The state of Dart salmon and likely reasons for decline

Summary of the likely pressures that could be causing declines, specifically to Atlantic Salmon in the River Dart Catchment.

Prepared for:
The Sharpham Trust

Prepared by:
Catie Gutmann Roberts

27 March 2025

Project/File:
330202966

Stantec UK Limited

Revision	Description	Author	Quality Check	Independent review
1	For review and discussion	Catie Gutmann Roberts	Aoife Codyre	Ryan Oakley
2	Final amendments	Catie Gutmann Roberts	Robyn Cloake	Ryan Oakley

Table of Contents

List of Figures

Table of Tables

Executive Summary

Stantec UK Ltd was commissioned to write the River Dart salmon decline study report to assist The Sharpham Trust in understanding the specific pressures causing the decline of salmon in the River Dart Catchment. This request came from the Environment Agency, which aims to incorporate the findings into the Dart Catchment Action Plan.

The objective of the study is to summarise the likely pressures affecting Atlantic salmon, using the Likely Suspects Framework from the Missing Salmon Alliance. The report assesses the state of the salmon at different life stages and locations within the catchment, comparing findings with other catchments where relevant, and identifies available data on potential drivers. Any data gaps will be highlighted, and suggestions for addressing them will be provided.

The scope of this report did not include the requirement for new data collection, instead relying on existing data that was open access, or provided from Westcountry Rivers Trust (electric fishing results) and the Environment Agency (net and rod and line capture records and licences).

The post-smolt survival can be affected by the river conditions and a tagging study on that life stage would be needed to confirm if that were the case. Aligning the collection of environmental data in the catchment with the biological data in terms of sites surveyed and timing of those, would be required for a thorough analysis into the effects of the environmental conditions on the salmon population.

The available data indicates a significant decline in Atlantic salmon populations within the Dart catchment across all monitored life stages: fry, parr, and adult. While trends for fry and parr vary by site, many locations that previously recorded fry now show their absence. However, a few sites have seen minor increases in parr numbers in the 2024 surveys. Adult salmon numbers are at a record low in the Dart catchment, and the Dart catchment performs particularly poorly compared to other catchments in the Southwest.

To better understand population bottlenecks and improve site-based spawning habitats, coordinating redd counts would be beneficial. The lack of data on the smolt life stage limits the understanding of where these bottlenecks occur. Some fry and parr data are held by third parties, and enabling open access to this data, ensuring it is comparable with current data, should be considered.

Global and regional declines in salmon suggest that broader drivers of mortality are also affecting the Dart salmon. However, the Dart's poorer performance compared to other regional populations indicates that local river or marine conditions may also be contributing to mortality. While a quantitative analysis of these conditions was beyond the scope of this report, one commonly cited issue is low pH levels. However, high fry and parr numbers are found at Cherry Brook, a site within the catchment with low pH conditions. Post-smolt survival may be influenced by river conditions, and a tagging study on this life stage would be necessary to confirm this. For a thorough analysis of the effects of environmental conditions on the salmon population, it is essential to align the collection of environmental data with biological data in terms of surveyed sites and timing.

1 Introduction

Stantec UK Limited have been commissioned by The Sharpham Trust (the "Client") to produce a report detailing the data on the suspected decline of Atlantic salmon (*Salmo salar*), hereafter referred to as 'salmon', in the River Dart catchment.

1.1 Overview of the River Dart Catchment

The River Dart (hereafter referred to as 'Dart') catchment, located in Devon, England, originates from the moorlands of Dartmoor. The river flows approximately 48 kilometres, traversing diverse landscapes including upland moors, woodlands, and agricultural areas, before discharging into the sea at Dartmouth. The catchment area is characterised by its ecological diversity, supporting a range of habitats and species. The Dart is particularly significant for its Atlantic salmon population, which has been experiencing notable declines.

1.2 Objective of the Report

The objective of this report is to summarise the state of the salmon population and the likely pressures, that could be causing declines, in the Dart Catchment.

1.3 Scope of Work

The report will examine the state of the Dart salmon, where data is available, at different life stages and across different locations in the catchment, and where helpful may draw comparison to other catchments. The potential drivers to be investigated will be based on the Likely Suspects Framework, devised by the Missing Salmon Alliance. The work here will identify available data on each of those drivers and attempt to summarise them, or where data is missing, highlight those and where possible suggest a way to fill the data gaps. The scope of this report did not include the requirement for new data collection, instead relying on existing data. Initially only open access data was included but following the report review from client we were requested to use datasets provided that originated from the Westcountry Rivers Trust (electric fishing results) and the Environment Agency (net and rod and line capture records and licences).

1.4 Use of Information

This information is intended to be used to determine the best management and conservation actions which could be incorporated into the Dart Catchment Action Plan.

1.5 Purpose of the Report

The purpose of this report is to review the state of salmon in the Dart, highlighting available data sources on salmon and review possible causes of low population numbers. The report will focus on data specifically relating to salmon and the environmental conditions they experience at different life stages. Where relevant, data on Sea trout (*Salmo trutta*) may also be included, especially where identification is estimated and could be misidentified as sea trout, but also as they have similarities in migration strategies and life cycle, hence, they could both be susceptible to the same threats, and where there are divergences, this could indicate the drivers of decline.

2 The state of salmon in the Dart

A review of the South West Rivers showed the Dart salmon performed the worst in 2022 with only 1% of the conservation limit attained and the fourth worst in 2023 with 18%, with their status of being “at risk” of extirpation (CEFAS et al., 2023, 2024). In the latest Salmon stock assessment, every river in the South West was ‘At Risk’ or ‘Probably At Risk’ (CEFAS et al., 2024).

The Missing Salmon Alliance are collating a database of salmon data ‘Salmon Ecosystem Data Hub’ (SalHub) but currently there are no records for the Dart catchment (SalHub 2024).

The Devon River Authority surveyed salmonid populations in the Dart using electrofishing in 1965 (Nott and Beale, 1969). They surveyed different life stages within the Dart including Atlantic salmon parr and adults, brown trout (all young life stages) and sea-trout, using stop nets and fishing till they were satisfied few or no fish were left in the stretch. Records of adult salmon captured by anglers were reported from 1950 to 1965 which are required by Byelaw. However, for anglers these were overall numbers for the Dart making it difficult to compare the findings to recent Environment Agency (EA) monitoring; which are recorded at specific locations. The angling records were also noted to be inaccurate due to anglers not always following their statutory duty to record their catch or reporting inaccurately. In addition to this, the report data from draft nets (also known as seine nets) in the estuary dating back to 1950, provides some evidence of success rates of migratory salmon during those years. The EA have provided the data records from 1951 to 2019 from the commercial net fishery; however no licences have been given since 2015 due to the Net Limitation Order (NLO) which was put in place to protect the declining salmon stocks. The Net Limitation Order was for a period of 10 years, expiring in October 2025.

The Dart catchment has 79 sites that have been monitored for freshwater fish by the EA in the last decade, however, salmon have only been recorded at 64 of these sites (EA Ecology and Fish data explorer, 2024). These fish are listed in age bands as; 0+ which we will be summarised in the fry section and >0+ which will be summarised in the parr section. Available data goes back as far as 1996 but have varied by survey type and are often non consistently monitored on consecutive years. This can make understanding long term trends and site comparisons difficult. The EA data download contained multiple spreadsheets and contained some errors in age band classification (that have since been amended), and procedures on survey/ data entry have changed over time. The Westcountry Rivers Trust (WRT) also hold electric fishing data but do not have a central repository for open access data downloads and instead this is available on request. The dataset received contained salmon and trout, with records split between fry and parr, with not all surveys having data recorded between the life stages. The dataset spans from 2012 to 2021, across 79 named sites and the surveys consisted of semi quantitative electric fishing using five minute time surveys without stop nets, as per Crozier and Kennedy (1994).

Data available from the EA Ecology and Fish explorer were numbers of juvenile (fry and parr) salmon surveyed from electric fishing. Electric fishing protocols, carried out by the EA, varied between years, with four survey types recorded in the Dart catchment. Temporal sites (Te) which are surveyed every two years with a single catch sample. Spatial sites (Sp), where the whole catchment is surveyed every six years on a single run. Spatial sites which are wider (Dip) and therefore cannot be surveyed in a single run and therefore sampled for twenty minutes. Sites with single runs had lengths between 30 – 50m and were fished up to a top net. Salmon surveillance sites (5min) monitoring which ceases to continue on the Dart and were sampled for five minutes with a backpack with no stop nets and no defined areas. The range of methods used makes spatial and temporal comparisons difficult. Most sites did not have data over consecutive years, making analysis over time difficult. Data downloads are formatted over four spreadsheets which need combining to attain total counts, the current method involves measuring the first 50 fry and then the remainder are counted and all parr are measured. Data entry methods appear to have changed over time, where at some point 10 fry and parr were measured during catch per unit effort surveys, but the date of change in survey protocols and how it varied on other survey types was not known by EA staff. These changes in methodology and the limited accessibility on knowledge of method changes could introduce errors on analysing data over time. We processed the data to extract counts of fry (0+) and parr (>0+) by site and sample date. Survey data was available from 1996 to 2024.

Salmon numbers are very variable by site, with sites such as Lower Cherry Brook (in 1996) and U/S Postbridge (in 2014) having over 400 fish. There were 79 sites that had at least one survey, 26 of these had less than 5 salmon totalled across all surveys, and 15 of those had zero salmon ever caught. Many sites have had less than 100 individuals sampled across the whole sampling period such as Longacre, Beardown, Tally Ho Bridge and Crockern Tor (Fig. 1). Sampling effort has varied across the catchment with some sites sampled up to 20 times, such as U/S Postbridge and 18 sites only surveyed once (e.g. Brimpts Woods, Dunnabridge and Fox Tor Mire). One site surveyed by both EA and WRT methods show differing numbers of salmon at similar timepoints with the WRT trend showing an increase and the EA method showing a decrease, showing how variable methods and specific stretches can give differing results. The mean number of salmon from the Lower Cherry Brook stands out as higher than any other site sampled even though it is not the location with the most sampling effort (Fig. 2).

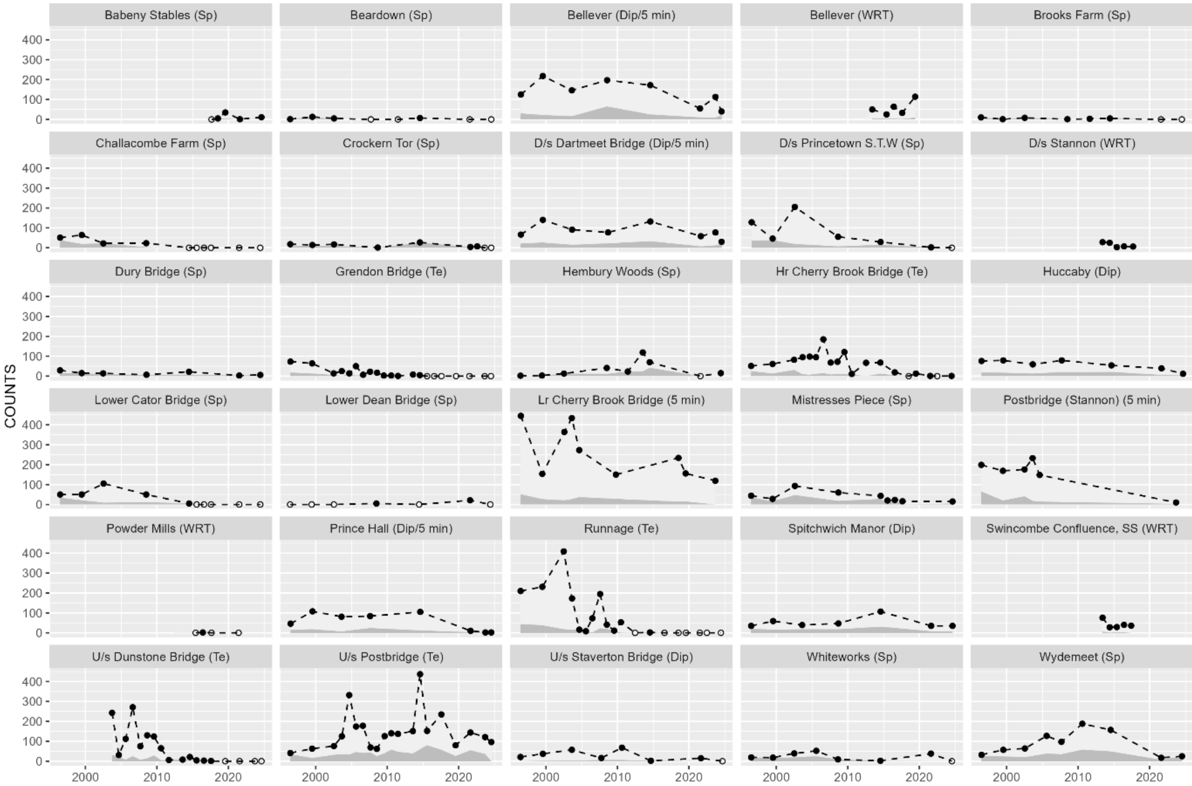

Figure 1. Environment Agency and WRT sampling records showing Atlantic salmon caught from various electric fishing protocols for both age classes; 0+ (young of the year/ fry; light grey) and >0+ fish (parr; dark grey), showing sites that had five or more records and where maximum salmon count was at least 5 fish. Hollow circled indicate zero salmon captured. Site name and sample type in brackets. Dashed trend line represents total salmon.

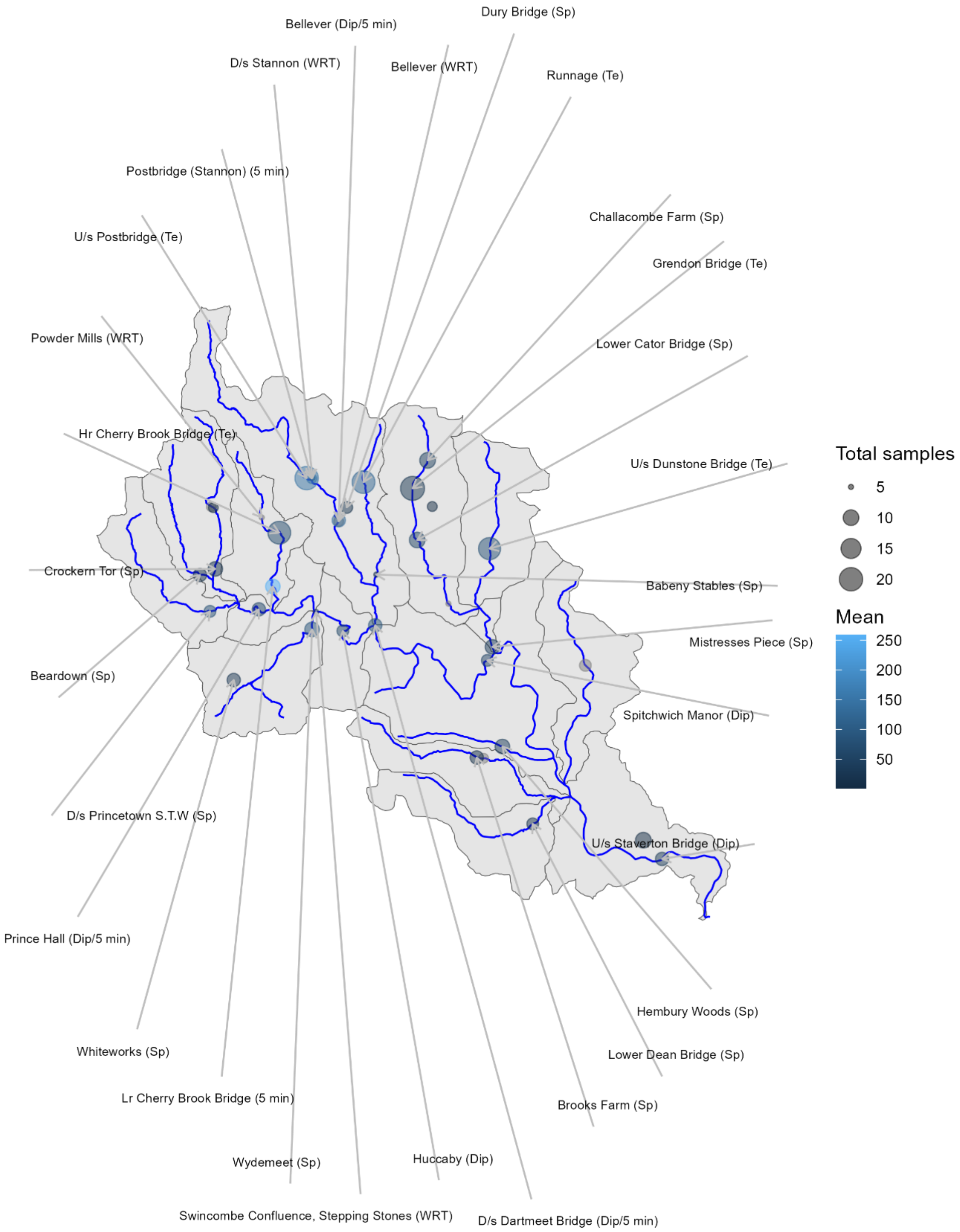

Figure 2. Environment Agency and WRT data on salmon fry (0+) and parr (>0+) from the Dart catchment with bubble colour denoting mean counts across the surveys and bubble size showing total number of surveys per site. Only showing tributaries that flow directly into the River Dart as opposed to those flowing directly into the estuary.

