomass to habitat and chemistry in headwater streams. *Environmental Biology of Fishes,* Volume 88, pp. 51-61.

6.0 Appendices

6.1 Appendix A

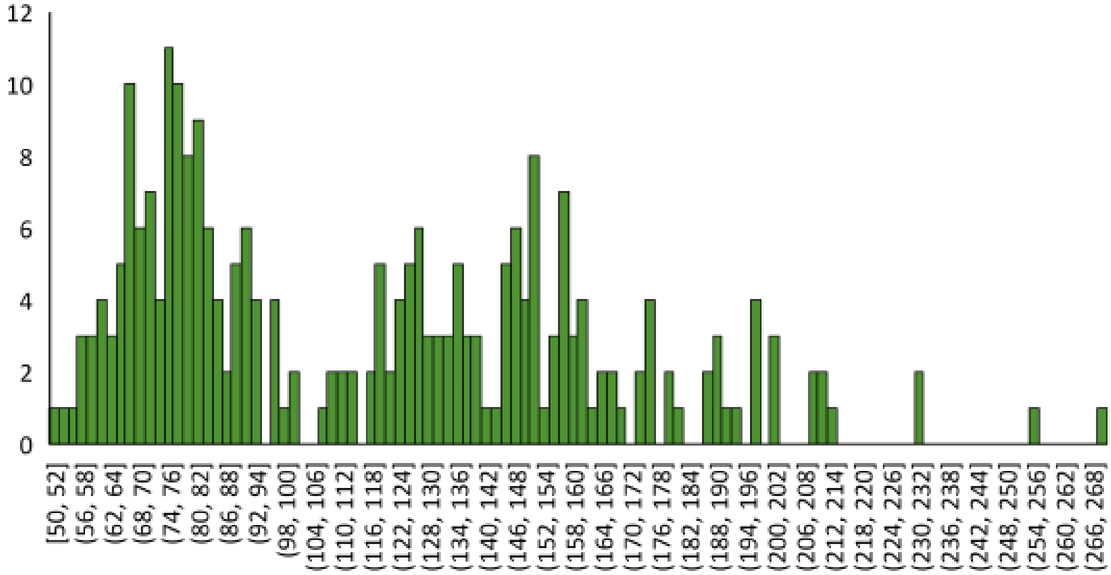


Appendix A.1 Cumulative brown trout fry densities on the Ribble catchment for 87 sites fish 2008 – 2020 including 5 year moving average.

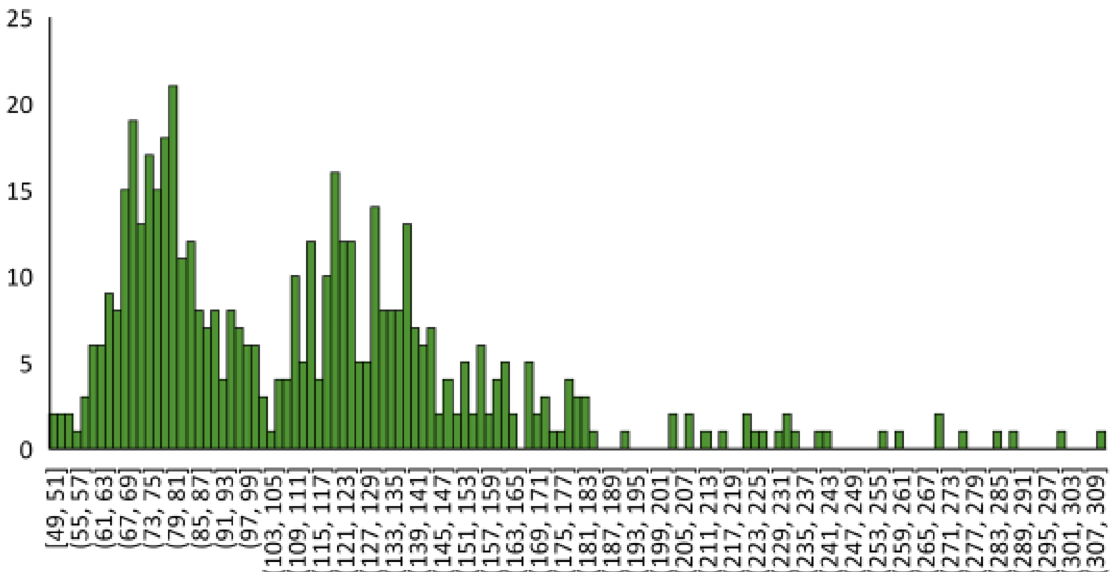


Appendix A.2 Cumulative Atlantic salmon fry densities on the Ribble catchment for 87 sites fish 2008 – 2020 including 5 year moving average.

