Salmon Monitoring & Fisheries Research Review

Produced by the GWCT's Salmon & Trout Research Centre

2024

Environment Agency

THE MISSING SALMON ALLIANCE

Game & Wildlife Conservation Trust

Our fisheries work featured extensively in the media during 2024. Here the team are being filmed by ITN.

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Foreword

By Dylan Roberts, GWCT Head of Fisheries

Welcome to our *Salmon Monitoring & Fisheries Research Review* of 2024. Here we outline the work of the Salmon & Trout Research Centre team in continuing the long term work on salmon in the River Frome, in Dorset, and our wider aquatic research. The Frome hosts one of the most detailed datasets available on juvenile and adult wild Atlantic salmon and grayling.

Firstly, I would like to congratulate Dr Daniel Osmond and Dr Robert Needham who both successfully defended their PhDs, which were part sponsored by GWCT.

2024 was a mixed bag on many fronts. The year started against the backdrop of the International Union for the Conservation of Nature (IUCN) in December 2023 having upgraded the conservation classification of wild Atlantic salmon in the UK from 'Least Concern' to 'Endangered' on their Red List. This was a result of a 30-50% decline in British populations since 2006 and a 50-80% projected decline between 2010-2025. This news made us determined to work even harder to find solutions to their decline.

This worrying trend has been mirrored on the Frome where, in the 1980s the 10-year average number of salmon entering the river annually was estimated to be around 2,500 fish, while now, in 2024 the estimated number of adults that entered the river was just over 400 individual salmon.

Then there was rain. 2024 was one of the wettest years on record, with records for monthly rainfall being broken with alarming regularity. This had a major effect on our work programmes. The River Frome, burst its banks in November 2023 and flows did not recede until May. This meant that we were unable to complete a planned salmon redd survey in February and we could not operate the smolt trap until mid-April, some five weeks later than planned.

On the upside, following a good (for the last 10 years) 2SW adult run in 2022, these larger more productive fish led to good numbers of their offspring in the river in 2023, and a good smolt estimate leaving the river in spring 2024. Fingers crossed we should see the benefit of this in 2025 and 2026. However, juvenile abundance during our fieldwork in August and September 2024 was disappointingly low, showing how variable juvenile salmon numbers can be.

Despite the highs and lows, the GWCT team, working in collaboration with the rest of the Missing Salmon Alliance, and other partners, are mining our data at pace to understand why the River Frome, and other salmon populations, are not so abundant as they used to be. And, more importantly, how we can stem the decline.

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The salmon population monitoring is carried out on the River Frome.

1. Summary

This report summarises the salmon population monitoring carried out on the River Frome by the Game & Wildlife Conservation Trust (GWCT) at its Salmon & Trout Research Centre during the 2024 salmon year (1 February 2024 to 31 January 2025).

The nett upstream adult estimate of salmon for 2024 from the East Stoke resistivity counter was 405 fish, which is 34% down on the 10-year average. The largest salmon recorded by the video at the resistivity counter in 2024 was 110cm with a mean Multi-Sea Winter (MSW, fish spending >1 winter at sea) size of 86cm (standard deviation (SD) (±10cm). From video observations and tagged fish returns, in 2024, roughly equal proportions of grilse (one sea winter fish, 1SW, salmon spending one winter at sea) to MSW fish were observed and estimated.

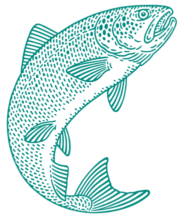
Based on the detection of Passive Integrated Transponder (PIT) tagged returning adult salmon from smolts in 2023, survival of 1SW fish for 2024 was 0.42%, which continues to be well below the long-term average (2013-2024, 2.32%). The return rate for 2024 2SW salmon was 0.57% which is also below average (2014-2024, 1.30%).

We estimated that there were just over 69,079 salmon parr (±18,500 95% CI) in the River Frome catchment in September 2024 which is 25% below the 10-year average. This contrasts with our estimate for 2023 which is 38% above the 10-year average.

Our 2024 salmon smolt estimate was 21,553 (±3,038 95% confidence interval (CI), which is 105% above the 10-year average and in line with the higher-than-average 2023 parr estimate (127,499, ±17,954 95% CI) and high 2SW returns in 2022.

HIGHLIGHTS

- The nett upstream adult estimate of salmon for 2024 from the East Stoke resistivity counter was 405 fish, which is 34% down on the 10-year average.
- Although more 2SW tagged returning salmon were seen than 1SW, there was a decline of both from the 10-year average.
- Estimated salmon parr numbers in the River Frome catchment in September 2024 were 25% below the 10-year average.
- Estimated number of salmon smolts in 2024 was 21,553 (±3,038 95% CI). This is 105% above the 10-year average (10,541) and in line with the above average 2023 parr estimates.