2.1 Spawning

Salmon deposit their eggs in structures called redds, generally deposited in the first 30 cm of gravel and the locations are based on accessibility, substrate and flow and the sizes of gravel that can be used also relates to the body size of the female (Riebe et al., 2014).

In other catchments such as the River Teign, anglers and other citizen scientists have been tasked with searching for redds and recording their locations. As part of the River Teign Restoration project, volunteers received training, signed risk assessments, and were assigned specific areas to search. Access permissions were obtained for them, and the collected data was then inputted. All of this was coordinated by employed staff. Whilst citizen science can assist with collecting data, it requires co-ordination and standardisation, especially in a catchment like the Dart which predominantly runs through privately owned land.

The most recent spawning map (based on observations) available, from 2001, shows barriers, some of which are no longer complete obstacles. As a result, new areas may now be accessible (Fig. 3). From the Salmon Action Plan (2001) the methods or survey effort, to create the spawning map, were not given and therefore it is possible that some areas without recorded observations could be due to a lack of survey effort. Equally, due to reductions in salmon numbers some sites may no longer be spawning grounds. To inform site-based spawning habitat improvements, it would be useful to co-ordinate redd counts.

Figure 8 - Barriers to Migration and Principle Salmon Spawning Areas

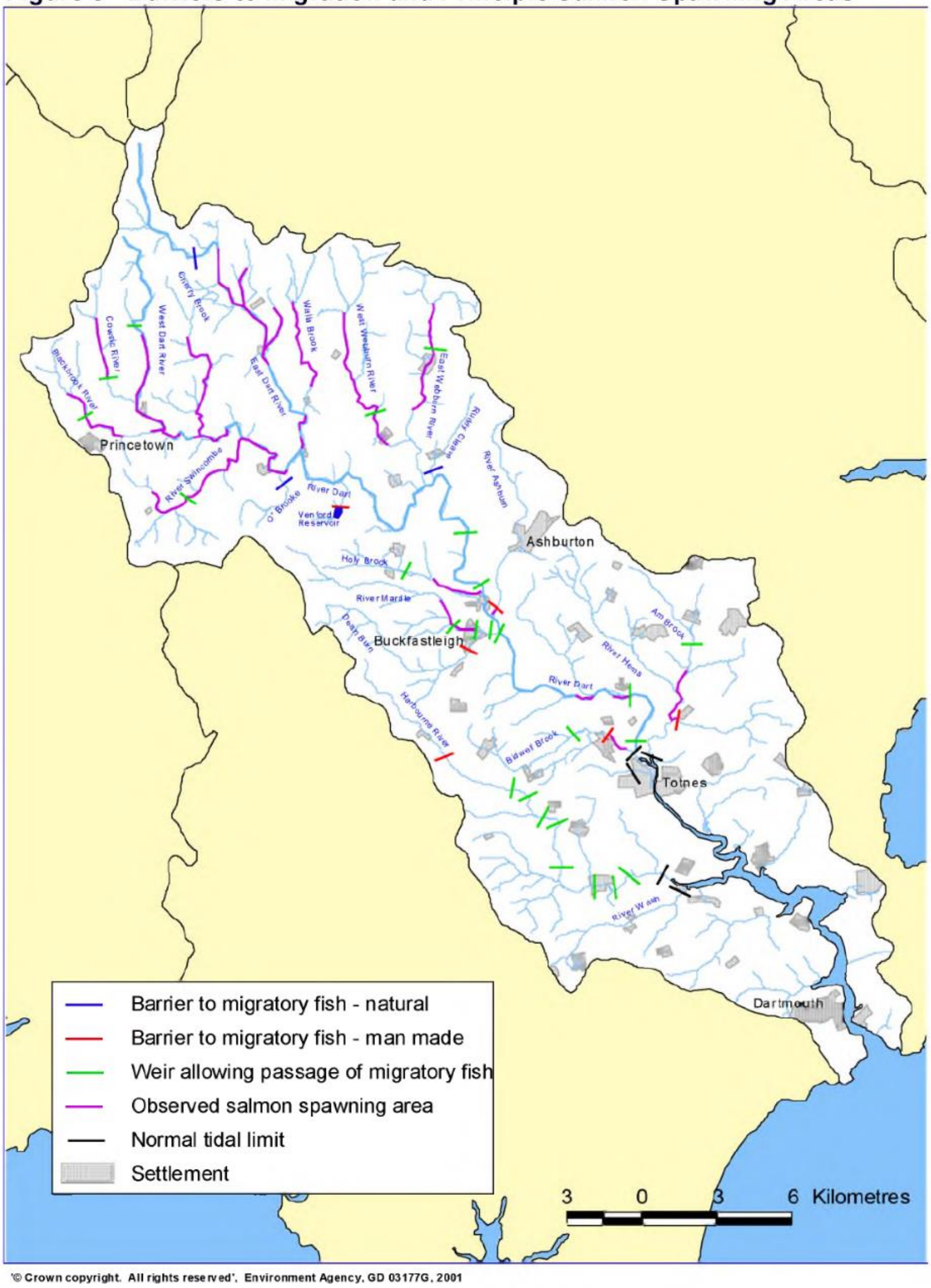

Figure 3. This is shared from The River Dart SAP Consultation Document (Environment Agency, 2001).

2.2 Eggs

Eggs and alevins are in the sediment for a number of months during the winter and are affected by the temperature and oxygen, whilst they have their own food supply in the yolk sac (Armstrong and Nislow, 2006).

No available data has been found on the number of eggs deposited nor survival rates. The Salmon Stock and Fisheries assessment estimated 530,000 eggs were deposited, based on accessible wetted area (calculated from GIS but not openly available) and estimates of adult returns and spawner abundance from rod and line fishing. Other rivers have the adult returns based on fish counters, despite there being a fish counter in the Dart (adult data in 2.6) this data was not within the Salmon and Freshwater Fisheries report (Table 23). No stocked salmon were released in 2022 or 2023 according to the Salmon and Freshwater Fisheries statistics (CEFAS et al., 2023, 2024).

2.3 Fry

Fry stage is the period from the emergence out of the gravel in the first year of life, fry tend to disperse downstream and defend feeding territories. From the EA data those recorded as 0+ fish are characterised as fry. This is a critical part of the life stage and mortality can be high, and survival can be density dependent (Gilson et al., 2008). In these early stages fry are vulnerable to predation (Falkegard et al., 2023), high flow events (Jonsson and Jonsson, 2010) and require prey suited to their limited gape size (Wañkowski 1979).

All data are from the Fish and Ecology Data Explorer, methods explained in section 2.1.

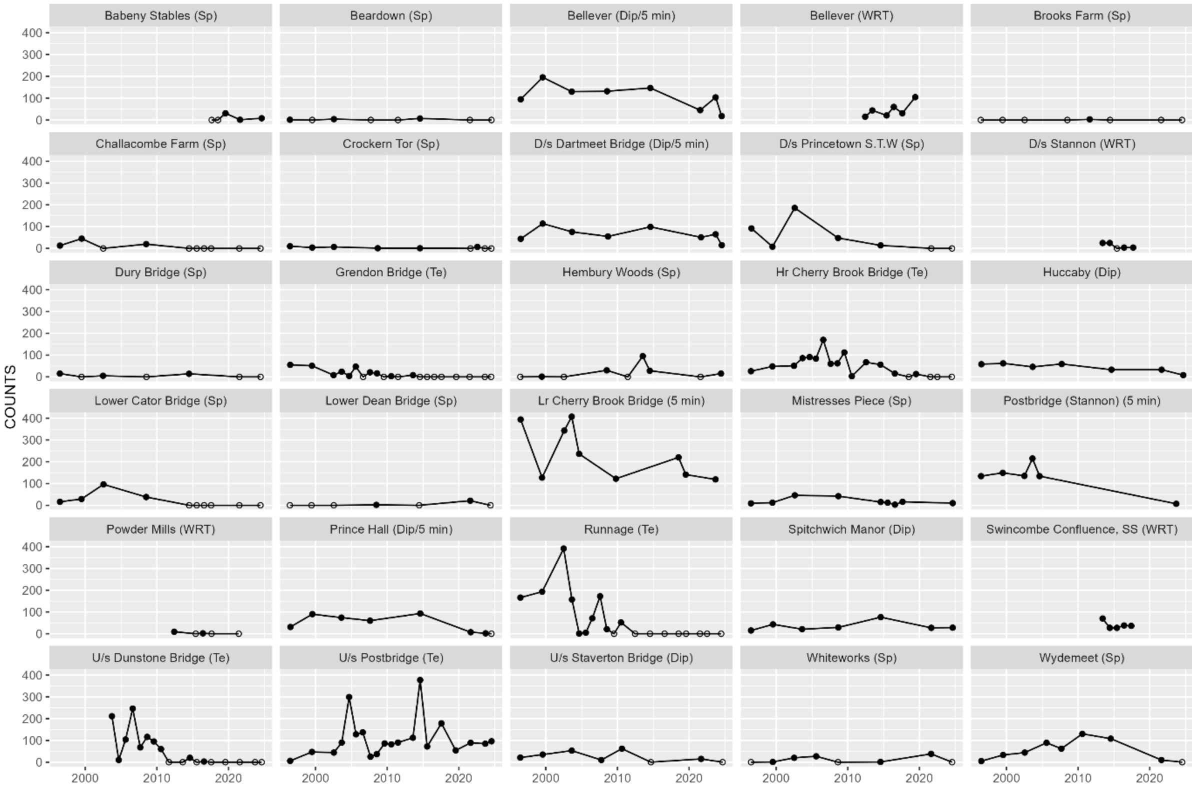

Figure 4. Environment Agency and WRT sampling records showing Atlantic salmon fry (0+) caught from various electric fishing protocols. Sites displayed are those with at least 5 sampling occasions and with at least 5 fish (fry and parr) caught. Hollow circled indicate zero salmon captured.

There is no clear consistent trend in salmon fry over time within the Dart catchment. Several sites have had consistently low salmon abundance across the timeframe such as Beardown in the Cowsick River, Crockern Tor in the Main West Dart and at the Dury Bridge in Dury Brook (East Dart), both having no salmon caught on the last two sampling events. Several sites that have historically had over 100 fry in a single site now also have not had salmon in consecutive sampling events such as U/S Dunstone Bridge, Runnage and Hr Cherry Brook Bridge (Fig. 4).

2.4 Parr

Salmon parr growth and survival is determined by temperature and resource availability, and they can move large distances downstream (Ibbotson et al., 2013) within a river reach, making estimates of survival from fry sites difficult. From the EA data those recorded as >0+ fish are characterised as parr and have generally been in the river for at least a year.

As with the fry, there is no straightforward temporal pattern replicated across the whole catchment for parr. As shown in Fig.5, 19 out of 29 (69%) sites had no parr present in their last sampling event. Six sites had a slight increase in abundance at the final sampling event, compared to the previous. Only three sites had more than 60 parr on a single survey date, U/S Postbridge in the Main East Dart (2015), Postbridge in the Stannon Brook (1996) and Bellever in the Main East Dart (2008).

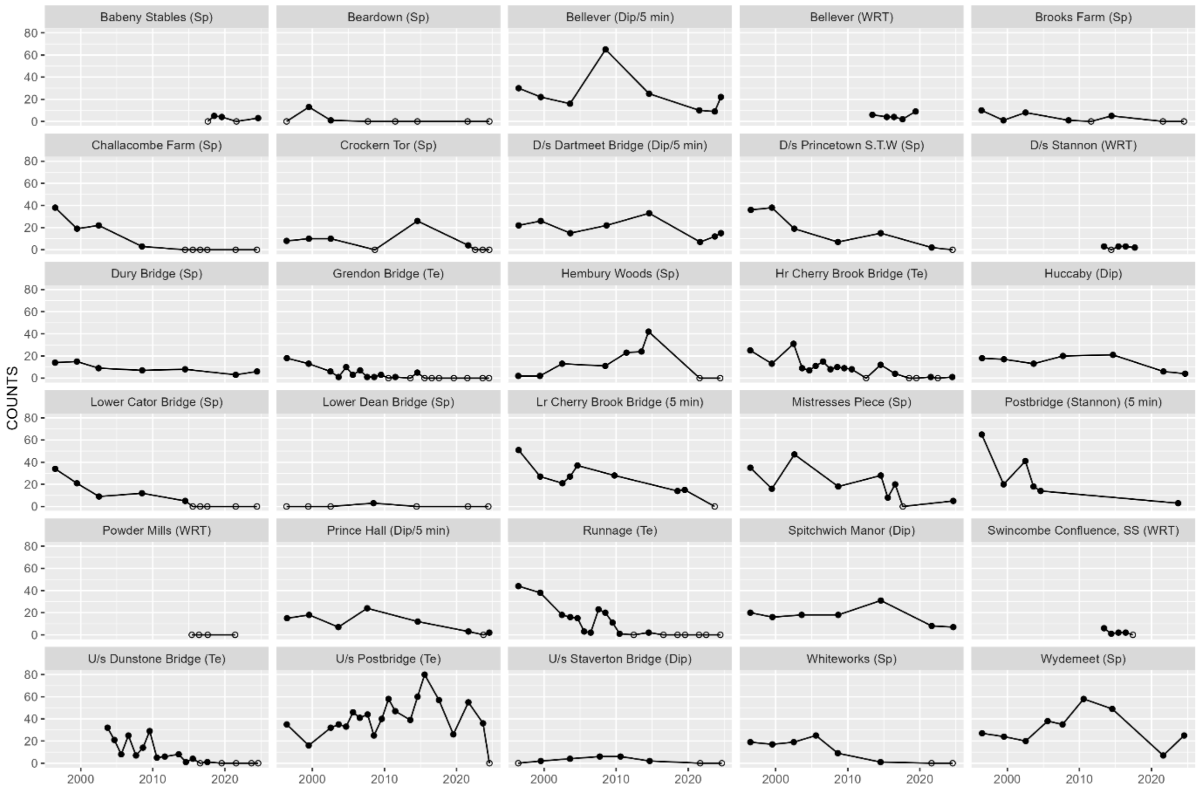

Figure 5. Environment Agency and WRT sampling records showing Atlantic salmon parr (>0+) caught from various electric fishing protocols from the counts dataset. Sites displayed are those with at least 5 sampling occasions and with at least 5 fish (fry and parr) caught.

When comparing the results from the 'The River Dart Fisheries Survey Report' (Nott and Beale, 1969), for the following locations: Postbridge, Bellever, Crockern Tor, Beardown, Grendon bridge, Huccaby, Princehall), populations of salmon parr were significantly higher in 1965 at the given survey location, suggesting a significant decline in recorded salmon populations. For example, at Bellever salmon parr records show that 179 parr were recorded in 1965 (Nott and Beale, 1969) and in 2024 (Figure 5) this number has dropped to 20. Beardown has the lowest number of parr present in both the EA monitoring records and the 1965 study with 1965, 1996 and 2024 (Figure 5) all having records of 0 (Nott and Beale, 1969). However, as a range of survey methodologies were used for the EA monitoring surveys and with this varying from the methods used in the 1965 any direct comparisons should be met with caution.

2.5 Smolts

This life stage involves the transition from river to sea and involves a change in shape, colour, behaviour and physiology. Usually a parr stays in the river for 2 – 3 years before transitioning to a smolt and once the have attained lengths of 10 cm. Despite being captured on the cameras at the Totnes Weir Fish counter (DAA, 2016), there are no available data on the numbers of smolts. Understanding the numbers of smolts and the challenges during this migration period is key to managing stocks and requires the use of tags and tracking.

2.6 Adults

Adult salmon return to their natal rivers after spending at least one year at sea, sometimes multiple years. Some adult salmonids migrate upstream through the Totnes counter in May, June and July and whether they are salmon or trout is estimated based on size (FishTek, 2024). During high flow conditions the weir face is passable, therefore not all fish will pass through the counter (FishTek, 2022). The time series available went back to 2017, where only combined salmon and trout values were available at a high of 1843 adults, followed by a sharp decline to 1006 in 2018 and then increasing again in 2019. From 2019, data is available estimated to sea trout and salmon, and whilst there are almost 6 times more sea trout than there are salmon, their temporal pattern is very similar. The only difference is the sea trout adults migrating downstream which show a steady decline, versus salmon showing a small increase again in 2021 before decreasing. The lowest number of salmonids was recorded in 2023 with 59 salmon and 464 sea trout (Fig. 6).

When comparing adult salmon numbers, the River Stour and Axe have lower means from 2013 to 2022 than the Dart (Fig. 7). Several Dartmoor rivers have many more adult salmon such as the Teign and Tavy. Angler records can be used to monitor adult salmon numbers and only 2,one sea winter and 7 multi sea winter salmon were caught in the last Salmon Stock and Fisheries report (2023).