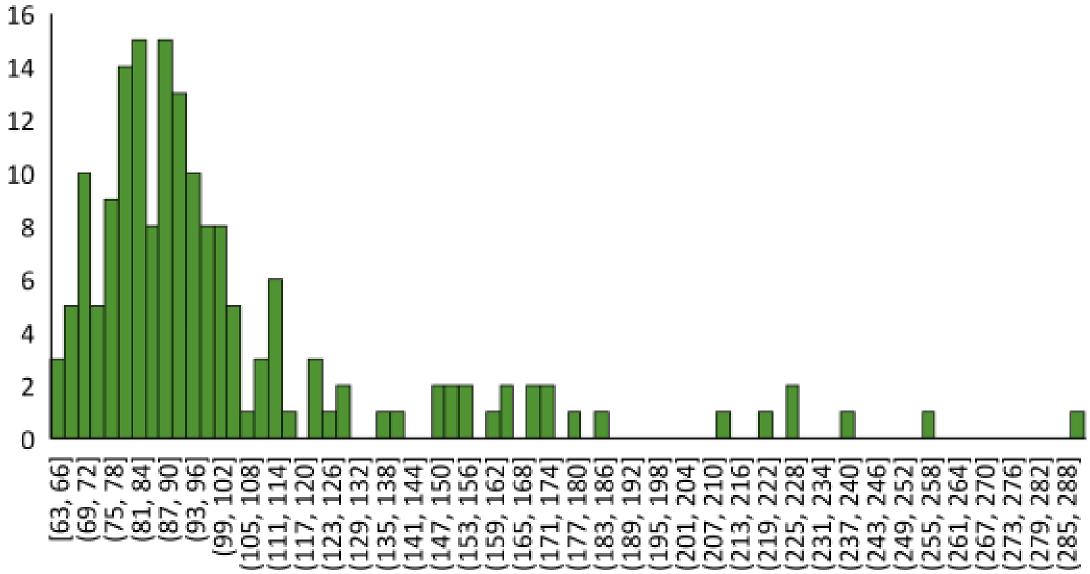
6.2 Appendix B



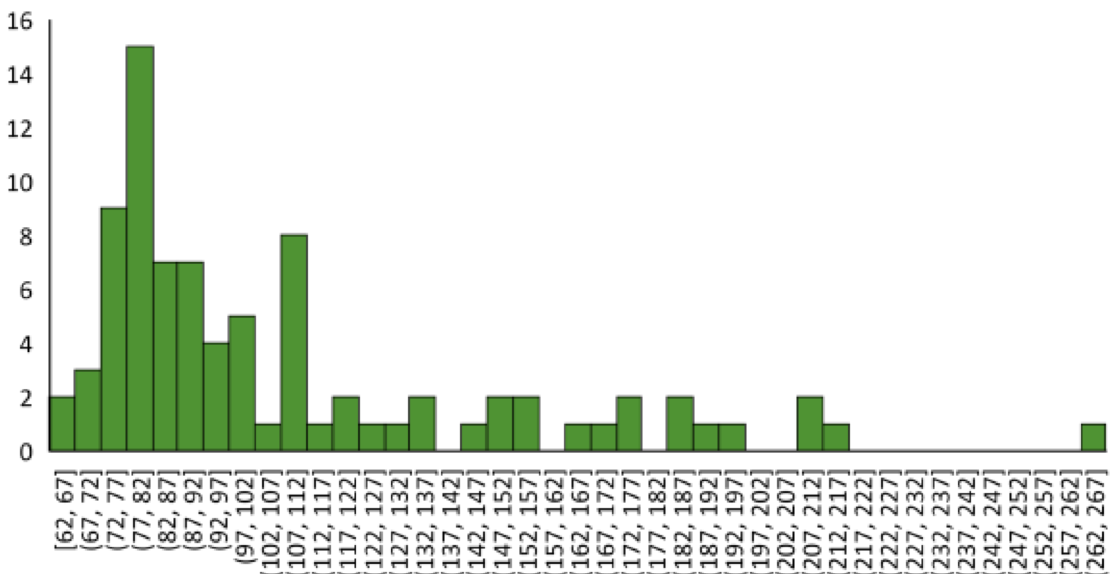
Appendix B.1 Fork length histogram of all brown trout captured on the Calder catchment 2020. Maximum fork length for 0-year trout = 100 mm at time of survey