The nett upstream adult estimate of salmon for 2024 from the East Stoke resistivity counter was 405 fish, which is 34% down on the 10-year average.

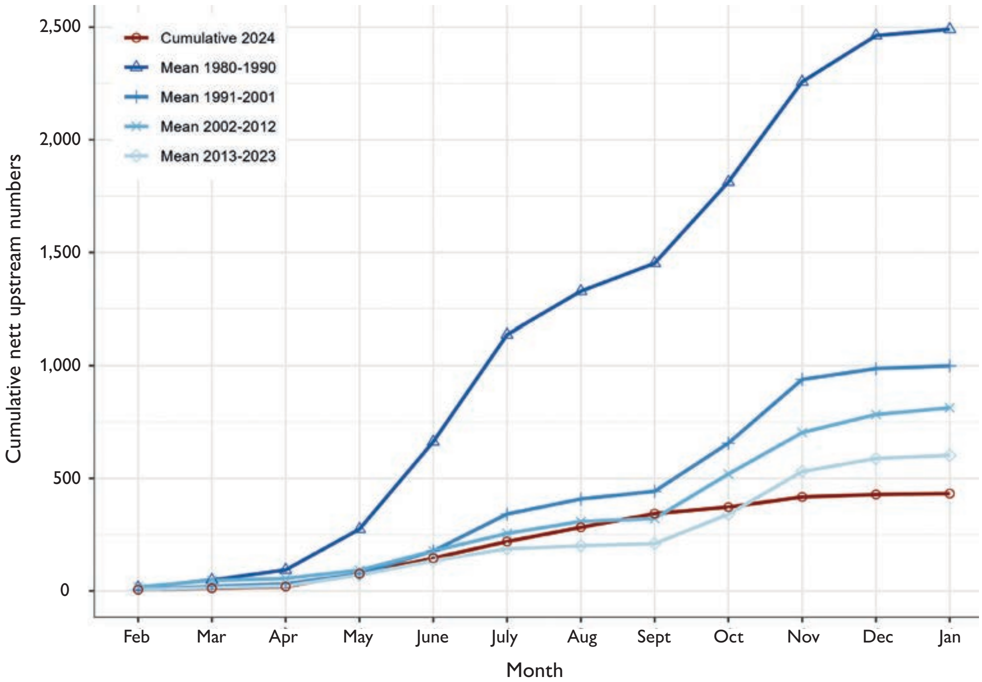


Figure 1

Cumulative nett upstream adult salmon estimate for 2024 and 10 year average cumulative upstream movements recorded by the resistivity counter at East Stoke

Adult salmon are monitored through our resistivity fish counter and PIT tag readers. Juvenile salmon are monitored by electrofishing and a fish trap.