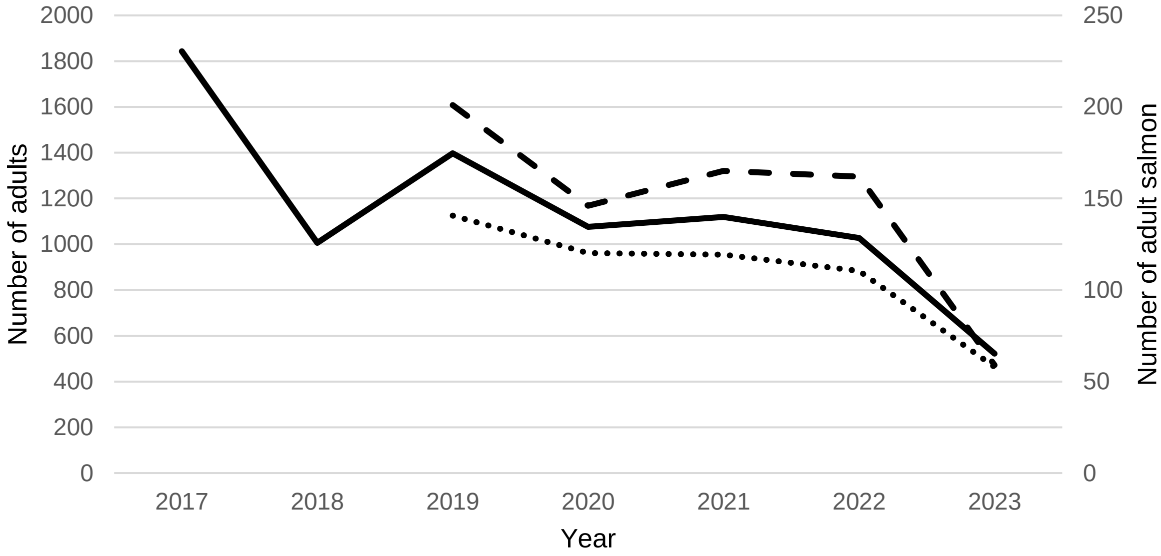

Figure 6. Upstream adult migrating salmonids (solid black line) separated by estimated sea trout (dotted) and Atlantic salmon (dashed), note the Atlantic salmon numbers are on the secondary axis. Data from the FishTek reports on the Totnes resistivity counter.

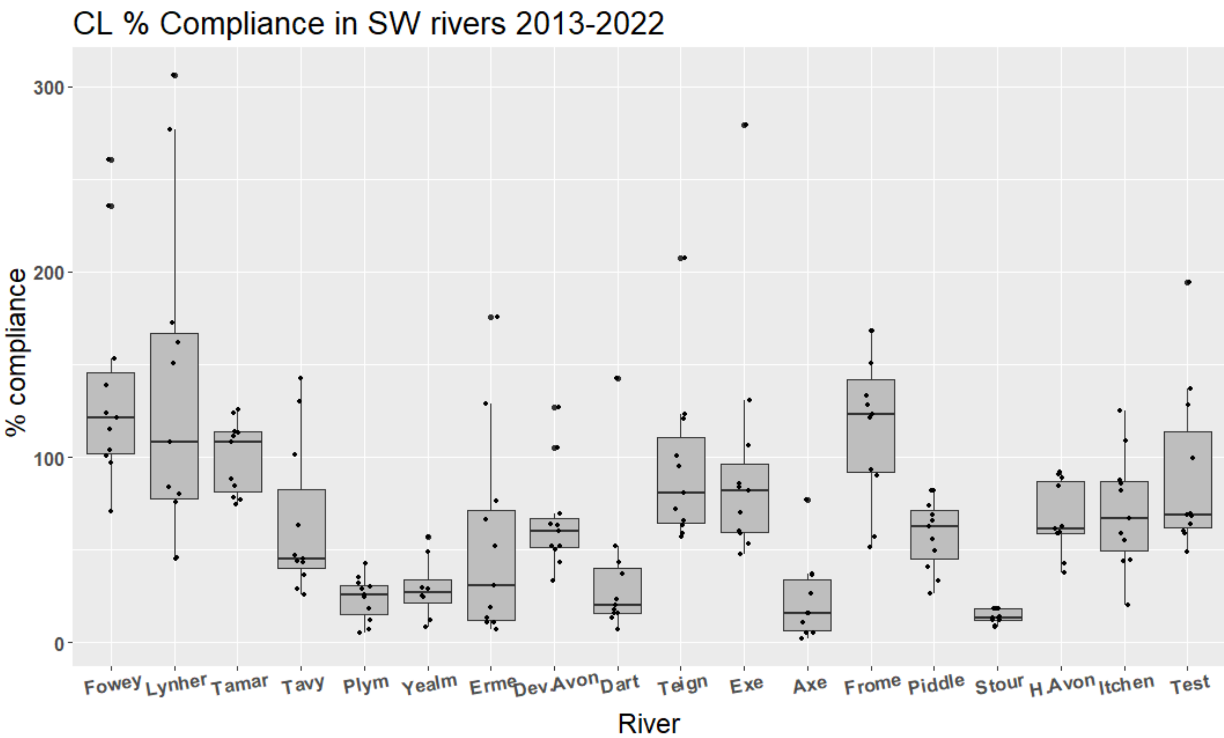

Figure 7. Boxplots of ten-year (2013 - 2022) variation in Conservation Limit (CL) compliance for English Channel rivers, ordered west to east, showing median (horizontal line) quartiles and outliers. Data from Cefas et al., (2023) (Milner 2024)

Declared rod catch data from the EA shows the much higher adult salmon numbers caught in the 50's and 60's with a decline in the 70's followed by some increases in the 80's and early 90's (Figure 8.) Followed by almost constant declines in catches since then, with the lowest annual catch of 1 Atlantic salmon being caught in 2022.

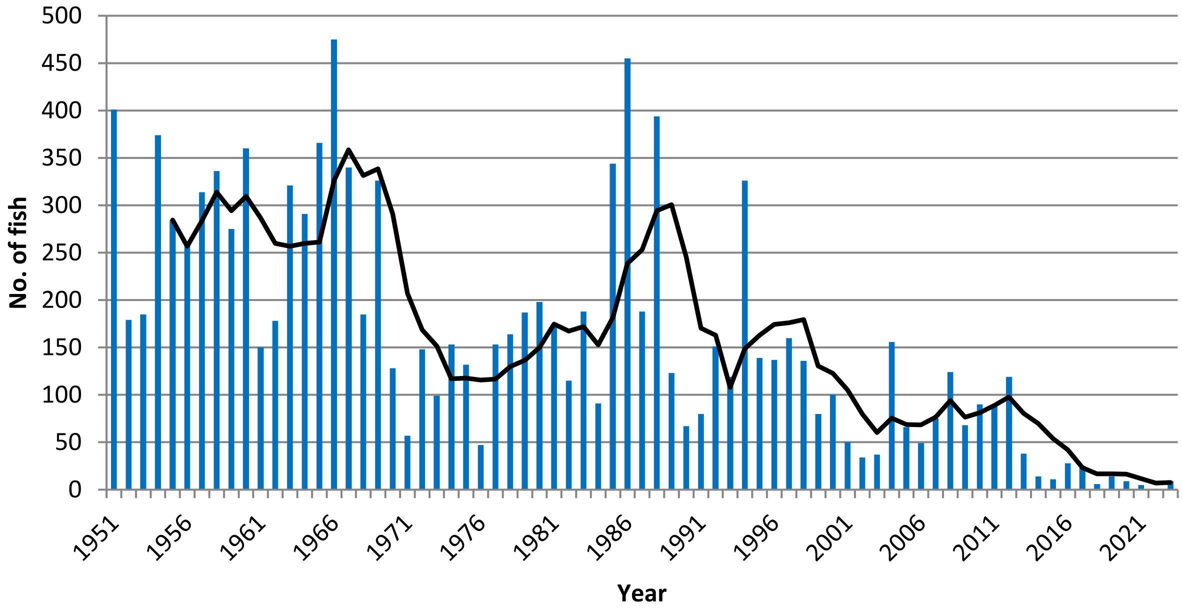

Figure 8. Declared rod catch of Atlantic salmon from the River Dart (1951 – 2023) with black line as 5 year rolling average

While angler catch data is a very valuable asset in monitoring both the adult population and a measure of how they are targeted, it does not have the same standardised effort as scientific monitoring. Catch can have varying effort with anglers being based in different locations and with different equipment and skills. To standardise the dataset, from 1994 the number of days of fishing carried out for migratory salmon was also collected. Effort has also declined along with the number of salmon, even when accounting for the reduction in effort, with catch per licence day there is still a reduction in the catch rate of salmon from the Dart (Figure 9). The National Salmon and Sea Trout Protection Byelaws 2018 renewed measures to protect the spring run of generally larger MSW fish which were first introduced by the National Spring Salmon Byelaw in 1998. These were to prohibit the removal of salmon taken by rod and line and introduce method restrictions before 16th June.

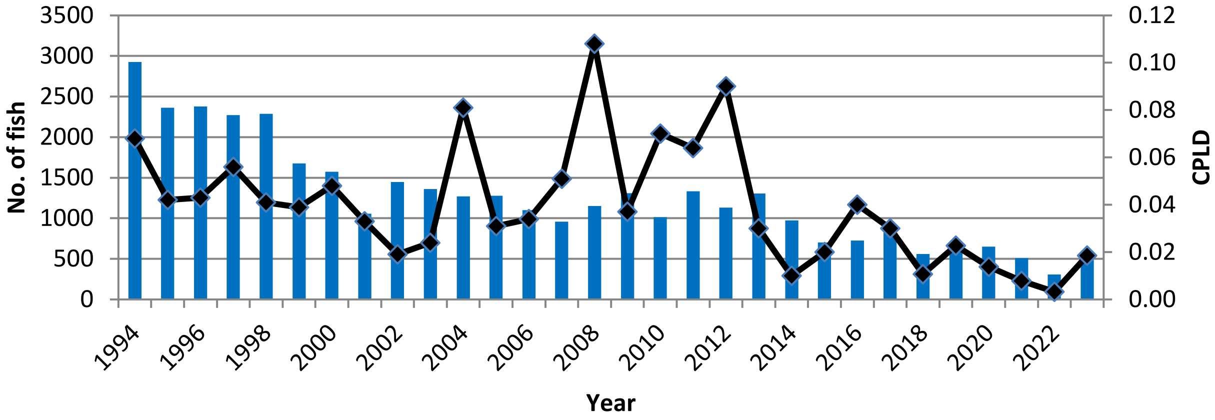

Figure 9. Number of Atlantic salmon (primary y axis) and rod catch per licence day (CPLD; secondary y axis) over time (2007 – 2023)

Atlantic salmon were also being caught in seine nets until 2015 when no licences have been given since. Numbers of salmon caught declined rapidly from 1987 and licences declined from 1994 (Figure 10. No new seine netting licences were allowed in the Dart from 1975 due to the Salmon and Freshwater Fisheries Act 1975, allowing only the 18 existing licences to remain. With no licences from 2016 onwards due to the Net Limitation Order (2015). In January 2019, the National Salmon and Sea Trout Protection Byelaws 2018 were introduced which prevents the taking of Atlantic salmon by net fisheries for a ten-year period (expiring in December 2028).

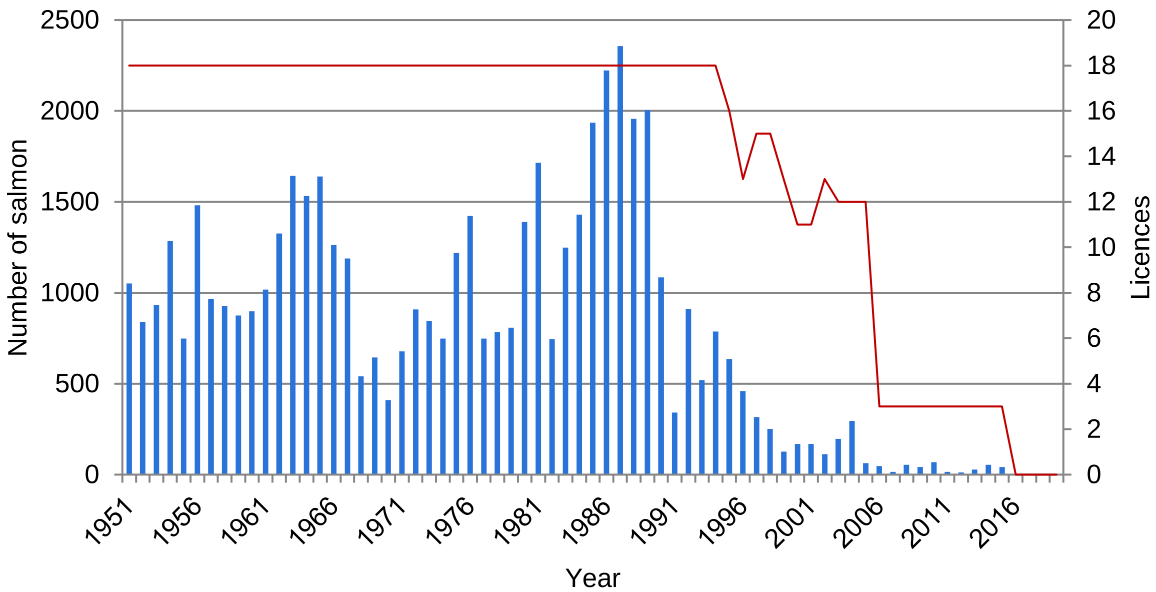

Figure 10. Number of salmon caught from seine nets (blue bars, primary y axis) and the number of licences (secondary y axis, red line) from the River Dart, over time 1951-2014 (Environment Agency)

3 Processes leading to salmon mortality

The following section outlines processes that could be causing salmon mortality in the Dart across a range of scales from global, regional and local scale threats, as outlined by the Likely Suspects Framework (Bull et al., 2022). As other literature covers the global and regional issues, more time has been spent discussing the localised potential causes of decline, and additional factors from available literature have been included, outside of the likely suspects framework where relevant.

3.1 Global scale

Climate change can affect the growth and survival of salmon at all life stages. Bayesian life cycle models have been applied to salmon, including those from South England (Olmos et al., 2020). Demonstrating a common trend across the North Atlantic explaining 37% of the temporal trend from 1971 to 2014, with salmon declining by a factor of 1.8. Post smolt survival is largely explained by sea surface temperatures and primary productivity.

Biogeography affects salmon, showing population changes through geological space and time. This impacts the genomics of salmon and their gut microbiomes (Llewellyn et al., 2016). The location of the geographic populations such as North America or European influence their migratory routes to their marine feeding grounds in the Labrador Sea and Norwegian seas respectively (Olmos et al., 2020). These global scale patterns are described in many other literature sources and will not be directly applicable for management in the Dart catchment so are only briefly touched upon with no specific analysis.

3.2 Regional scale

Regional scale factors affecting the UK, England and the South West are covered in other literature and were outside the scope of this time-limited project. The regional factors affecting salmon include sea surface temperature, salinity, precipitation and the terrestrial and aquatic biome (Bull et al., 2022).

Salmon are declining across the range, including in North America where the fishery has been drastically reduced suggesting regional or broader ocean issues. The only location where salmon are not suffering in reduced reproductive capacity is the Gulf of Canada (WGNAS, 2021). Other than those listed, the primary productivity of a region can also be linked to salmon population dynamics (Olmos et al., 2020).

3.3 Localised Marine Conditions

Localised Marine conditions affect salmon survival such as front/ gyre development and food web dynamics (Bull et al., 2022).

3.3.1 Competition (natural)

Salmon migrating into the Dart Estuary and then the Western Channel to the Norwegian sea will face feeding competition from other fish, seabirds and marine mammals along their routes and across a wide timescale. No studies could be found showing the migratory routes for adult salmon from the Dart or other South West rivers. Disentangling these impacts is extremely complex.

Some changes close the to the Dart Estuary include an establishment of some new marine mammals such as harbour seals, usually frequenting Scottish waters but previously rare in the South West have been sighted in the Dart Estuary since 2006, with recent (2019, 2020) records of confirmed breeding (Westcott, 2021).

3.3.2 Reduced prey (natural)

Fish larvae and large zooplankton will be the prey during early marine migration (Rikardsen et al., 2004) and larger fish predation will occur as salmon mature (Jacobsen and Hansen, 2001) such as capelin (*Mallotus villosus*), Blue whiting (*Micromesistius poutassou*) and sand lance (*Ammodytidae spp*) (Bull et al., 2022). Large zooplankton and fish larvae have changed in abundance in the South West of England but not with clear uniform patterns (McEvoy et al., 2023). With regard to UK fish stocks, blue whiting are one of the top 10 most landed, in terms of biomass, with landings tripling from 2019 to 2021 (Oceana in the UK, 2023), with a potential reduction available for salmon to predate.

Smolts cue their timing to sea to match with optimal sea surface temperatures that will allow for optimal survival, but this is based on river temperatures. Salmon smolts are already initiating migration earlier due to climate change but adaptation to warming varies across taxa so the rate of change for smolts and their prey may not align and can result in mismatches (Simmons et al., 2021). Tyldesley et al. (2020) demonstrate that data taken from the ‘continuous plankton recorder’ and areas recorded that smolt travel through show that zooplankton in some areas have increased in energy whilst others have noticeably decreased, without smolt tracking data from the Dart, other nearby tracking data such as from the rivers Tamar or Frome could be used as proxies.

3.3.3 Predation (natural)

Ocean predation of salmon has been studied using satellite tags showing most predation was from ectothermic fish, marine mammals and large ectothermic fish, in that order (Strom et al., 2019). Even though this study didn’t specifically include any salmon from England, the patterns are likely similar.

3.3.4 Marine fishing (anthropogenic)

The Salmon Stocks and Fisheries in England and Wales report (2022; 2023) cover marine fishing, showing no seine net fishing in the Dart since 2019 and the last compensation measures recorded were in 2013. The 2023 report states the previous Dart fishery was seine netting and no licences have been administered since 2015. The rod fishery is managed on the Dart through mandatory catch and release. Previous reports show that one of the main factors for the Dart not reaching compliance in 2003 was due to exploitation (NASCO, 2020).