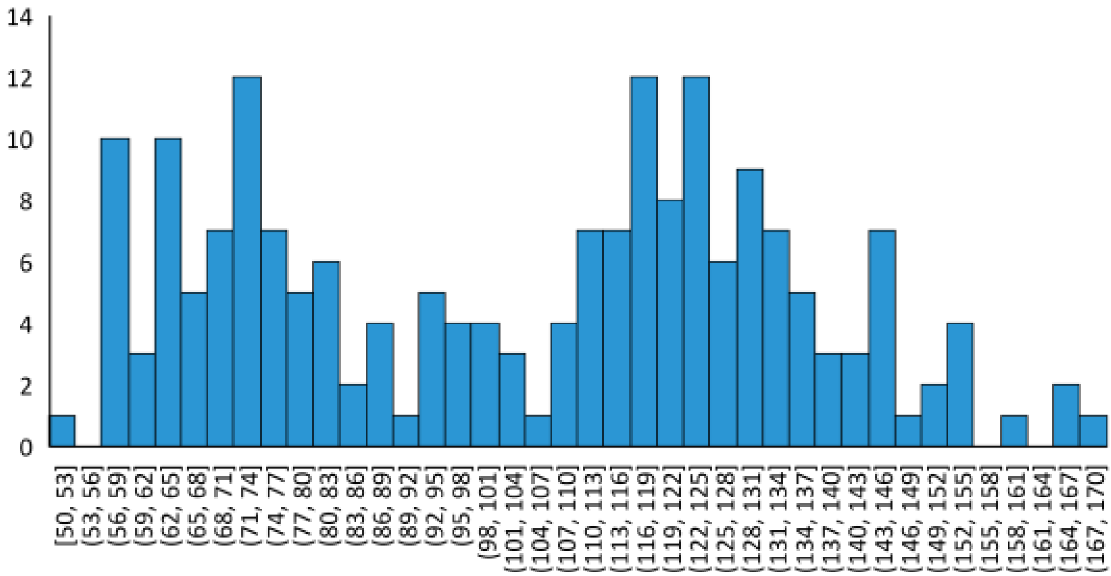
Appendix B. 2. Fork length histogram of all brown trout captured on the Hodder catchment 2020. Maximum fork length for 0-year trout = 102 mm at time of survey.



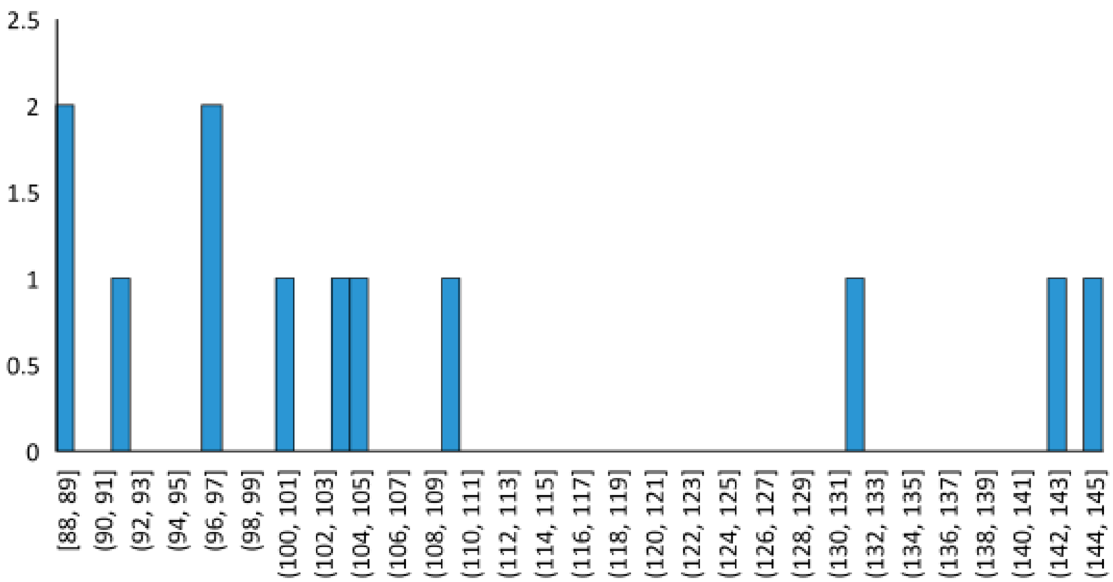
Appendix B. 3. Fork length histogram of all brown trout captured on the Mid-Ribble catchment 2020. Maximum fork length for 0-year trout = 102 mm at time of survey.