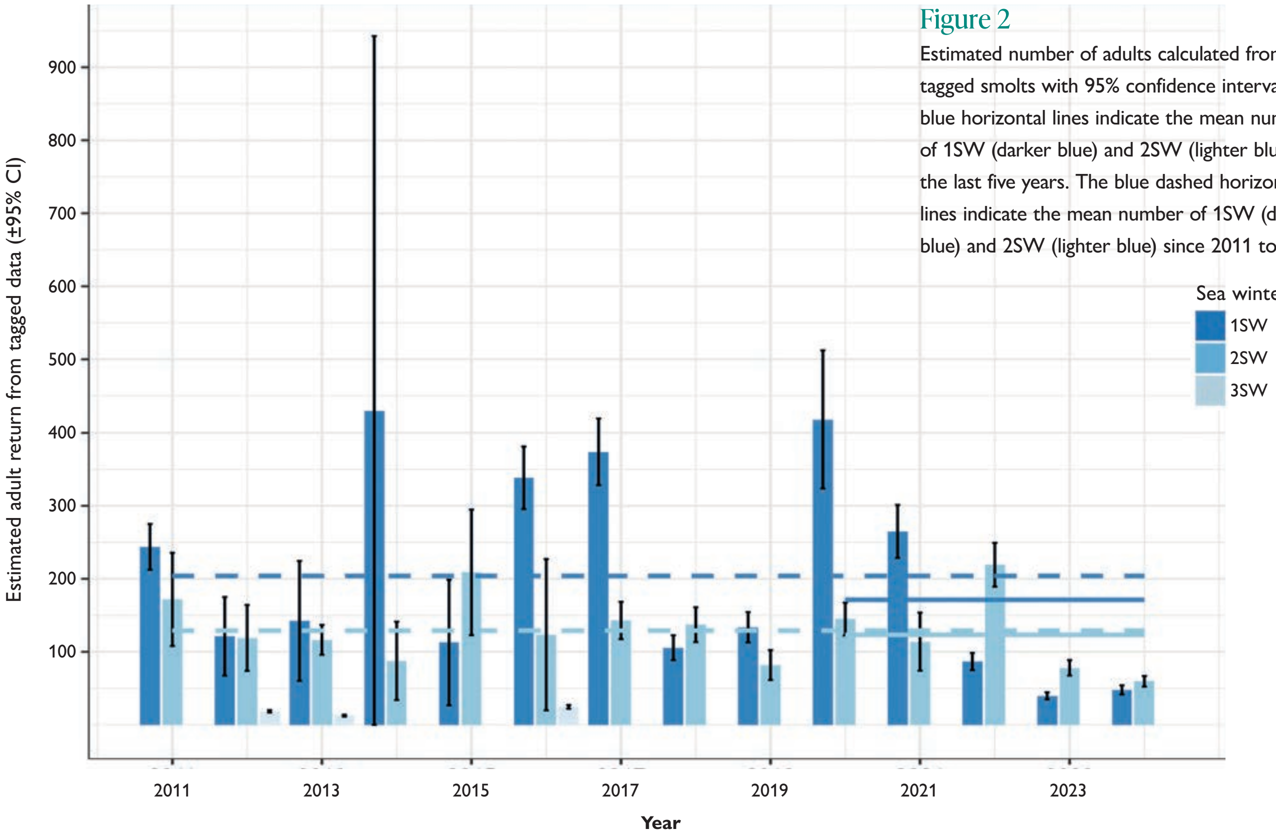


Figure 2

Estimated number of adults calculated from tagged smolts with 95% confidence intervals. The blue horizontal lines indicate the mean number of 1SW (darker blue) and 2SW (lighter blue) for the last five years. The blue dashed horizontal lines indicate the mean number of 1SW (darker blue) and 2SW (lighter blue) since 2011 to 2024

TABLE 1

Estimated 1 and 2SW return rates (%) from PIT tagged wild salmon smolts on the River Frome

Smolt cohort	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Average
1SW	2.45	3.09	1.52	4.96	3.76	2.37	1.15	4.45	2.00	1.32	0.38	0.42	2.32
2SW	1.32	1.50	1.66	2.09	1.38	1.84	1.24	1.21	1.66	1.18	0.57		1.30
3SW		0.17		0.12					0.07				0.12

Estimated number of salmon smolts in 2024 were 105% above the 10-year average (10,541) and in line with the above average 2023 parr estimates

Salmon parr (top) and trout parr (below).

Figure 3

Estimated number of salmon parr in the Frome catchment in September with 95% confidence intervals (2005-2024). The dark blue horizontal line indicates the mean for the last 10 years. The dark blue dashed horizontal line indicates the mean since 2005 to 2024