3.3.5 Aquaculture (anthropogenic)

Despite salmon being the predominant fish species farmed in the UK, this is primarily in Scotland, and none were established in the Southwest England region, with no future plans for establishment due to the preference of cooler waters further North (Devon and Severn IFCA, 2021).

3.3.6 Climate change (anthropogenic)

Just as climate change affects salmon and the global scale it will also affect localised sea surface temperature, precipitation and food webs. A review of this was outside of the scope of this report.

3.4 Localised freshwater conditions

Temperature affects salmon in a range of ways, from being able to cause mortality, affecting growth and swimming speeds (Jonsson & Jonnson, 2010). The natural geomorphology of the river will also shape the habitats available to salmon and in some cases, which headwaters are accessible (Kennedy et al., 2013). The river regime and natural flow patterns will also affect salmon at their varying life stages, especially timing of migration upstream for returning adults and out-migrating smolts (Jensen et al., 2021).

3.4.1 Competition (natural)

Competition is most likely with other animals that occupy the same niche, this is most likely with other salmon, especially in the juvenile stages and results in density dependence. Due to the low number of juvenile salmon in the catchment it is unlikely this has a strong impact. Competition also depends on the availability of food resources, and even if salmon abundance is high, if matched by an equally high food source then it may not be limiting. Juveniles are territorial and visual predators awaiting drifting prey and their competitors could be other drift invertebrate feeders such as pied wagtails and other invertebrates such as net spinning caddisflies (Nislow et al., 2010). Invasive species can be competitors with salmon for food and habitat, currently the INNS mapper only has invasive plants logged within the catchment (INNS Mapper, 2024). Reviewing all possible competitors for Atlantic salmon in the Dart was outside the scope for this report.

3.4.2 Reduced prey (natural)

Salmon fry and parr will feed on insect larvae (Jonsson and Jonsson, 2011). Studies on Welsh headwaters show that sites that are acidic, have less invertebrate density and biomass than comparative sites, however, trout were able to adapt their diets to incorporate chironomids and more terrestrial invertebrates (Ormerod et al., 2004). Trout and salmon have varying diets largely due to their gape size differences, and trout can be more opportunistic (Montori et al., 2006) and more active hunters than salmon (Bardonnet & Bagliniere, 2000). It may be possible to estimate overall whether likely prey sources for salmon have decline based on data from the Fish and Ecology Explorer, however, that was not achievable within the scope of this report.

3.4.3 Predation (natural)

Seals are observed below Totnes weir, and from other studies it shows returning spawners can be vulnerable to seal predation, especially the early returners (Butler et al., 2006). Predation pressures are higher below barriers (Bendall et al., 2008).

Otters can predate on adult migrating salmon, and this can sometimes occur prior to spawning. Depending on the catchment the proportion of pre-spawning adult salmon predated can be high - for example 81% in Søre Vartdalselva in Norway, leading to a reduction in recruitment (Sortland et al., 2023). Predation risk can be studied using predation and temperature tags. Predation risk can vary depending on the habitat types available and salmon may be able to seek refuge in deep pools (Sittenthaler et al., 2019). Otters have been recorded in the Dart catchment from 1974 to 2018 in low density and spread across the catchment (NBN gateway, 2024).

In other places in Western Europe, catfish (*Silurus glanis*) have predated on adult salmon in fishways (Boulêtreau et al., 2018) and there is one accepted record of catfish in the Dart catchment in 2001 (NBN gateway, 2024). The location of that record is in the Dittisham mill stream however, the co-ordinates have an uncertainty of 7000 m. In a French river, 35% of adult salmon were predated by catfish in a fishway (Boulêtreau et al., 2018). Therefore, considering the risk of this large invasive species in the catchment is important.

In river mortality of smolts can be high, between 35 – 65% in the River Bush in Ireland for example, and much of this can be attributed to predation (Flavio et al., 2019). Avian predators that have been observed predating smolts in other places include cormorants (*Phalacrocorax carbo*), gulls (such as *Larus argentatus*) (Flavio et al., 2020), both of which are widespread across the UK and present across the Dart catchment, including observations of them downstream of Totnes hydropower.

Predation can also have some positive population effects through removing weak individuals.

3.4.4 Loss Genetic Diversity (anthropogenic)

Salmon parr genetics from the Dart were included in a study by Griffiths et al., (2010) showing a significant change from 2005 to 2006. The Dart was generally clustered with the genetics from salmon in other South West rivers, as would be expected. In the study the mixed stock analysis apportioning was more accurate for the Southern sites, which consisted of Southern England, France and Spain when compared to the rest of the UK, probably reflecting their genetic uniqueness. Further research on the genetics in the catchment was not possible within the scope of this report.

3.4.5 Climate change (anthropogenic)

Climate change affecting temperature, precipitation and flow across the river environment is becoming a threat to salmon. Salmon eggs are the most vulnerable to river temperature, then alevins and parr (Elliott and Elliott, 2010). Knowing the locations of redds will be important if the rising temperature effects are to be countered with active measures. Critical upper limits for eggs is 16°C, alevins 23 – 25°C and parr and smolts 22 – 33°C (Elliott and Elliott, 2010). Therefore, modelling the temperature at different times of year and across different years would be needed to understand the impacts on salmon. Fig. 11 shows that most in river mean temperatures do not exceed the life stage requirements, however it is important to note that there is a lack of sampling points in most of the headwaters where salmon spawning would occur. From looking at the EA water quality archive records from 2021 – 2024 the warmest records were at Gara at Slapton bridge at 20.2°C in July 2021 and 19.6 in June 2023, with the next highest at Totnes weir at 18.4°C in June 2023. As June and July are outside of the adult migration, spawning and egg incubation these will reflect conditions that relate to the parr life stage. Searching just the winter conditions (November – February) in line with the spawning and incubation timing the maximum temperature was 12.6 at the Gara in November 2021.

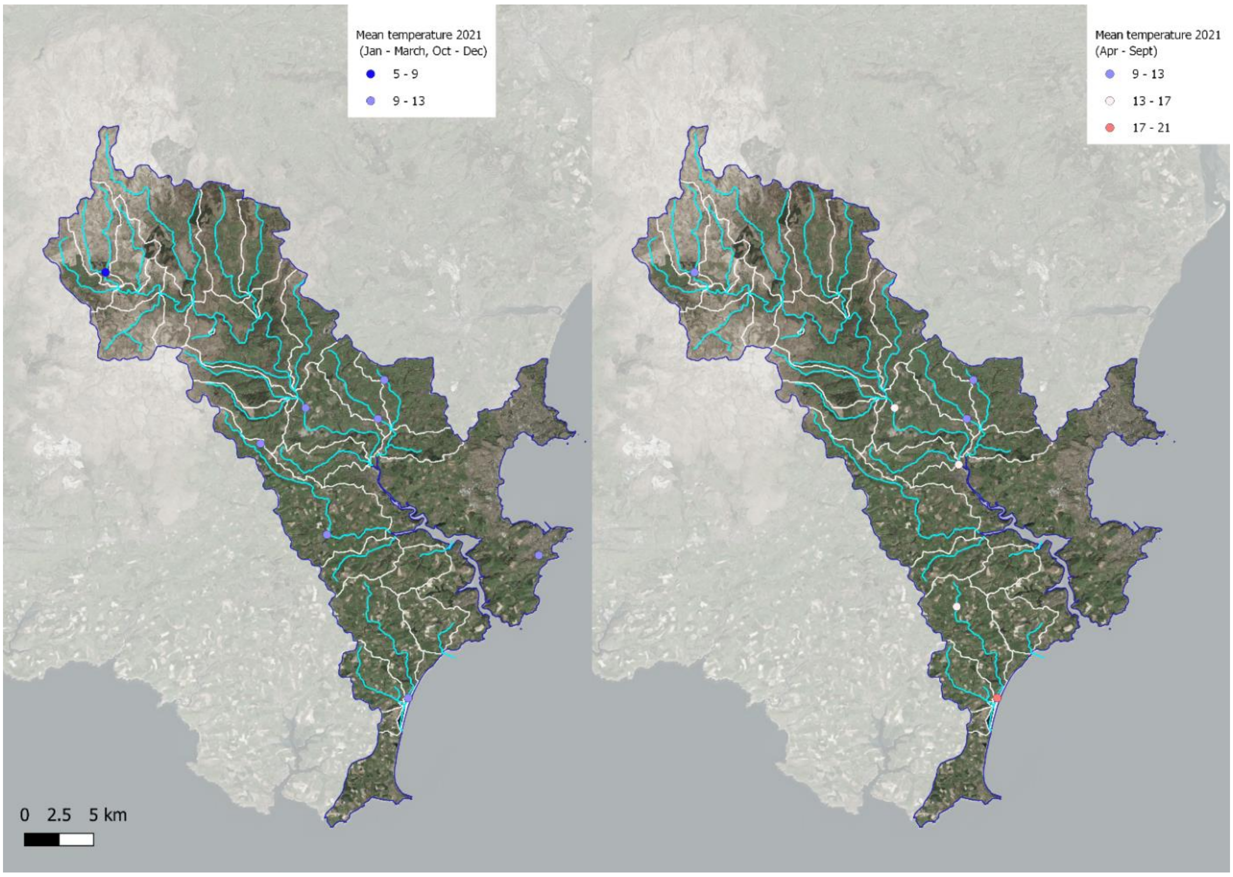

Figure 11. A map of the Environment Agency, open access environment data for the year 2021 split across Jan – Mar and Oct – Dec and April to September, showing water temperatures as means in points. Sub-catchment areas in white and blue lines represent river channels, dark blue outlines the estuary and catchment edge. Created by the University of Plymouth; C. Gutmann Roberts and S. Lewin

3.4.6 Pollution (anthropogenic)

Pollution that enters watercourses has been linked to declines in salmon catches, such as insecticides used in Canada (Fairchild et al., 1999). River pollutants, such as industrial pollution, can impact salmon movement, survival and reproduction (Rossland & Kroglund, 2011).

In the Dart, active groups are monitoring water quality, and many parameters are available for download from the EA water quality archive database. Analysing these is beyond the time available for this report.

A search through a recently requested Freedom of Information on consented discharges returned 112 active discharges in the Dart catchment with 103 of those being a type of sewage discharge - 7 being trade discharges, 1 combined sewage and trade, and one miscellaneous. Some of these discharges have been permitted since 1964, such as the aggregate waste from extraction and quarrying and the most recent from South West Water to discharge sewage in 2023 near the River Webburn.

The last waterbody assessment (2019) showed the Dart failing to meet water framework directive requirements for chemicals but other specific pollutions reported as high environmental status (2019 and 2022). The specific chemical failures related to Mercury (and its compounds), Perfluorooctane sulphonate (PFOS) and Polybrominated dipheyl ethers. Mercury has been documented to cause sub lethal effects on salmon such as reduced feeding, necrosis and altered brains (Berntssen et al., 2003). Perfluorooctane sulphonate has led to alterations in body and head regions in salmon larvae (Spachmo & Arukwe 2012).

3.4.7 Freshwater fishing (anthropogenic)

The Byelaws in the Dart state that no worm or maggot be used as bait, and no shrimp or prawn except below Staverton bridge (CEFAS et al., 2023). All salmon must be released before 16th June, due to the National Salmon and Sea Trout Protection Byelaws (2018). Angling records are presented in the earlier section of this report (2.6). The major fishery owners and interests such as the Duchy of Cornwall, the Dart Angling Association (DAA) and Dart Fisheries and Conservation Association (DFCA) have engaged in promoting C&R and other voluntary measures such as method and timing restrictions with the aim of protecting salmon in particular. For example, the Duchy now actively prohibits the taking of any salmon or sea trout on its waters and stipulates fly fishing only. The DAA recommend catch and release for all migratory salmonids and enforce a rule whereby the first salmon caught in a season must be returned. The DFCA promote a range of measures designed to achieve a C&R rate of 90% for salmon including returning the first salmon caught per season, a bag limit of two salmon per season and returning any salmon over 10 lbs.

From other studies it has been shown that most salmon (91%) survive catch and release, but it can induce downstream movements and further delays in upstream movement. Catch and release mortality can also be higher when undertaken during higher temperatures, which will become more likely with climate change (Havn et al., 2015).

3.5 Issues not listed on Likely Suspects Framework

3.5.1 Connectivity

Anthropogenic barriers can inhibit or delay migration both to sea (Marschall et al., 2011) and back from the sea. The barrier can also have an interactive effect by altering environmental conditions, such as reducing substrate mobility and altering local geomorphology, and altering seasonal patterns of flow and temperature (Mueller et al., 2011). River barriers are often in the form of dams and weirs, these can be very variable based on the height, slope and substrate that the barrier is made of. One significant barrier in the Dart is the Totnes weir which is used to power a hydro power plant with a twin Archmides screw system, this has a fish pass added to support fish migration (TRESOC, 2025).

The last available barrier assessment for the Dart catchment is from 2001, showing five barriers in the main Dart channel, listed as passable for migratory fish (Environment Agency, 2001). There are several tributaries with barriers to migratory fish, and some of these are relatively close to the entry point of that tributary e.g. the Ashburn. Criteria for the assessment of passability for salmon was not defined in that report. However, that weir has since been made passable to some migratory fish due to notches being cut and fish passes added (WRT, 2022). Other barriers that may still exist near the entrance of tributaries include an impassable barrier in the Dean Burn and Bidwell Brook. Other barriers that were previously noted as passable, may not be passable anymore such as the old walls weir on the West Webburn (personal comms, 2024). Considering the Conservation Limits are set based on accessible wetted area, it is worth considering that for other rivers such as the River Monnow these have been edited after barrier passage has been altered (State of Salmon report, 2022). There are no records of that for the Dart.

Despite the increased recent connectivity in the Ashburn, the 2024 monitoring at Belford Mill, upstream of the barrier had no salmon fry. The Belford Mill monitoring site is about 5.5 km upstream of the barrier at the bottom of the Ashburn but the nearer monitoring site at Pridhamsleigh (~0.9 km upstream of the barrier) which had salmon in 1996 and 1999, had no salmon in 2002 and has not been surveyed since. Other river restoration projects that show complete barrier removal can see fry and parr as soon as days after the restoration and up to 2.5 km upstream (Gardner et al., 2011).

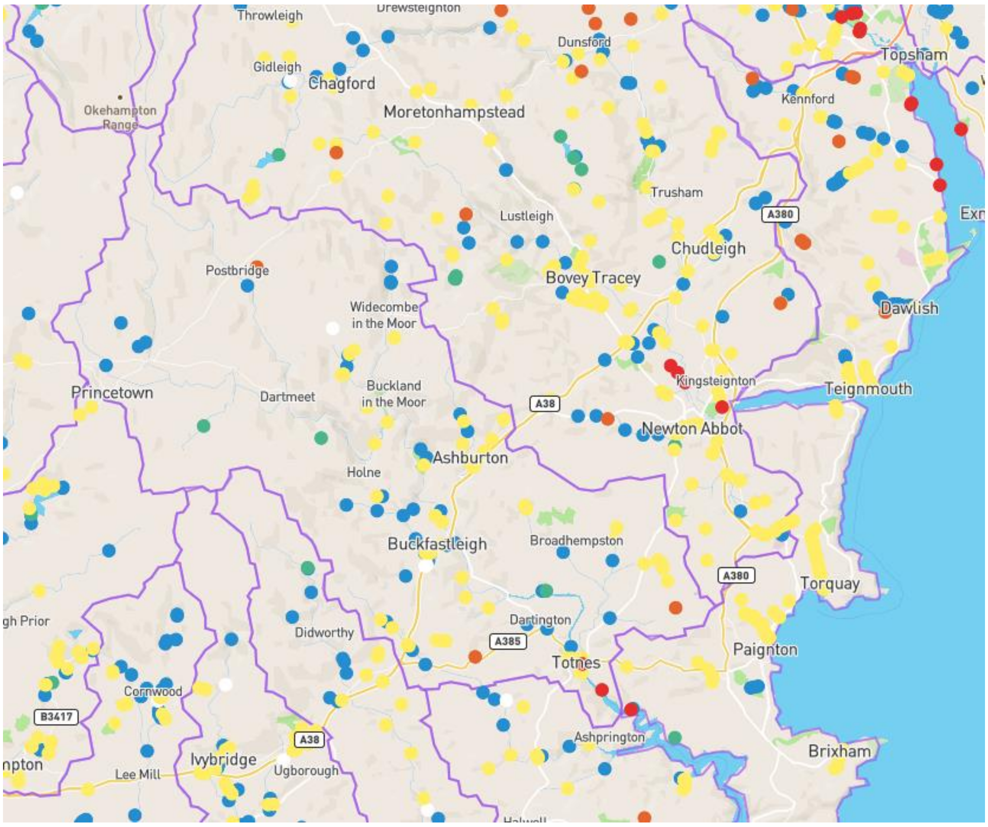

Figure 12. Screenshot of the recorded barrier (points) data from AMBER, colours represent – blue: weir, green: dam, yellow: culvert, orange: ford, red: sluice, purple: ramp, and white: other (Amber Consortium, 2020)

Other data sources on barriers exist from citizen science records and available from AMBER barrier atlas (AMBER, 2020), though not in the format of whether they are passable or not to migratory fish, but classified on barrier type e.g. weir, culvert, ford, other. A total of 121 barriers have been logged within the Dart catchment through AMBER (Fig. 12) with associated latitude, longitude and estimated height. Despite users submitting photographs and height estimates alongside their locations, these are not available for viewing or download from the website.