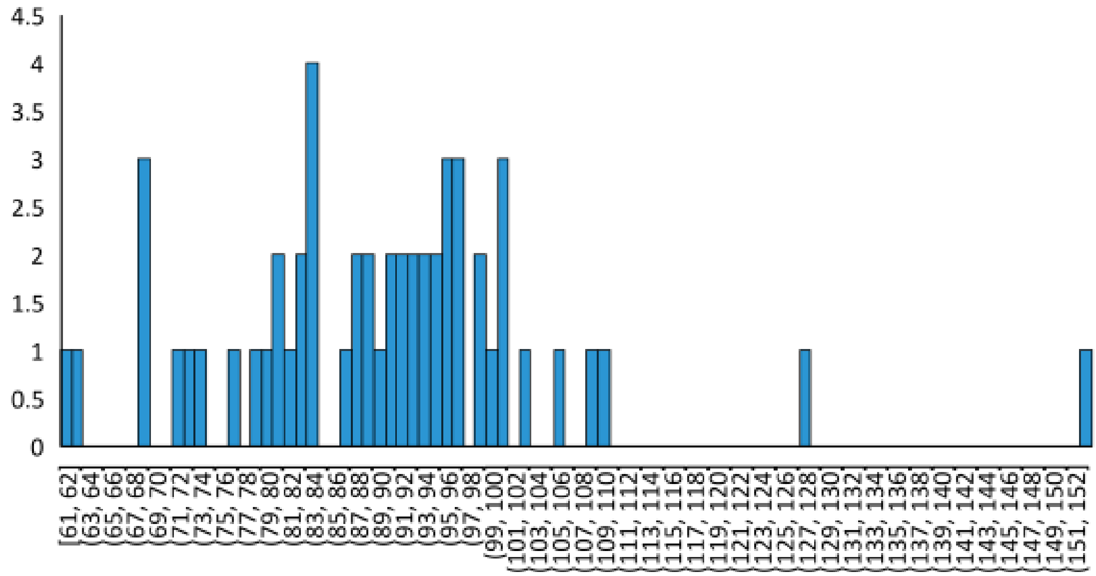
Appendix B. 4. Fork length histogram of all brown trout captured on the Upper-Ribble catchment 2020. Maximum fork length for 0-year trout = 102 mm at time of survey.



Appendix B. 5. Fork length histogram of all Atlantic salmon captured on the Hodder catchment 2020. Maximum fork length for 0-year salmon = 102 mm at time of survey