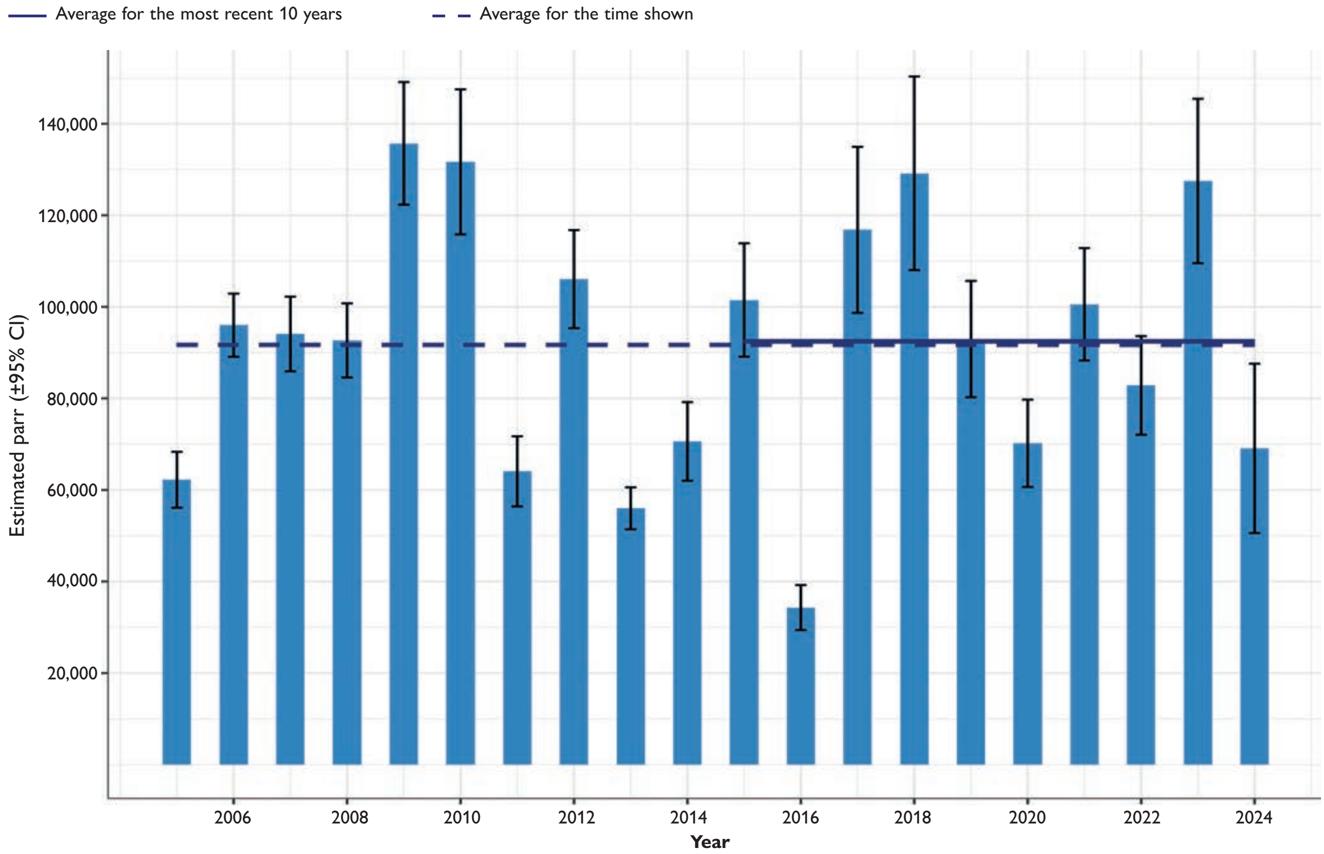
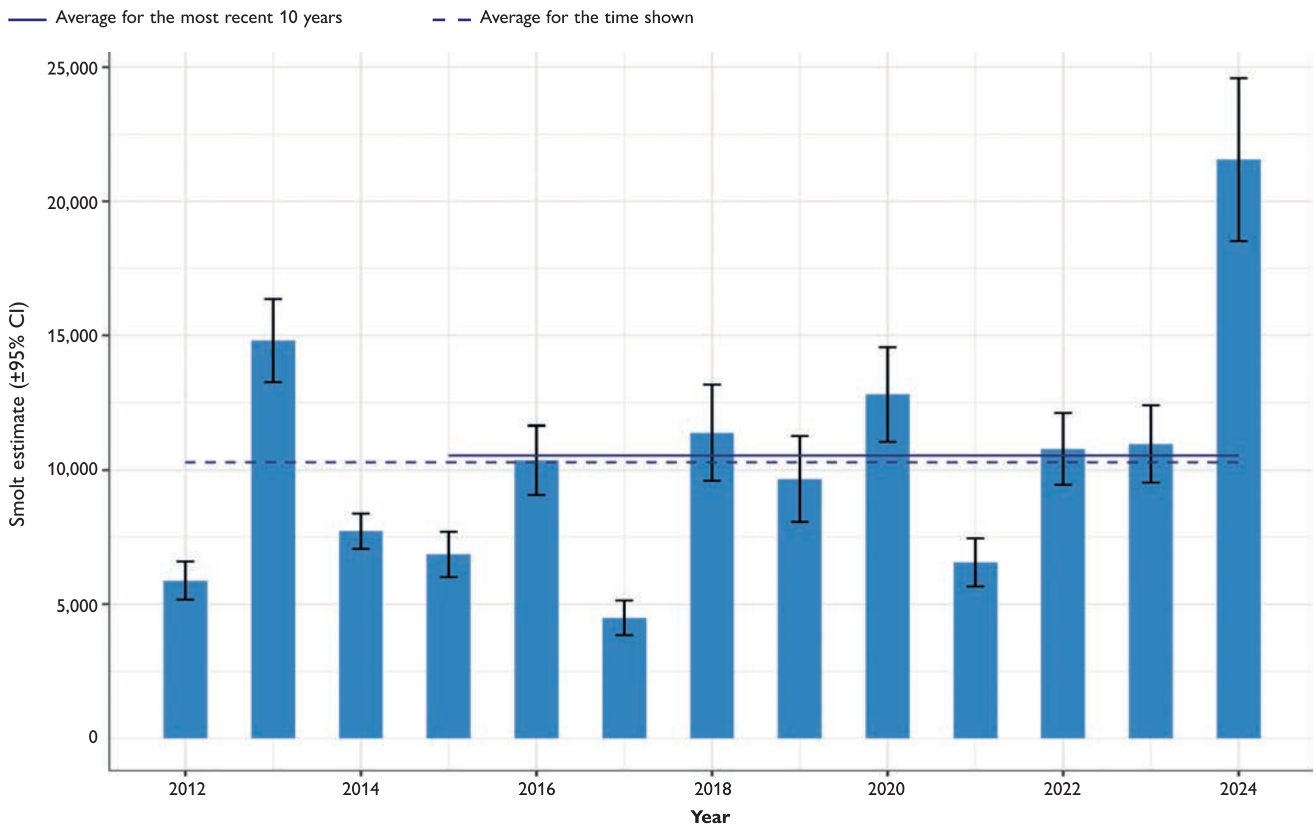