Ideally an updated catchment wide assessment would be made, to inform whether connectivity is a limiting issue for salmon. The WFD UKTAG (2015) River assessment method on River continuity could be used and details the passability requirements for salmon.

3.5.2 pH and metals

Salmon fry mortality increases from 4 to 70% when pH drops from 6.1 to 5.0 for 30 days (Lacroix et al., 1985), the spring and summer in the main Dart was below pH 5.5 for 3.4 days (Eycott-Martin, 2024). - Salmon smolt mortality has been recorded from streams between pH 5.6 and 5.8 (Leibich et al., 2011), in a similar time of year eight out of 10 sites had minimum pH within or between that range (Eycott-Martin 2024), suggesting this could be a factor in salmon smolt mortality in the Dart catchment. Acidity interacts with some chemicals making them more bioavailable and increasingly toxic, such as arsenic and aluminium (Dennis & Clair, 2012).

From EA monitoring data the lowest pH has been recorded in the last 24 years was 3.8 from the West Dart and in the main channel, with the highest pH also recorded in the main channel of 9.2. The Cherry Brook and the West Dart have the lowest mean pH in the last 24 years at 6.26 and 6.28, respectively. A minimum pH of 2.93 in the West Dart was cited by Dawson (2021). The low pH has previously led to a failure of good ecological status in the Cherry Brook and West Dart. An element of the acidity in this area is natural due to the acid igneous rock and peat bog run off, but this has been historically exacerbated from acid rain coming from the nearby industrial dockyards and city of Plymouth (Batterbee et al., 2013). Despite the acidity in the Cherry brook tributary, it is the site with the highest number of salmon fry (Fig. 4). As well as historic industrial pollution leading to acidity there is some evidence that increasing conifer coverage in the riparian zone has contributed to acidity and to lower salmon densities (Harrison et al., 2014; Malcolm et al., 2019). The mechanisms of the conifer forestry affecting river pH is explained by Nisbet & Evans (2014), including how canopy height is key in attracting air borne pollutants, and therefore even cutting down a conifer forest and replanting will have the potential to reduce acidity and by the time a canopy has reached full height the aerial pollution will have reduced greatly. There are three stands of conifer forest in the Dart catchment, named in the Dartmoor Forest Plan (2016 – 2026), Soussons (215ha), Bellever (416ha) and Brimpts (58ha), predominantly made up of Sitka spruce. Overall, the Dartmoor forest plan aims to reduce conifer coverage by 3% by 2026.

There are very few locations with both fish data and pH data in the same years and at the same/ nearby sites. Making any substantive analysis from existing data difficult. It seems that high salmon fry/ parr abundance has occurred at times and sites with low pH (Fig. 13), however a more thorough analysis of the spatial and temporal effects of pH should be carried out. The long-term impact of exposure has been shown to be impactful, for example short term acid exposure during early life stages can have large physiological effects during the smolt migration (Monette et al., 2008), suggesting that fry and parr monitoring would not be an adequate tool to detect this in the Dart.

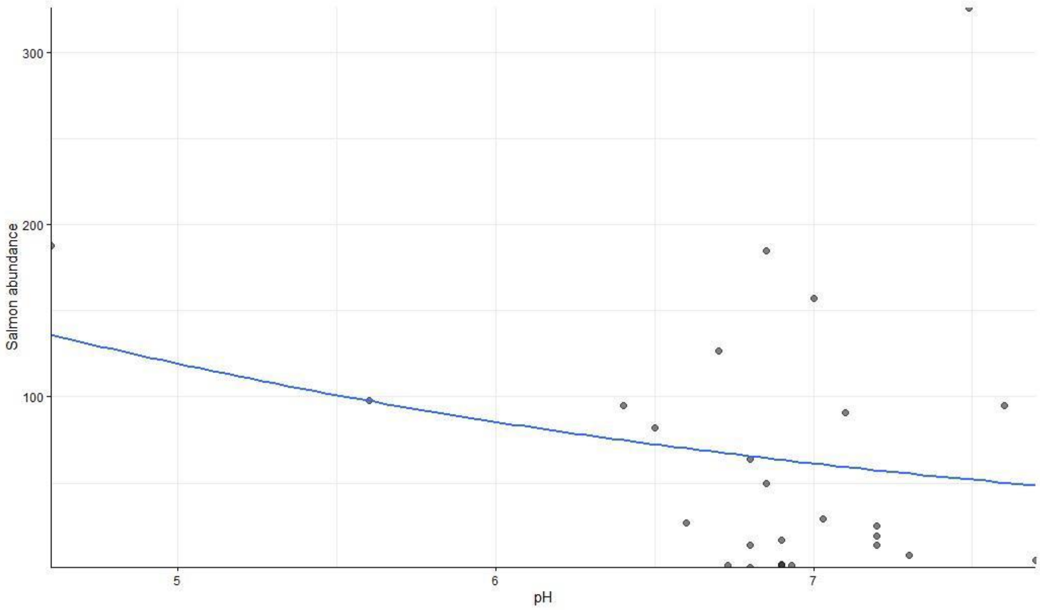

Figure 13. Figure created by Eycott-Martin, 2024 University of Plymouth showing The relationship between pH and salmon abundance for available rivers within the Dart catchment, with GAM fitted to raw abundance data

3.5.3 Land use

To some extent this interlinks with the natural river geomorphology, but human land use practices are affecting river habitats and water quality. From animal and plant farming to urban developments, industrial processes and afforestation. Understanding land use is key to understanding mortality rates of Salmon and habitat quality. If livestock have free roam into the Dart and associated tributaries they may be trampling spawning gravels or increasing sediment load through poaching of the banks. A study in North Cornwall on eight catchments of the Tamar and Neet found that sediment load had major influences on egg survival within redds, due to reduced oxygen, where trampling and grazing by livestock was the primary cause of collapsed banks. Subsequently the introduction of local fencing brought a 34% reduction in sediment and 54% improvement in trout egg survival (Stubbing, 2009). This highlights the importance of understanding land use and putting in place appropriate mitigation to reduce the impacts i.e. fencing to prevent livestock from entering the watercourse, helping banks to stabilise and prevent excessive erosion/sediment disposition. It is important to work with farmers and landowners to assess how they are managing their land. Glyphosate use, planting non-native species close to watercourses, chemical fertilisers and nutrient run off-are known to have detrimental effects to rivers, these can be mitigated by looking at alternative methods and leaving vegetated buffers (10m) to both stabilise the banks and filter run off (Hu., et al., 2023, Rotherham, 2021.). See section 3.4.6 on pollution for impacts to salmon species.

Conifer plantations are described in the previous section on pH but they also affect a range of other chemical parameters, soil dynamics and temperature. Several of the North West parts of the Dart contain bog and this covers the headwaters of the Blackbrook, Cowsick, West Dart, Cherry Brook. Much of the catchment contains grasslands and some arable areas (Fig. 14).

No studies could be found directly quantifying the habitat quality in the Dart catchment, which can be used to estimate egg to emergence survival. Recent research in the Exe catchment showed that out of 26 surveyed potential spawning sites 19 of them had estimated egg mortality rates above 50% due to the impact of siltation (Freer-Carmicheal, 2022).

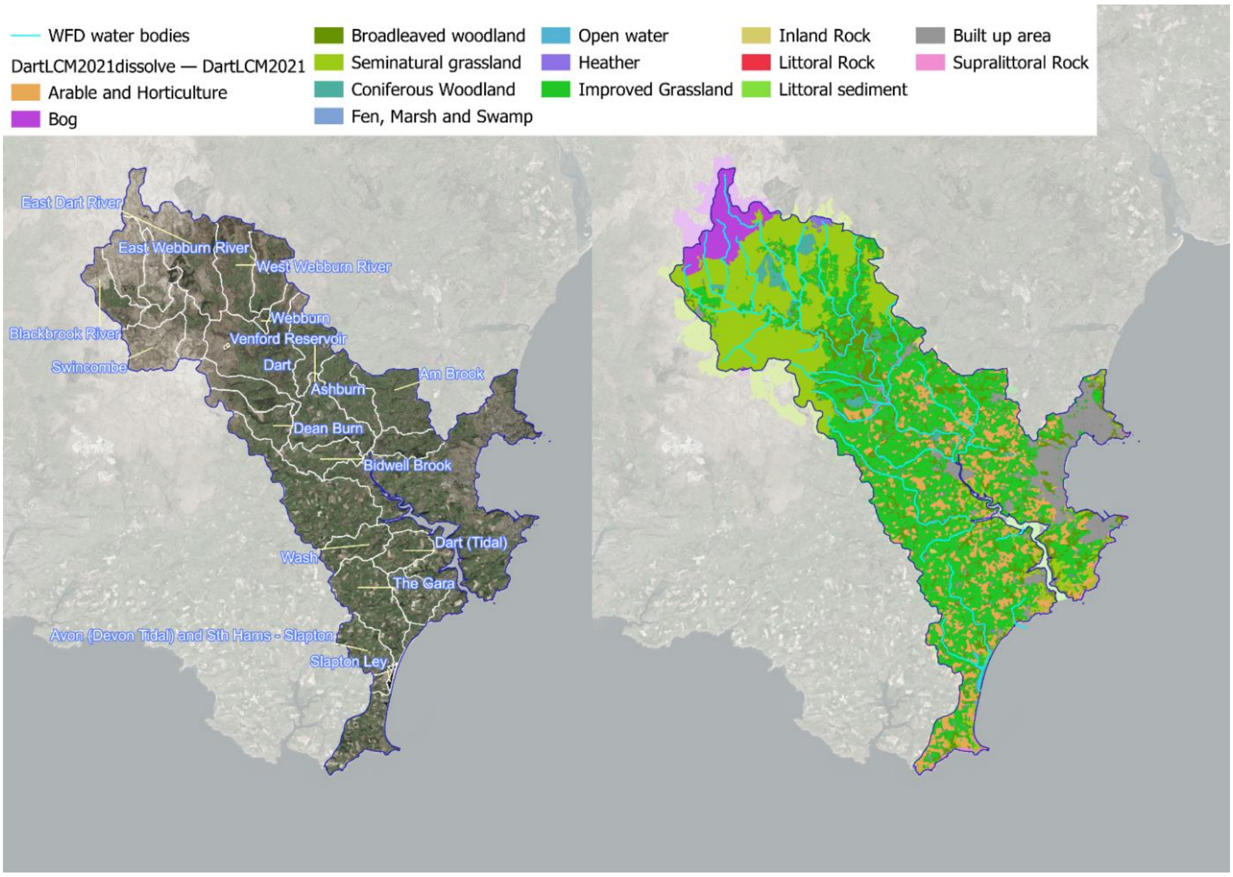

Figure 14. Land use map created from CEH data 2021 for the Dart catchment, created by the University of Plymouth; Gutmann Roberts, C. and Lewin, S

3.5.4 Water availability and flow

Water availability can be affected by natural seasonal cycles, and these may be altered from climate change. Natural seasonal changes in water availability and flows are linked to Atlantic salmon life cycles, and therefore the change in magnitude and timing of these flows can negatively impact salmon (Armstrong et al., 2002). In the UK summer limited water availability can trap salmon in isolated pools limiting movement and at times of high temperature, lead to loss of oxygen and mortality (Riley et al., 2009; Environment Agency, 2022). These can also be directly influence from water abstraction for uses for drinking water, domestic uses and industrial uses. Analysis on flow levels have been carried out for this report where the national flow archives show a single site on the main Dart at Austins Bridge, one in the East Dart at Bellever and one in the West Dart at Dunnabridge, suggesting limited spatial analysis to study the impacts on salmon. A site appeared at Buckfasteligh but contained no flow data, this must be a recent installation and could provide comparative data in the future.

To explore the relationship between salmon abundance and flow, we use annual “Q-values”. These are effectively percentiles of daily flow observations and “Qx” can be read as the flow value (m^3/s) that is exceeded “x” amount of the time. Here we use Q95 to represent the “low flow” conditions, and Q5 to represent the “high flow” conditions of a given year. The location of fish monitoring locations (EA ecology and fish data explorer, and the Westcountry Rivers Trust) in relation to flow gauging stations is shown in Fig. 15 along with the relationship between low flows (Q95; the flow value in m^3/s, or cumecs, that is exceeded 95% of the time) at headwater gauging stations (Dunnabridge and Bellever) with the gauging station at Austins Bridge. There are a number of fish monitoring locations at the top of the catchment that don’t have a “local” gauging station. The use of local flow gauges informs understanding of useable habitat, while regional flow (taken from Austins Bridge) is useful in understanding energy implications for movement. Dunnabridge and Bellever experience much lower low flows than Austins Bridge, although they are both positively correlated, as you would expect.

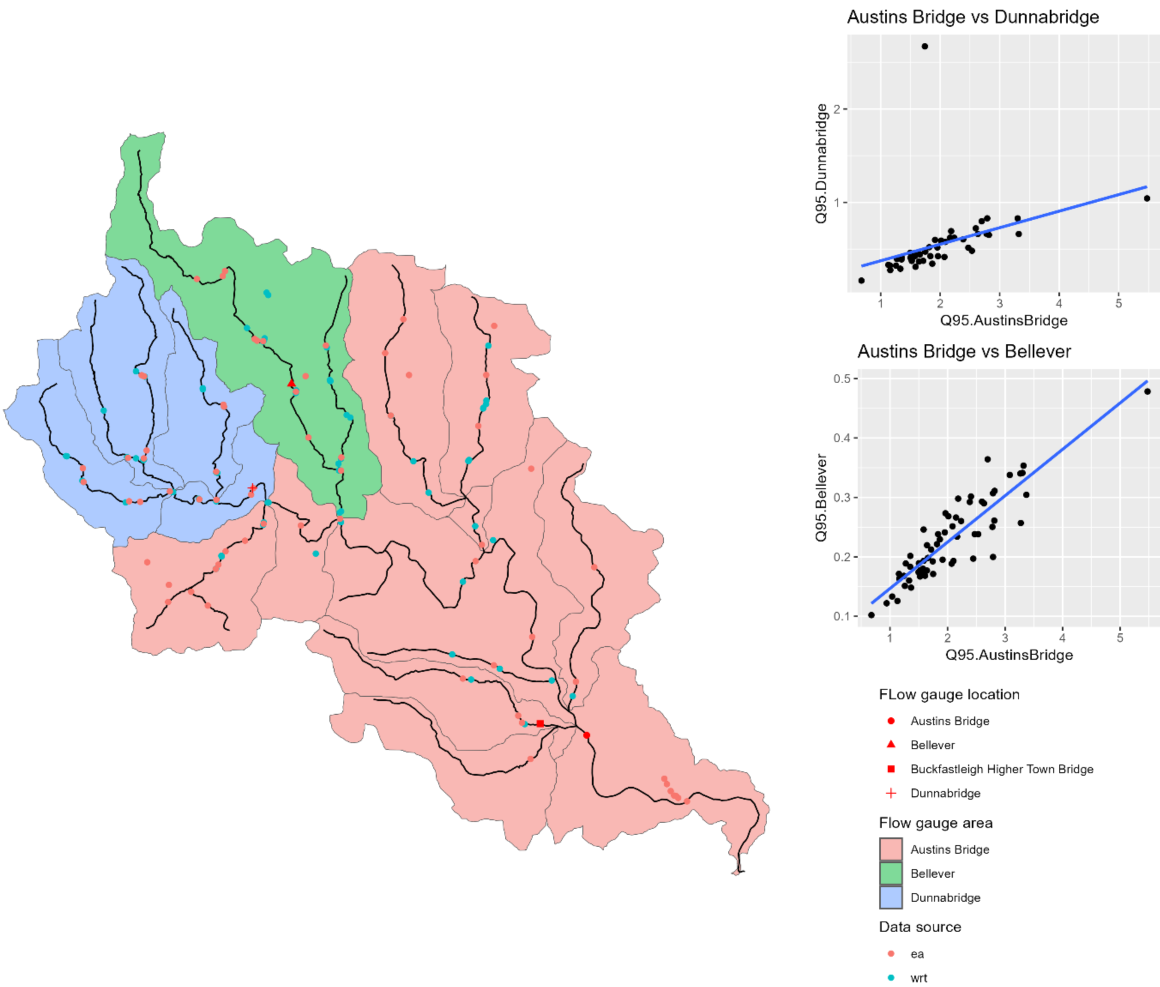

Figure 15. Dart catchment map; waterbodies are coloured to indicate which flow gauge best captures the local flow regime. Fish monitoring sites (Data sources; EA and WRT) are shown as points. Flow gauge stations are represented by red symbols. The relationship between low flow (Q95, in cumecs) between Gaugeing stations are approximately linear

The monitoring is targeted at specific waterbodies (Fig. 16) along the main channel of the Dart up to the headwaters in the East Dart River where the sampling effort is greatest. Salmon (fry and parr) populations are greater in the upper catchment streams; Cherry brook has the highest average and maxima salmon counts, and the East Dart River is a close second (both central in the upper catchment). The East Webburn River (rightmost of the upper catchment) is the only other waterbody to report a survey with more than 200 individual salmon. The sampling bias in East Dart River should be taken into consideration when interpreting the relationship between flow and fish abundance.