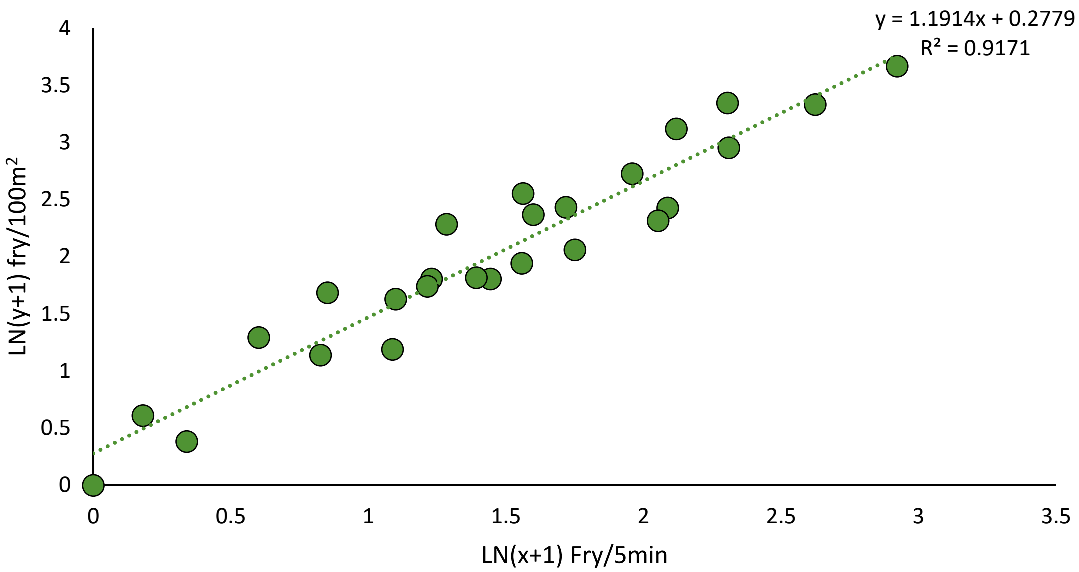
Appendix B. 6. Fork length histogram of all Atlantic salmon captured on the Mid-Ribble catchment 2020. Maximum fork length for 0-year salmon = 101 mm at time of survey



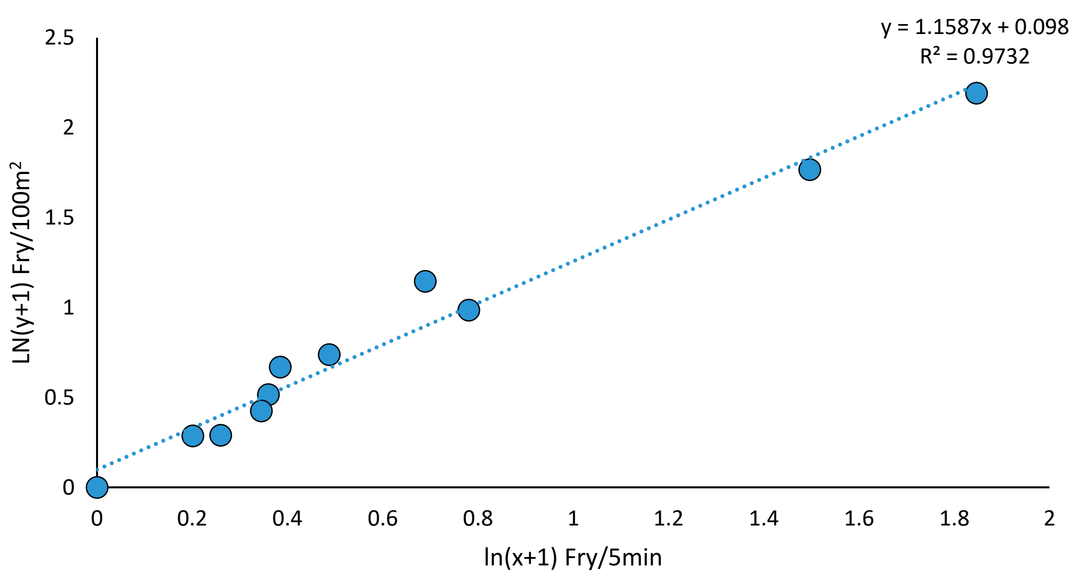
Appendix B. 7. Fork length histogram of all Atlantic salmon captured on the Upper-Ribble catchment 2020. Maximum fork length for 0-year salmon = 102 mm at time of survey

6.3 Appendix C

DUE TO COVID 19 AND TIME RESTRICTION - Q DATA FROM 2020 WITH THE ADDITION OF DATA FROM 2019 HAS BEEN USED TO CREAT THE CALIBRATION FOR THIS YEAR



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) = 0.2779 + 1.1914 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) = 0.098 + 1.1587 Ln (x + 1)