Figure 4

Estimated spring smolt population with 95% confidence intervals between 2012-2024. The dark blue dashed horizontal line indicates the mean since 2012 to 2024. The dark blue horizontal line indicates the mean for the last 10 years



River Frome counter at East Stoke with the BAFF bubble curtain set up to divert smolts down the mill stream

2. Introduction

A resistivity fish counter has monitored the upstream movement of wild adult Atlantic salmon on the River Frome since 1973. As such, the River Frome has one of the most comprehensive, long-term records of salmon spawning migrations in Europe.

The resistivity counter enables population estimates to be calculated as well as adult migration timings, which we relate to environmental factors (e.g., discharge, temperature etc.). Data from the counter also provides estimates of adult fish length for individuals captured by the video, which informs us of changing patterns in marine growth and the migration timing of different sizes of fish. Since adult salmon monitoring started in the 1970s, extensive research infrastructure has been established within the River Frome catchment (see Figure 5), including data loggers for monitoring environmental parameters such as temperature, turbidity, and discharge, as well as a smolt trap.

In 2002, full river coverage PIT-tag readers were installed at East Stoke on the River Frome. These antennae, in conjunction with the annual parr tagging, enable us to estimate the numbers of juveniles in the catchment, smolt migration, and adult returns (e.g., Gregory et al., 2017). As the PIT-tags are individual identifiers, the PIT-tag antennae also enable us to study individual life histories and relate them to changing environmental and river conditions (e.g., Gregory et al., 2019; Simmons et al., 2020; 2021). In 2014, the PIT-tag antennae at East Stoke were upgraded, and a further three sites in the catchment were either equipped with or augmented with new PIT-tag antennae (see Figure 6).

The combination of the adult resistivity counter and PIT-tag data offer a unique opportunity to answer questions about salmon life history at catchment scale that would be difficult to repeat on other rivers. The adult counter data give us a long-term view of spawning migration timing, which can be related to dependence on environmental conditions. The PIT-tag data enable us to understand the critical mortality phases of salmon, together with the freshwater factors that affect mortality and life history patterns. From a management perspective, the ability to quantify both smolt production and returning adults enables us to analyse loss rates in freshwater and at sea separately.