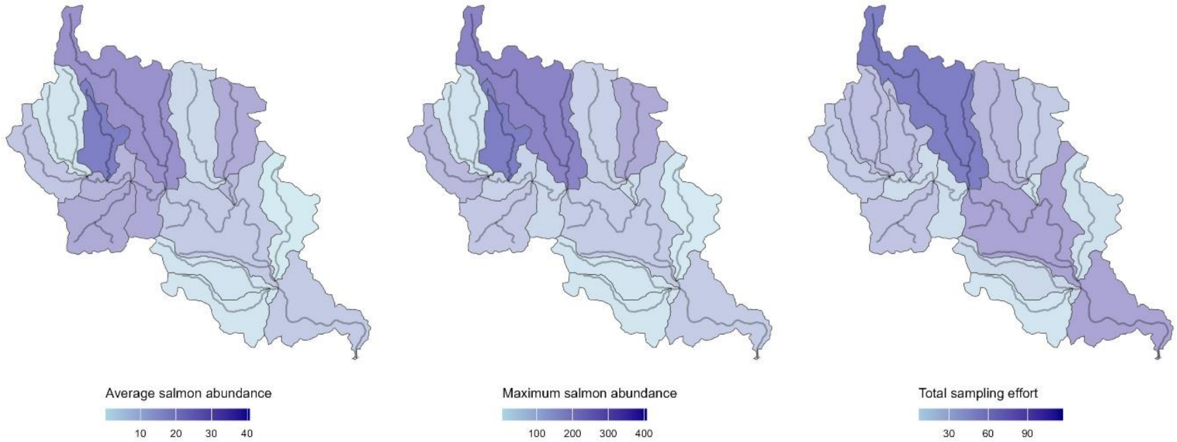

Figure 16. Summary of all salmon (fry and parr) monitoring (Environment Agency and Westcountry Rivers Trust) since 1996 in the Dart catchment by waterbody

Lower “low flow” conditions are associated with higher salmon abundance; as “low flow” increases salmon abundance decreases, likely only among fry, and particularly in the upper catchment (Figure 17). This is more pronounced when referencing flows from the nearest “local” gauging station which tend to be lower than those found at Austins Bridge at the downstream end of the catchment. This seems a counterintuitive considering extremes in water flow are known to be detrimental for Atlantic salmon (Jonsson & Jonsson 2010), however, the lowest low flows are likely found in late summer when fry are mobile and able to swim to deeper water if needed. Higher high flow conditions are also associated with a slight increase in salmon abundance; however, this influence varies between areas of the catchment and whether local or regional flow conditions are consulted. Higher high flows are associated with lower salmon abundances in sites upstream of Dunnabridge. High flows are likely to displace salmon fry further downstream. A plot showing flow over time matched to juvenile salmon abundance over time still does not show clear links to low flow and salmon declines (Fig A1).

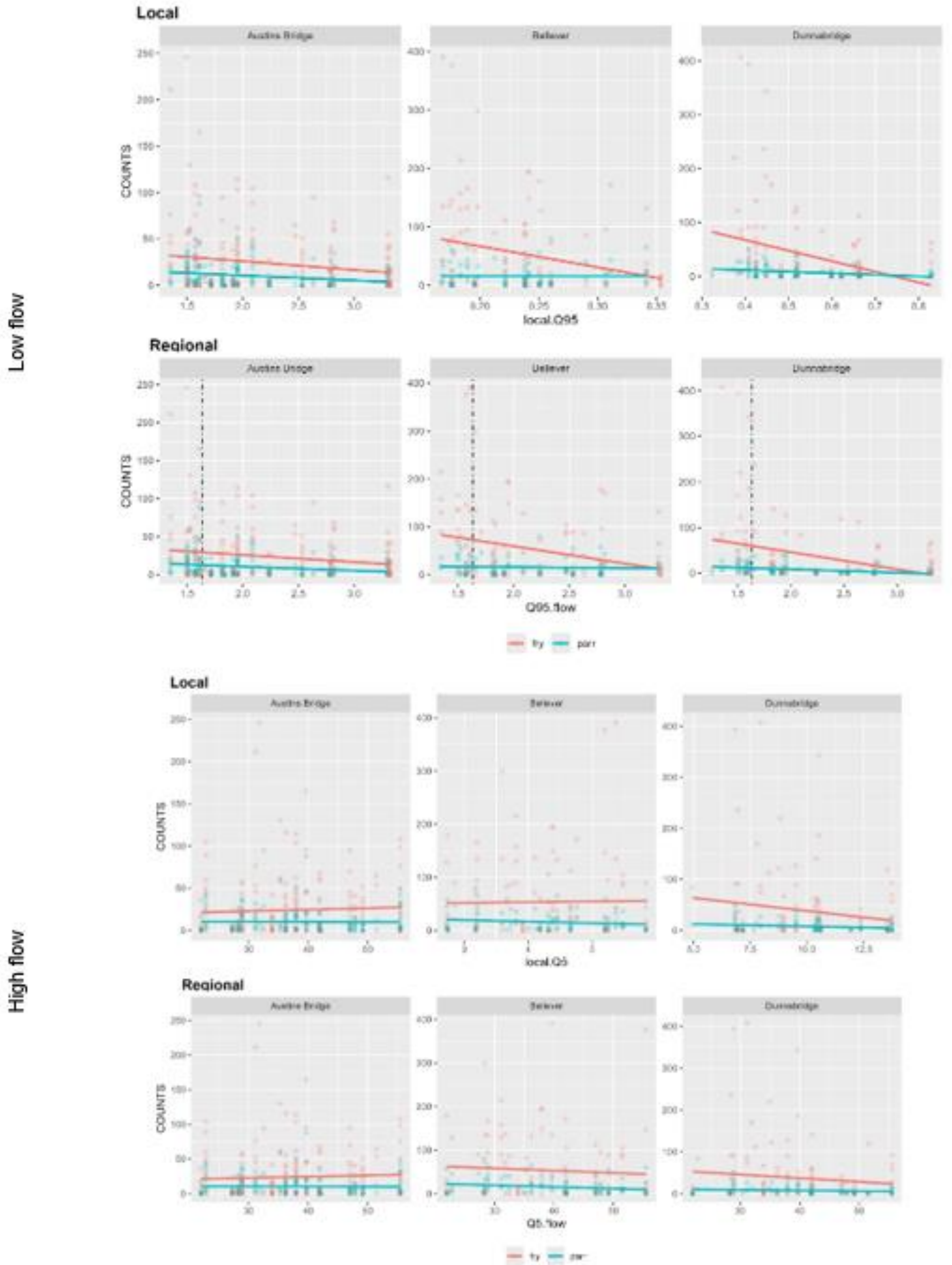

Figure 17. Salmon (fry and parr) count in relation to low (top) and high (bottom) flows at various points in the catchment. The historic Q95 (all measures from Austins Bridge) is used as a threshold to identify drought conditions and here predented as a vertical dotted line

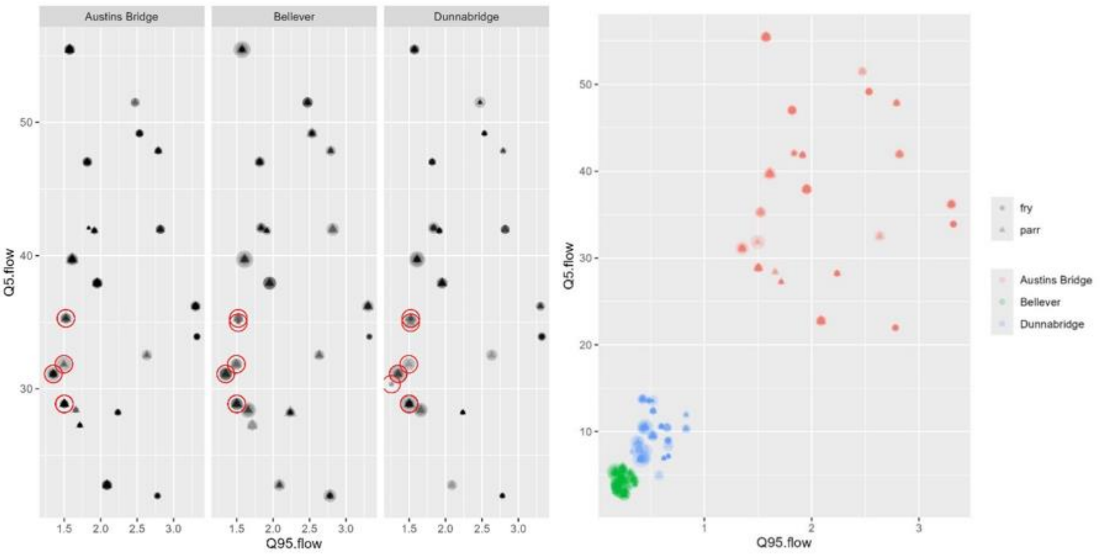

Figure 18. Flow regime (Q5:Q95) in relation to salmon counts (size of points), with left plots showing all counts across each flow gauge values and right matching counts to their local gauging station. The shape of the points indicates fry (circle) and parr (triangle). The six lowest flow years are circled in red

The relationship between high and low flow (the range or variability) is also important. Figure18 suggests that surveys taken in years where the Q95 is ~ 2m^3/s or lower and the Q5 does not exceed 40 m^3/s, with the exception of the year where Q5 was over 55 m^3/s had higher salmon counts than surveys where annual Q95 and Q5 values were outside of this range. Local gauging stations show that sample locations in the upper catchment experience a reduced range of flows (blue and green points) and tend to have higher salmon counts (point size) (Figure 18 right). It is not clear if the dominant influence on salmon abundances is related to the local or the regional flow conditions.

Figure 19 shows how the difference between Q95 and Q5 influences salmon abundance. The largest abundances occur in the centre of the x-axis (Qdiff), away from extreme events, suggesting that if the range of flows is too small or too large, salmon abundances will be smaller. The range of variability in flow regime is a feature of concern for climate researchers (Kay et al., 2021); river flows are expected to become more extreme, which appears to be a feature of the Dart flows over the last 30 years (**Error! Reference source not found.**). Range of flows as represented by the difference in Q5 and Q 95 (Qdiff) is increasing over time slightly in the headwater sites while at Austins Bridge is increasing and becoming more variable (Fig. 20).

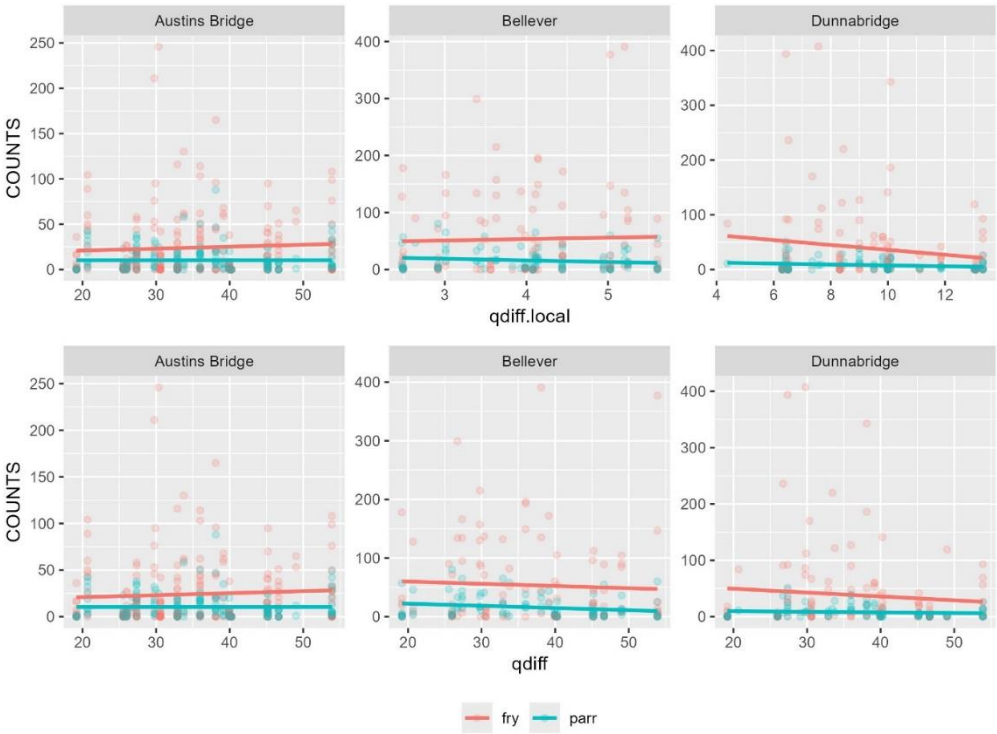

Figure 19. The influence of flow variability on salmon abundances (fry and parr stages). Presented here as the difference between Q5 and Q95 or "qdiff"/"qdiff.local"

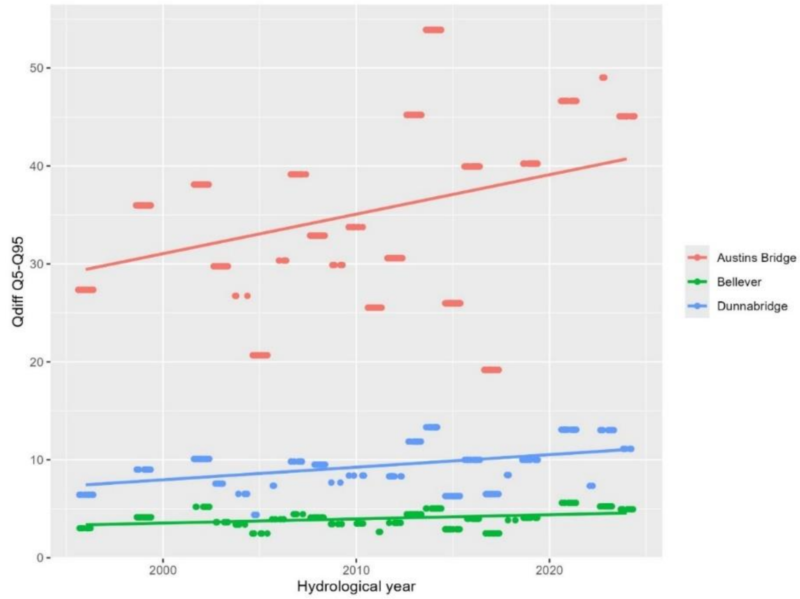

Figure 20. Range of flows as represented by the difference in Q5 and Q95 (Qdiff) over time at the three gauging sites (denoted by colours)

3.5.5 Disease and parasites

Ulcerative Dermal Necrosis (UDN) was anecdotally suggested to be a problem 7 – 8 years ago in salmon in the Dart catchment, with visible fungal infections (personal communications with Dart Anglers), also supposedly affecting the Teign salmon. Anglers estimated 30 – 40% of observed fish were affected, which was mostly visible near the head. UDN is a disease that affects mature salmon and causes ulcers on the skin which are then vulnerable to secondary infections (Provotorov et al., 2023). Salmon with suspected UDN were sent for investigation to the Environment Agency National Fish Laboratory in 2013 but none had confirmed UDN, and instead had confirmed Saprolegnia infections (Matthews, 2019). According to the National Fish Laboratory there has never been a confirmed case of UDN in the Dart or any of its tributaries.

Infection can cause mortality but often it leads to sublethal effects. Salmon that are infected can be more vulnerable to predation, especially during already stressful events such as migration (Furey et al., 2021).

3.5.6 Recreation

No studies were found on direct impact of human recreation on Salmon habitat or populations in the Dart specifically. However, recreational activities in the Dart Estuary such as mooring from boats, passenger ferry transport, crabbing and other activities were linked with lower biodiversity than other areas where these activities were not happening (Schuwerack et al., 2007). Although this study did not make any direct links to Salmon, such activities can cause disturbance and create inhospitable environments for wildlife. The Dart Estuary is an important migratory route for salmon using the Dart.

The Dart is a popular river for human recreation (Seymour et al., 2023). The most common activities are swimming, walking/running, shortly followed by paddleboarding, kayaks, canoes etc, wildlife spotting, picnics/bbqs, visiting pubs and restaurants, and children playing (Seymour et al., 2023). Activities such as swimming and children playing in the watercourse can lead to poaching of the banks when entering the stream/river, where they are likely to be trampling on gravel once in the watercourse potentially disturbing spawning habitats. If these areas are heavily used by humans, the impact can be similar to cattle poaching banks as mentioned in the land use section 3.5.3.

Studies on Atlantic salmon in Eastern Canada have shown that redds, eggs, and juveniles are generally more susceptible to most threats from human recreation than smolts and adults. However, some activities have significant destructive potential such as all-terrain vehicle use in or around spawning habitats, as they have the potential to crush fertilised eggs. Other significant risks include pathogen and invasive species transfer via angling gear, waders, canoes, and other equipment that may be moved across systems without proper cleaning (Reid et al 2024, Anderson2015). As mentioned in section 3.5.5 on disease, this can lead to mortality in salmon. The spread of INNS such as Himalayan balsam, Japanese knotweed cause bank erosion, sediment disposition and the aquatic plant; parrots feather can lead to a reduction in dissolved oxygen where present in high densities (Green, 2021, Desa & Lee.,2017), posing lethal risks to salmon.