Figure 5

Site plan of the monitoring equipment in the River Frome at East Stoke

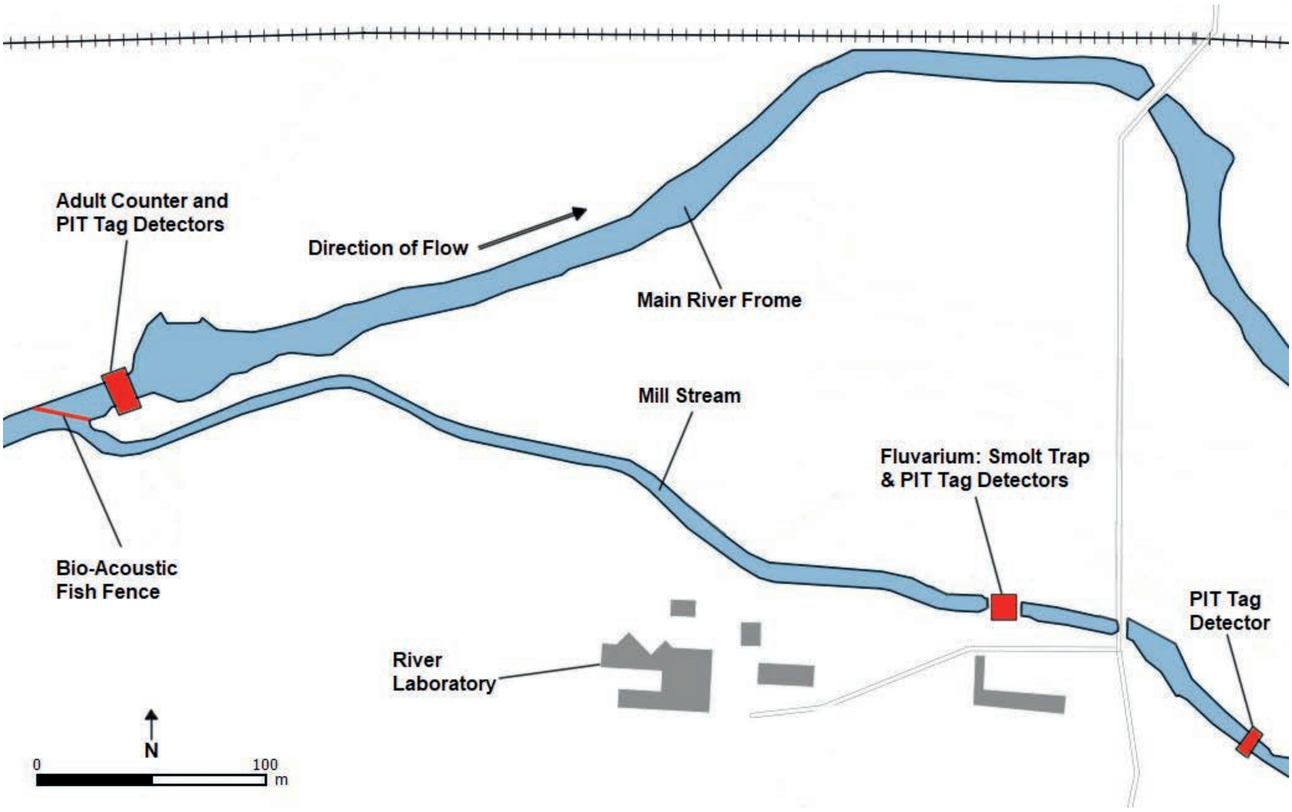
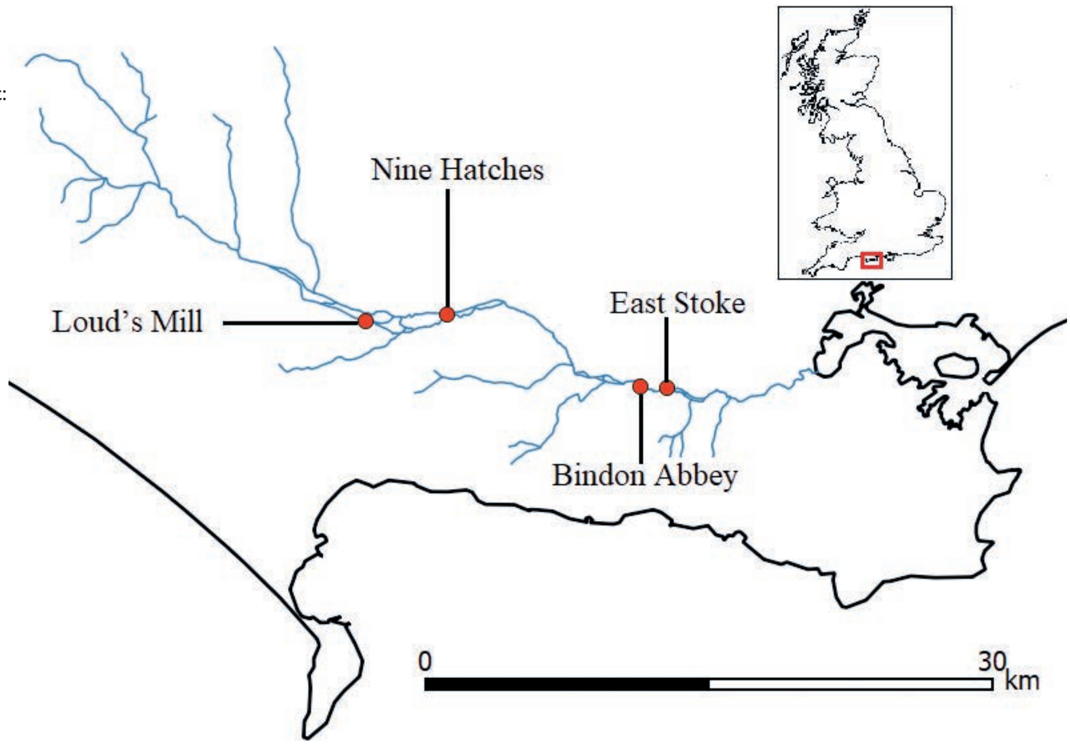