Parasites can be spread through recreational activities such as on angling equipment and canoes which can cause a low risk of local spread to neighbouring rivers (Peeler et al., 2004). An example of that is *Gyrodactylus salaris* a freshwater, ecto-parasite of Atlantic salmon. It has been seen to have detrimental effects to stocks of Atlantic salmon in Norway where the parasite multiplies unchecked by an immune response, causes death in juveniles and dramatic reductions in wild populations. It is also known to infect rainbow trout (*Oncorhynchus mykiss*) permanently and causes infection of less than 50 days in other species (Peeler., et al 2004). The movement of live rainbow trout is the most important route of transmission of *G.salaris* between river catchments in England and Wales. There have been no documented cases of *G. salaris in* the UK yet (GOV.UK, 2024). Another example of an invasive species spread through human recreation includes *Dikerogammarus villosus* an invasive amphipod, present in the UK, poses a hazard as they predate on small fish such as salmon and trout and can have significant impacts on the whole ecosystem. At the moment there are no records of this invasive amphipod in the Southwest, however, these studies highlights the need to conduct regular monitoring programmes to prevent spread of disease, pests and parasites and put biosecurity control factors in place, such as wash down facilities for boats and recreational use of the river/streams with information signs and citizen science opportunities (Anderson et al., 2014).

Recent studies have found chemicals such as imidacloprid and fipronil in our waterways spread through pet flea treatment from mostly dogs being allowed to enter rivers and streams and the chemical washing off their fur into the waterbodies. Now in tabulated form, pets are excreting these toxins into waterways. There are records of potentially harmful concentrations of fipronil in the Dart catchment, which is toxic to fish (FBA, 2024). Understanding how salmon are responding to these pressures is essential in determining mortality rates.

The release of stock and non-native species into rivers and streams can negatively impact wild salmon populations, from habitat and resource competition to disease and parasites, as aforementioned. Salmon farming has reduced survival of wild salmon and trout in many populations and countries (Ford & Myres, 2008). Interactions with released stock could reduce productivity of wild populations, for example released salmonids may destroy the nests of wild females if the latter spawn earlier (Hodder and Bullock 1997, Web *et al*.,1991). Studies have found that brown trout and rainbow trout negatively impacts salmon populations through overlap in niche and it is thought that these species are generally more aggressive than Atlantic salmon and outcompete them for the resources, leading to sub-optimal habitat use and reduction in growth (Houde *et al*.,2015)

4. Summary of data gaps and potential next steps

Currently, some data on Dart salmon is available for fry, parr and adults with no data for eggs and smolts (Table 1). Data available on fry and parr have varying capture methods and lack consistency in time and space. Annual monitoring at key sites would enable population trend monitoring. Data from third parties on fry and parr were accessible through direct enquiry. To add consistency methods should be aligned with the EA monitoring and ideally loaded onto the open access database. Having all fish monitoring in the catchment being held on the EA Ecology and Fish data portal would enable data comparisons and research, to support this in the counts database, there is an option to state that the data is from a third party. Enabling open access with consistent methods will allow for more informed and rigorous research to be carried out on the Dart salmon.

Table 1. Summary of the state of the salmon (by life stage) and likely impacts showing whether the level of currently available data is a total gap (no data), poor data or enough to make a modest assessment. With details on what research would be required to fill the gap.

State of the Salmon (life stages)	Level of data	Research required
Egg	No data	There is currently no specific data on egg deposition or egg survival for the catchment and the knowledge of spawning areas are over 20 years old without a referenced method for their collection. Egg deposition estimates calculated by CEFAS are based on wetted accessible areas, but these GIS files were not publicly available. Having this data is essential to identify mortality rates within the Dart and could be collected by redd counts, walkover surveys and in situ determination of survival with Vibert boxes.
Fry	Modest assessment	These are surveyed through fish monitoring by the Environment Agency, with methods varying over time and not all sites are monitored in consecutive years. There are also some records from Westcountry Rivers Trust (2012 – 2021) that are available on request. Ensuring that several sites have consistent consecutive years of monitoring across the catchment and in alignment with environmental monitoring would allow for a fuller understanding of the salmon population and their impacts.
Parr	Modest assessment	These are surveyed through fish monitoring on by the Environment Agency, with methods varying over time and not all sites are monitored in consecutive years. There are also some records from Westcountry Rivers Trust that are available on request, from 2013 to 2021. Inclusion of parr at all fish monitoring allows for an understanding of survival beyond the first year.
Smolts / Survival	No data	Currently there is only video footage data of smolts which has not been extracted into data format, as far as we are aware. Understanding the number of smolts migrating through the catchment gives key knowledge on the total number of salmon surviving from the catchment, and as this is the time when mortality is likely to occur, it may reveal a significant population bottleneck. Using tags can inform mortality, environmental conditions and routes of travel, further data is needed.
Adults	Poor	Whilst annual reports are available on the adults based on a resistivity counter, the data are not openly accessible, and they are not being used in stock assessments. Making these data openly available and ensuring they are as rigorous as other national monitoring datasets could improve the stock assessment that currently relies on limited catch data. Other adult count data has been supplied from net and rod fisheries but with these being restricted and reduced they do not provide consistent effort and no netting will occur until at least 2028.
Population assessment	No data	Limited data is available, and lack of consistency makes it difficult to compare data and would be unreliable to do so. Consistent and annual monitoring at key sites would enable population trend monitoring. Making data openly available and ensuring they are as rigorous as other national monitoring datasets could improve the stock assessment that currently relies on limited catch data. As far as we are aware there is currently no mechanism linking together all the existing life stage data, and without key stages such as the smolts it would not be possible.

Migration routes	No data	No studies were found on the migration routes of adults at sea for either the Dart or other South West salmon, which is an important knowledge gap to fill. As there are many marine threats to salmon, being able to spatially match threats to populations is the first step to understanding impacts and then designing mitigation.
Likely freshwater reasons for decline		
Competition	Poor	For the freshwater conditions, we were not able to compile data for the many possible competitors for food at the varying life stages which can include everything from other fish to birds and even potentially large macroinvertebrates competing for prey with fry. Even if dietary overlap with other species could be determined from stable isotope analysis there is only competition if the food resource is limiting, this is a very difficult thing to determine in the wild.
Reduced prey	Poor	It may be possible to review available prey in the river through EA macroinvertebrates monitoring, which was not possible in the scope of this work.
Predation	No data	Quantitative data is not available on the various predators, that we are aware of, but studying this through either mortality tags on the salmon or just quantifying predator populations or activity would be informative.
Loss of genetic diversity	Moderate assessment	The salmon in the Southwest are genetically unique in comparison to the rest of the UK stock and therefore preserving this level of diversity should be considered. Genetic diversity can be altered through stocking, so careful consideration of this risk would need considering if that option were to discussed.
Freshwater fishing	Modest assessment	There are currently relatively good levels of data on freshwater fishing through mandatory catch returns.
Temperature	Poor	Climate changes impacts on temperature are not currently exceeding or near to the upper critical limits for Dart salmon in the summer or winter, suggesting this is not currently leading to mortality. However, there are a lack of temperature recording locations in the headwaters where spawning has been observed and to be able to make predictions about where and when temperatures will become limiting, new temperature monitoring should be included. This is recommended to provide insight into climate change / impacting mortality and sublethal effects.
Water Quality	Poor	An analysis on water quality was not possible in the scope of this report, however chemical pollution was the cause of WFD failure in 2019 highlighting priority hazardous substances, such as mercury, in high amounts which is known to have sublethal effects on salmon. The chemical status of waterbodies to longer requires assessment (2022), without the data, assessment the likelihood of the threat is not possible. Regular water quality monitoring is essential to identify the conditions of the River Dart and whether it is healthy enough to support salmon populations or if there are toxic levels of metals or pollutants leading to their mortality.
Connectivity/ Barriers	Poor	There is lacking data on the connectivity of the catchment and recent improvements need documenting on a catchment scale alongside a robust assessment of their passability for salmon.
pH	Poor	Further temporal and spatial coverage for pH is required to understand this complex issue alongside the relevant metals, and monitoring sites should be co-ordinated with fish monitoring sites. This should be paired with catchment specific experimental work on salmon as there may be local tolerances.

Land Use and Siltation	Poor	Determining land use, erosion patterns and in river habitat quality would be an important data gap to fill as siltation can drive high proportions of egg and larval mortality.
Water levels and flow	Poor	An analysis of river flows was carried out for the catchment based on three gauging stations, but years with the lowest flows were not correlated with low juvenile salmon abundances. A new gauging station has been added at Buckfastleigh, this will potentially add some flow relation ability to the River Mardle. There are several tributaries currently lacking any flow gauging such as the River Ashburn.
Disease	Poor	Historic angler reports of ulcerative dermal necrosis were found to be Saprolegnia infections. Environment Agency National Fish Laboratory records are not openly accessible, and reporting is done on an ad hoc basis. Increasing reporting advice for disease and parasites could improve knowledge on the conditions of the salmon in the catchment, although this doesn’t currently seem to be of great concern. Regular monitoring would highlight if disease were present and how this is impacting salmon populations.
Recreation	Poor	The River Dart is very popular for recreation, and this can pose threats to salmon from disturbance, being a potential conduit for invasive species and damaging key habitats. No studies or data were available to assess the impacts of recreation on the Dart salmon.

In terms of environmental and biological impacts affecting salmon in the Dart, the scope of this is vast due to the differing life stages and how mobile salmon are through their life. This report touches on many of the environmental and biological factors that could be leading to salmon mortality but it was not possible to quantify many of these and certainly not to model their combined effects. Some of the lacking data above, on routes of movement in the sea for Dart salmon and other South West salmon make inferring marine mortality very difficult. Aligning the environmental and biological conditions at sea to the Dart salmon, when it is not known where they are in space and time makes this impossible.

5 References

AMBER Consortium (2020). The AMBER Barrier Atlas. A Pan-European database of artificial instream barriers. Version 1.0 June 29th 2020. *https://amber.international/european-barrier-atlas/* Accessed on 26th November 2024.

Anderson, L.G., Dunn, A.M., Rosewarne, P.J. and Stebbing, P.D., 2015. Invaders in hot water: a simple decontamination method to prevent the accidental spread of aquatic invasive non-native species. *Biological Invasions*, *17*, pp.2287-2297.

Anderson, L.G., White, P.C., Stebbing, P.D., Stentiford, G.D. and Dunn, A.M., 2014. Biosecurity and vector behaviour: evaluating the potential threat posed by anglers and canoeists as pathways for the spread of invasive non-native species and pathogens. *PloS one*, 9(4), p.e92788.

Armstrong, J.D., Braithwaite, V.A. and Fox, M., 1998. The response of wild Atlantic salmon parr to acute reductions in water flow. *Journal of Animal Ecology*, *67*(2), pp.292-297.

Armstrong, J.D. and Nislow, K.H., 2006. Critical habitat during the transition from maternal provisioning in freshwater fish, with emphasis on Atlantic salmon (Salmo salar) and brown trout (Salmo trutta). *Journal of Zoology*, *269*(4), pp.403-413.

Bardonnet, A., & Bagliniere, J.-L. (2000). Freshwater habitat of Atlantic salmon (*Salmo salar*). *Canadian Journal of Fisheries and Aquatic Sciences*, **57**, 497–506. https://doi.org/10.1139/f99-226

Bendall B, Moore A (2008) Temperature-sensing telemetry – possibilities for assessing the feeding ecology of marine mammals and their potential impacts on returning salmonid populations. Fish Manag Ecol 15:339–345

Battarbee, R.W., Shilland, E.M., Simpson, G.L., Salgado, J., Goldsmith, B.J., Gray, W. and Turner, S.D., 2013. Surface-water acidity in the River Dart area. Report for the West Country Rivers Trust.

Berntssen, M.H., Aatland, A. and Handy, R.D., 2003. Chronic dietary mercury exposure causes oxidative stress, brain lesions, and altered behaviour in Atlantic salmon (*Salmo salar*) parr. *Aquatic toxicology*, *65*(1), pp.55-72.

Boulêtreau, S., Gaillagot, A., Carry, L., Tétard, S., De Oliveira, E. and Santoul, F., 2018. Adult Atlantic salmon have a new freshwater predator. *PLoS One*, *13*(4), p.e0196046.

Bull, C. D., S D Gregory, E Rivot, T F Sheehan, D Ensing, G Woodward, W Crozier, The likely suspects framework: the need for a life cycle approach for managing Atlantic salmon (*Salmo salar*) stocks across multiple scales, *ICES Journal of Marine Science*, Volume 79, Issue 5, July 2022, Pages 1445–1456, https://doi.org/10.1093/icesjms/fsac099

Butler JRA, Middlemas SJ, Graham IM, Thompson PM, Armstrong JD (2006) Modelling the impacts of removing seal predation from Atlantic salmon, *Salmo salar,* rivers in Scotland: a tool for targeting conflict resolution. *Fish Manag Ecol 13:285–291*

Centre for Ecology Fisheries and Environment, Environment Agency, Natural Resources Wales (2023) ***Salmon Stocks and Fisheries in England and Wales in 2022.***

Centre for Ecology Fisheries and Environment, Environment Agency, Natural Resources Wales (2024) ***Salmon Stocks and Fisheries in England and Wales in 2023.***

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

Dart Angling Association, 2016. Smolts caught on camera – Dart Angling Association. Date accessed; 02/12/2024

Dawson, L. 2022. The efficacy of a newly developed method of controlled calcium carbonate introductions for anthropogenic acidification mitigation in a naturally acidic riverine environment. PhD Thesis, University of Plymouth.

Dennis, I.F. and Clair, T.A., 2012. The distribution of dissolved aluminum in Atlantic salmon (Salmo salar) rivers of Atlantic Canada and its potential effect on aquatic populations. *Canadian journal of fisheries and aquatic sciences*, *69*(7), pp.1174-1183.

Desa, R. and Lee, S., 2017. The effect of Myriophyllum aquaticum on freshwater bodies in British Columbia. *The Expedition*, *7*.

Devon and Severn IFCA, 2021. Mariculture Strategy report.

Elliott, J. and 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.

Environment Agency (2001) The River Dart SAP Consultation Document.

Environment Agency (2022) Press release -. Environment Agency rescues stranded fish during dry weather - GOV.UK

Environment Agency Ecology and Fish Data explorer, 2024, https://environment.data.gov.uk/ecology/explorer/. Data last accessed 28th November 2024.

Environment Agency Water Quality Archive, 2024. https://environment.data.gov.uk/water-quality/view/landing. Data last accessed 1st December 2024.

Eycott-Martin, J., 2024 Determining risk from pH to Atlantic salmon (*Salmo salar*) on the River Dart.

Fairchild, W.L., Swansburg, E.O., Arsenault, J.T. and Brown, S.B., 1999. Does an association between pesticide use and subsequent declines in catch of Atlantic salmon (Salmo salar) represent a case of endocrine disruption?. *Environmental Health Perspectives*, *107*(5), pp.349-358.

Fishtek consulting, 2022. Analysis of Fish Counter Data for 2021. Totnes Weir, River Dart.

Fishtek consulting, 2024. Analysis of Fish Counter Data for 2023. Totnes Weir, River Dart.

Floury, M., Colombet, J. and Desvilettes, C., 2019. Interspecific competition between restocked 0+ salmon parr (*Salmo salar*) and native fish species in a large European river. *Ecology of Freshwater Fish*, *28*(1), pp.69-84.

Ford, J.S. and Myers, R.A., 2008. A global assessment of salmon aquaculture impacts on wild salmonids.PLoS biology,6(2), p.e33.

Freshwater Biological Association, 2024 FBA Info Note 2. February 2024. Available at https://www.fba.org.uk/info-notes/pet-treatments-could-be-harming-freshwater-life#:~:text=The%20use%20of%20flea%20treatment%20on%20pets%20could,despite%20severe%20restrictions%20on%20agricultural%20use%20since%202018.

Nott, F.J. and Beale, P.B., 1969. River Dart fisheries survey 1965.

Falkegård, M., Lennox, R.J., Thorstad, E.B., Einum, S., Fiske, P., Garmo, Ø.A., Garseth, Å.H., Skoglund, H., Solberg, M.F., Utne, K.R. and Vollset, K.W., 2023. Predation of Atlantic salmon across ontogenetic stages and impacts on populations. Canadian Journal of Fisheries and Aquatic Sciences, 80(10), pp.1696-1713.

Flávio, H., Kennedy, R., Ensing, D., Jepsen, N. and Aarestrup, K., 2020. Marine mortality in the river? Atlantic salmon smolts under high predation pressure in the last kilometres of a river monitored for stock assessment. *Fisheries Management and Ecology*, *27*(1), pp.92-101.

Furey, N.B., Bass, A.L., Miller, K.M., Li, S., Lotto, A.G., Healy, S.J., Drenner, S.M. and Hinch, S.G., 2021. Infected juvenile salmon can experience increased predation during freshwater migration. *Royal Society Open Science*, *8*(3), p.201522.

Gardner, C., Coghlan Jr, S.M., Zydlewski, J. and Saunders, R., 2013. Distribution and abundance of stream fishes in relation to barriers: implications for monitoring stream recovery after barrier removal. *River Research and Applications*, *29*(1), pp.65-78.

Gibson, A.J.F., Bowlby, H.D. and Amiro, P.G., 2008. Are wild populations ideally distributed? Variations in density-dependent habitat use by age class in juvenile Atlantic salmon (Salmo salar). *Canadian Journal of Fisheries and Aquatic Sciences*, *65*(8), pp.1667-1680.

GOV.UK (2024). *Gyrodactylus salaris* (GS). [online] Available at: https://www.gov.uk/government/publications/gyrodactylus-salaris-gs#:~:text=Details&text=Gyrodactylus%20salaris%20(GS)%20is%20a,affecting%20Atlantic%20salmon%20in%20freshwater. [Accessed 23 March 2025].

Green, D., 2021. Determining the Most Impactful Invasive Vegetative Species on Freshwater Salmon Habitat in Western Washington During 2021: Using Literature and Surveying Professionals (Doctoral dissertation, Evergreen State College).

Griffiths, A.M., Machado-Schiaffino, G., Dillane, E., Coughlan, J., Horreo, J.L., Bowkett, A.E., Minting, P., Toms, S., Roche, W., Gargan, P. and McGinnity, P., 2010. Genetic stock identification of Atlantic salmon (*Salmo salar*) populations in the southern part of the European range. *BMC genetics*, *11*, pp.1-27.

Harrison, S. S. C., Hutton, S., Baars, J.-R., Cruikshanks, R., Johnson, J., Juhel, G., Kirakowski, T., Matson, R., O'Halloran, J., Phelan, P., & Kelly-Quinn, M. (2014). Contrasting impacts of conifer forests on brown trout and Atlantic salmon in headwater streams in Ireland. *Biology and Environment: Proceedings of the Royal Irish Academy*, *114B*(3), 219–231. https://doi.org/10.3318/bioe.2014.20

Havn, T.B., Uglem, I., Solem, Ø., Cooke, S.J., Whoriskey, F.G. and Thorstad, E.B., 2015. The effect of catch-and-release angling at high water temperatures on behaviour and survival of Atlantic salmon Salmo salar during spawning migration. *Journal of fish biology*, *87*(2), pp.342-359.

Houde, A.L.S., Wilson, C.C. and Neff, B.D., 2015. Effects of competition with four nonnative salmonid species on Atlantic salmon from three populations. *Transactions of the American Fisheries Society*, *144*(5), pp.1081-1090.

Hodder, K.H. and Bullock, J.M., 1997. Translocations of native species in the UK: implications for biodiversity. *Journal of Applied Ecology*, pp.547-565.

Hu, Y., Gao, L., Ma, C., Wang, H. and Zhou, C., 2023. The comprehensive reduction capacity of five riparian vegetation buffer strips for primary pollutants in surface runoff. *Applied Sciences, 13(6),* p.3898.

Ibbotson A.T., Riley W.D., Beaumont W.R.C., Cook A.C., Ives M.J., Pinder A.C. & Scott L.J. (2013) The source of autumn and spring downstream migrating juvenile Atlantic salmon in a small lowland river. Ecology of Freshwater Fish 22, 73-81.

INNS Mapper (2024). https://innsmapper.org/map. Accessed 20th March 2025.

Jensen, A.J., Finstad, B., Fiske, P., Hvidsten, N.A., Rikardsen, A.H. and Saksgård, L., 2012. Timing of smolt migration in sympatric populations of Atlantic salmon (*Salmo salar*), brown trout (*Salmo trutta*), and Arctic char (*Salvelinus alpinus*). *Canadian Journal of Fisheries and Aquatic Sciences*, *69*(4), pp.711-723.

Jonsson, B. and Jonsson, N., 2010. A review of the likely effects of climate change on anadromous Atlantic salmon *Salmo salar* and brown trout *Salmo trutta*, with particular reference to water temperature and flow. *Journal of Fish Biology*. Jonsson, B. and Jonsson, N., 2011. *Ecology of Atlantic salmon and brown trout: habitat as a template for life histories* (Vol. 33). Springer Science & Business Media.

Kay, A. L., Griffin, A., Rudd, A. C., Chapman, R. M., Bell, V. A., & Arnell, N. W. (2021). Climate change effects on indicators of high and low river flow across Great Britain. *Advances in Water Resources*, *151*, 103909.

Kennedy, R.J., Moffett, I., Allen, M.M. and Dawson, S.M., 2013. Upstream migratory behaviour of wild and ranched Atlantic salmon *Salmo salar* at a natural obstacle in a coastal spate river. Journal of Fish Biology, 83(3), pp.515-530.

Klinck, B., Palumbo-Roe, B., Cave, M. and Wragg, J., 2005. *Arsenic dispersal and bioaccessibility in mine contaminated soils: a case study from an abandoned arsenic mine in Devon, UK*. British Geological Survey.

Lacroix, G.L., Gordon, D.J. and Johnston, D.J., 1985. Effects of low environmental pH on the survival, growth, and ionic composition of postemergent Atlantic salmon (Salmo salar). *Canadian Journal of Fisheries and Aquatic Sciences*, *42*(4), pp.768-775.

Liebich, T., McCormick, S.D., Kircheis, D., Johnson, K., Regal, R. and Hrabik, T., 2011. Water chemistry and its effects on the physiology and survival of Atlantic salmon Salmo salar smolts. *Journal of Fish Biology*, *79*(2), pp.502-519.

Llewellyn, M.S., McGinnity, P., Dionne, M., Letourneau, J., Thonier, F., Carvalho, G.R., Creer, S. and Derome, N., 2016. The biogeography of the atlantic salmon (Salmo salar) gut microbiome. *The ISME journal*, *10*(5), pp.1280-1284.

Malcolm, I.A., Millidine, K.J., Glover, R.S., Jackson, F.L., Millar, C.P. and Fryer, R.J., 2019. Development of a large-scale juvenile density model to inform the assessment and management of Atlantic salmon (*Salmo salar*) populations in Scotland. *Ecological indicators*, *96*, pp.303-316.

Marschall, E.A., Mather, M.E., Parrish, D.L., Allison, G.W. and McMenemy, J.R., 2011. Migration delays caused by anthropogenic barriers: modeling dams, temperature, and success of migrating salmon smolts. *Ecological Applications*, *21*(8), pp.3014-3031.

Matthews, E., 2019. *Environmental factors impacting Saprolegnia infections in wild fish stocks.* PhD Thesis, Cardiff University.

McEvoy, A.J., Atkinson, A., Airs, R.L., Brittain, R., Brown, I., Fileman, E.S., Findlay, H.S., McNeill, C.L., Ostle, C., Smyth, T.J. and Somerfield, P.J., 2023. The Western Channel Observatory: a century of physical, chemical and biological data compiled from pelagic and benthic habitats in the western English Channel. *Earth System Science Data*, *15*(12), pp.5701-5737.

Mueller, M., Pander, J. and Geist, J., 2011. The effects of weirs on structural stream habitat and biological communities. *Journal of Applied Ecology*, *48*(6), pp.1450-1461.

Milner, 2024. Technical note on the effects of the Test drought permit on salmon in the River Itchen.

Monette, M.Y., Björnsson, B.T. and McCormick, S.D., 2008. Effects of short-term acid and aluminum exposure on the parr-smolt transformation in Atlantic salmon (Salmo salar): disruption of seawater tolerance and endocrine status. *General and Comparative Endocrinology*, *158*(1), pp.122-130.

NASCO – North Atlantic Salmo Conservation Organisation (2020). Focus area report on protection, restoration and enhancement of salmon habitat UK (England and Wales). IP(09)05

NBN Atlas, 2024. Record: 262631 | Occurrence record | NBN Atlas. Date accessed: 3rd December 2024.

Nisbet, T.R. and Evans, C.D., 2014. Forestry and surface water acidification. Research note, Forestry Commission.

Nislow, K.H., Armstrong, J.D. and Grant, J.W., 2010. The role of competition in the ecology of juvenile Atlantic salmon. *Atlantic salmon ecology. Blackwell, West Sussex, UK*, pp.171-197.

Oceana in the UK (2023). Taking stock: The state of UK fish populations 2023. Report produced by Macalister Elliott and Partners Ltd. for Oceana. St Austell, UK. DOI number: 10.5281/zenodo.8312508

Olmos, M., Payne, M.R., Nevoux, M., Prévost, E., Chaput, G., Du Pontavice, H., Guitton, J., Sheehan, T., Mills, K. and Rivot, E., 2020. Spatial synchrony in the response of a long range migratory species (Salmo salar) to climate change in the North Atlantic Ocean. *Global Change Biology*, *26*(3), pp.1319-1337.

Ormerod, S.J., Jones, M.E., Jones, M.C. and Phillips, D.R., 2004. The effects of riparian forestry on invertebrate drift and brown trout in upland streams of contrasting acidity. *Hydrology and Earth System Sciences*, *8*(3), pp.578-588.

Peeler, E.J., Gardiner, R. and Thrush, M.A., 2004. Qualitative risk assessment of routes of transmission of the exotic fish parasite Gyrodactylus salaris between river catchments in England and Wales. *Preventive veterinary medicine*, 64(2-4), pp.175-189.

Provotorov, D.S., Murzina, S.A., Ieshko, E.P. and Nemova, N.N., 2023. Ulcerative Dermal Necrosis (UDN) in Salmonids: A Review. *Biology Bulletin Reviews*, *13*(1), pp.20-27.

Reid, C.H., Taylor, J.J., Rytwinski, T., Possémé, C., Lennox, R.J., April, J. and Cooke, S.J., 2024. A review and risk analysis on potential impacts of riverine recreational activities on Atlantic Salmon (Salmo salar) in eastern Canada. Environmental Reviews, 32(4), pp.557-571

Riebe, C.S., Sklar, L.S., Overstreet, B.T. and Wooster, J.K., 2014. Optimal reproduction in salmon spawning substrates linked to grain size and fish length. Water Resources Research, 50(2), pp.898-918.

Riley, W.D., Maxwell, D.L., Pawson, M.G. and Ives, M.J., 2009. The effects of low summer flow on wild salmon (Salmo salar), trout (Salmo trutta) and grayling (Thymallus thymallus) in a small stream. *Freshwater Biology*, *54*(12), pp.2581-2599.

Rosseland B. O. , Kroglund F. 2011. Ecological consequences of pollution: lessons from acidification and pesticide. In Atlantic Salmon Ecology, pp. 387–408. Ed. by Aas Ø., Einum S., Klemetsen A., Skurdal J.. Wiley-Blackwell, Oxford, UK.

Rotherham, I.D., 2021. The impacts of recolonisation of an urbanised river by native and non-native species. *Frontiers in Ecology and Evolution, 9, p.618371*.

SalHub 2024 [Missing Salmon Alliance](#) Date accessed 14/11/2024

Schuwerack, P.M., Neal, M. and Neal, C., 2007. The Dart estuary, Devon, UK: a case study of chemical dynamics and pollutant mobility. *Hydrology and Earth System Sciences*, *11*(1), pp.382-398.

Seymour. K , Willis. M, Simons.A, 2023. River Use Survey 2023 – Summary Report. *Friends of the Dart*

Simmons OM, Gregory SD, Gillingham PK, Riley WD, Scott LJ, Britton JR (2021) Biological and environmental influences on the migration phenology of Atlantic salmon *Salmo salar* smolts in a chalk stream in southern England. Freshw Biol 66:1581–1594

Sittenthaler, M., Koskoff, L., Pinter, K., Nopp-Mayr, U., Parz-Gollner, R., & Hackländer, K. (2019). Fish size selection and diet composition of Eurasian otters (*Lutra lutra*) in salmonid streams: Picky gourmets rather than opportunists? *Knowledge and Management of Aquatic Ecosystems*, **420**(420), 29. https://doi.org/10.1051/KMAE/2019020

Sortland, L. K., Lennox, R. J., Velle, G., Vollset, K. W., & Kambestad, M. (2023). Impacts of predation by Eurasian otters on Atlantic salmon in two Norwegian rivers. Freshwater Biology, 68, 1176–1193. https://doi.org/10.1111/fwb.14095

Spachmo, B. and Arukwe, A., 2012. Endocrine and developmental effects in Atlantic salmon (*Salmo salar*) exposed to perfluorooctane sulfonic or perfluorooctane carboxylic acids. *Aquatic toxicology*, *108*, pp.112-124.

Strøm, J.F., Rikardsen, A.H., Campana, S.E., Righton, D., Carr, J., Aarestrup, K., Stokesbury, M.J., Gargan, P., Javierre, P.C. and Thorstad, E.B., 2019. Ocean predation and mortality of adult Atlantic salmon. *Scientific reports*, *9*(1), p.7890.

Stubbing, D.N., 2009. A study of Brown Trout, *Salmo Trutta* L., Egg Survival and Intra-gravel Ecology in livestock catchments with farm Management Plans to Mitigate Against Diffuse Pollution (*Doctoral dissertation, Guy's, King's and St. Thomas's School of Biomedical & Health Sciences).*

TRESOC (Totnes Renewable Energy Society). 2025. Online source; Totnes Weir | Totnes Renewable Energy Society. Accessed 25th March 2023.

Tyldesley, E., Banas, N., Bull, C. and Diack, G. 2022. A multi-scale view of the ocean along a 3,000 km Atlantic salmon post-smolt migration corridor. The Missing Salmon Alliance. Water Framework Directive UK Technical Advisory Group, 2015. UKTAG River Assessment Method River continuity Barrier to fish migration method (Scotland)

Wankowski, J.W.J., 1979. Morphological limitations, prey size selectivity, and growth response of juvenile Atlantic salmon, *Salmo salar*.*Journal of Fish Biology*,*14*(1), pp.89-100.Westcountry Rivers Trust (2022) A38 weir scheme finishes right on time - Westcountry Rivers Trust

Webb, J.H., Hay, D.W., Cunningham, P.D. and Youngson, A.F., 1991. The spawning behaviour of escaped farmed and wild adult Atlantic salmon (*Salmo salar L.)* in a northern Scottish river.*Aquaculture*,*98*(1-3), pp.97-110.

WGNAS2021 [Working Group on North Atlantic Salmon (WGNAS)]

Appendix 1

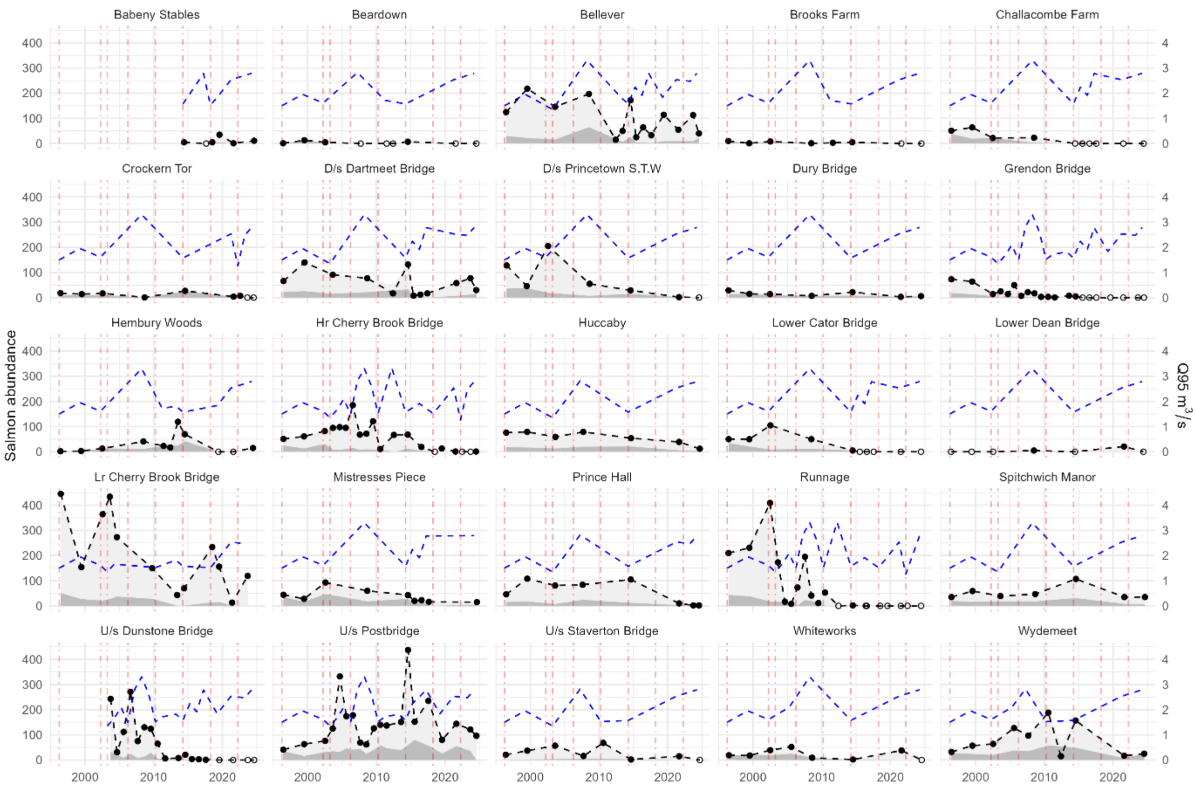

Figure A21. Environment Agency and Westcountry Rivers Trust sampling records showing Atlantic salmon caught from various electric fishing protocols for both age classes; 0+ (young of the year/ fry; light grey with black dashed line) and >0+ fish (parr; dark grey), showing sites that had five or more records and where maximum salmon count was at least 5 fish. Hollow circled indicate zero salmon captured. Site name and sample type in brackets. Drought years (1996, 2002, 2003, 2006, 2010, 2014, 2018, and 2022) are marked (dashed red vertical lines) and the low flow statistic (blue dashed line - Q95) is plotted on the second y-axis. Drought is relative to the long term Q95 (not annual) at Austins Bridge, annual Q95s that fall below this value are considered "Drought years"

With every community, we redefine what's possible.

Stantec is a global leader in sustainable engineering, architecture, and environmental consulting. The diverse perspectives of our partners and interested parties drive us to think beyond what's previously been done on critical issues like climate change, digital transformation, and future-proofing our cities and infrastructure. We innovate at the intersection of community, creativity, and client relationships to advance communities everywhere, so that together we can redefine what's possible.

North, St. John's Place, Easton Street
High Wycombe, United Kingdom
HP11 1NL