Figure 6

Location of PIT-tag antennae in the River Frome catchment: East Stoke; Bindon Abbey; Nine Hatches and Loud's Mill



Juvenile movement patterns

In mid-March 2023, we installed a new Wolf trap at East Stoke to capture smolts in spring. This replaced the much less efficient Rotary Screw Trap (RST). The Wolf trap is a system of grids that filter the migrating smolts from the water as they swim downstream. Wolf traps are highly efficient, and we have found that they catch almost 100% of the fish that are deflected down the Millstream by the Bioacoustic Fish Fence (bubble screen; BAFF) when running the trap. The RST was only between 40 to 65% efficient in low and high flows respectively. The BAFF can, however, also vary widely in efficiency depending on sediment and discharge, the latter of which was very high in 2024 (see Figure 12).

A feature of the PIT-tag antennae is that they operate 24/7 all year, hence the detection data from the PIT-tag antennae provide detailed information on movement patterns throughout the year and not just in the perceived migration periods. Not long after installing our first PIT-tag antennae at East Stoke, we realised that downstream movement of juvenile salmon also occurs during autumn and early winter in the River Frome. However, since the fish have not developed the ability to tolerate salt water in the autumn, we found that many of the fish overwinter in the lower river well into the freshwater part of the tidal zone downstream of Wareham (Pinder et al., 2007; Ibbotson et al., 2012).

The Wolf trap is a system of grids that filter the migrating smolts from the water as they swim downstream.

3. Results

Autumn parr estimate

From the number of parr PIT-tagged in autumn (end of August to mid-September) and the ratio of tagged to untagged smolts caught in the smolt trap the following spring, estimates of the number of salmon parr in the catchment at the time of tagging are calculated. The estimate for parr in 2024 is 69,079 (±18,500 95% CI). This is 25% below the 10-year average (92,493; see Figure 3). This contrasts with 2023, when the parr estimate was 38% above average (127,499 ±17,954 95% CI). The low 2024 parr estimates are in line with the low adult returns in 2023. On average 98% of parr captured on the River Frome are 0+ with the rest being 1+ parr. However, in 2024 7% of parr caught were 1+ parr.

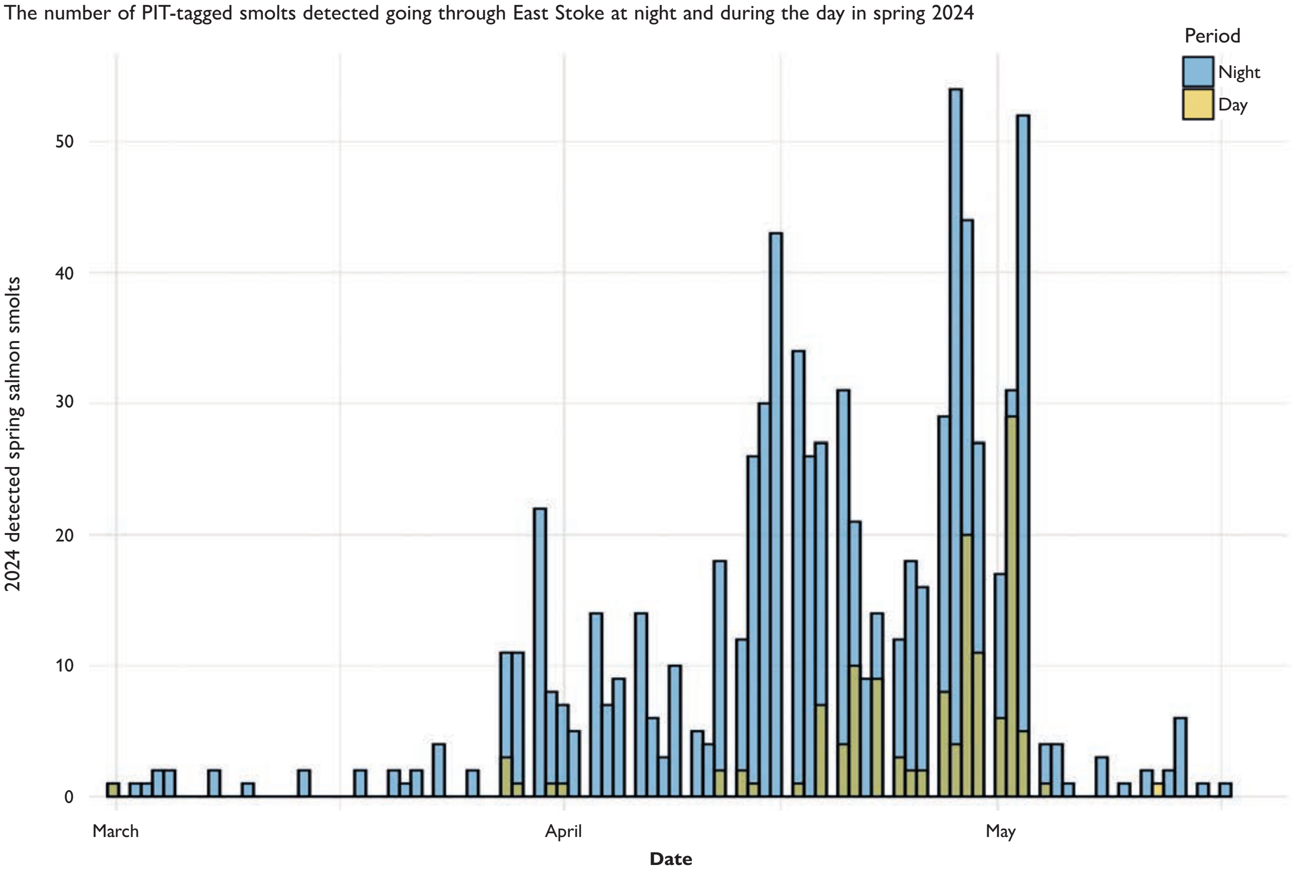
Smolt estimate

The estimated number of salmon smolts at East Stoke in 2024 was 21,553 (±3,038 95% CI; see Figure 4). This is 105% above the 10-year average (10,541), hence we are expecting a good adult run in 2025 and/or 2026 (depending on the ratio of 1SW to 2SW) from the 2024 smolt cohort, and if marine survival remains stable. The high smolt estimate for 2024 is likely to be a result of the corresponding higher than average 2SW returns in 2022 (see Figure 2), and increased 2022 egg deposition rate (see Figure 11).

The day/night detection pattern of salmon smolts at East Stoke during 2024 is shown in Figure 7. The peak of the smolt migration took place in mid-April and beginning of May following discharge periods (Simmons et al., 2021). Fifteen percent of the tagged smolts were detected moving during the daytime, which is lower than the last 10 years (23%).

Figure 7

The number of PIT-tagged smolts detected going through East Stoke at night and during the day in spring 2024



Adult estimate

In late 2021, new electronics for the resistivity counter were installed, since the old system had been in place for more than 30 years. This new counter was donated by the Environment Agency (EA), allowing the River Frome to benefit from what will become the default counting system for the EA-monitored counter network. Since the new system has been installed there have been no days without waveform data providing information on fish migration (see page 16 for methods). Daily gross upstream and downstream counts together with mean daily discharge data are shown in Figure 8. Table 2 shows monthly data from the counter and gives gross upstream and gross downstream counts as well as the nett upstream estimate.

The total nett upstream adult salmon estimated from the counter in 2024 was 405 salmon, which is 34% below the 10-year average (see Figure 1; Figure 9). Figure 1 shows that the cumulative estimate of nett upstream adult returns was in line with the 10-year average (2013-2023) until October 2024. However, the number of returning adults thereafter was lower than the 10-year average, which coincides with low 1SW returns in the autumn, relative to previous years (see Figures 1 and 2).

Despite an average smolt cohort for 2023 (see Figure 4), the number of 1SW salmon recorded was well below average in 2024 (see Table 1; Figure 2). In the last few years (2022 to 2024), an increase in 2SW returning adults relative to 1SW returns has been observed (see Figure 2 and Table 1). The majority of 2SW fish have been observed to be female (Trehin et al., 2021), and the number of eggs per female is strongly related to body size (Thorpe et al., 1984). The high number of parr seen in 2023, and smolts seen in 2024 is therefore likely to be partly because of the increased egg deposition from 2SW fish in 2022.

Figure 8

Daily gross up-stream (red bars) and downstream (green bars) counts for the 2024 salmon year and the associated daily mean river discharge (blue line)

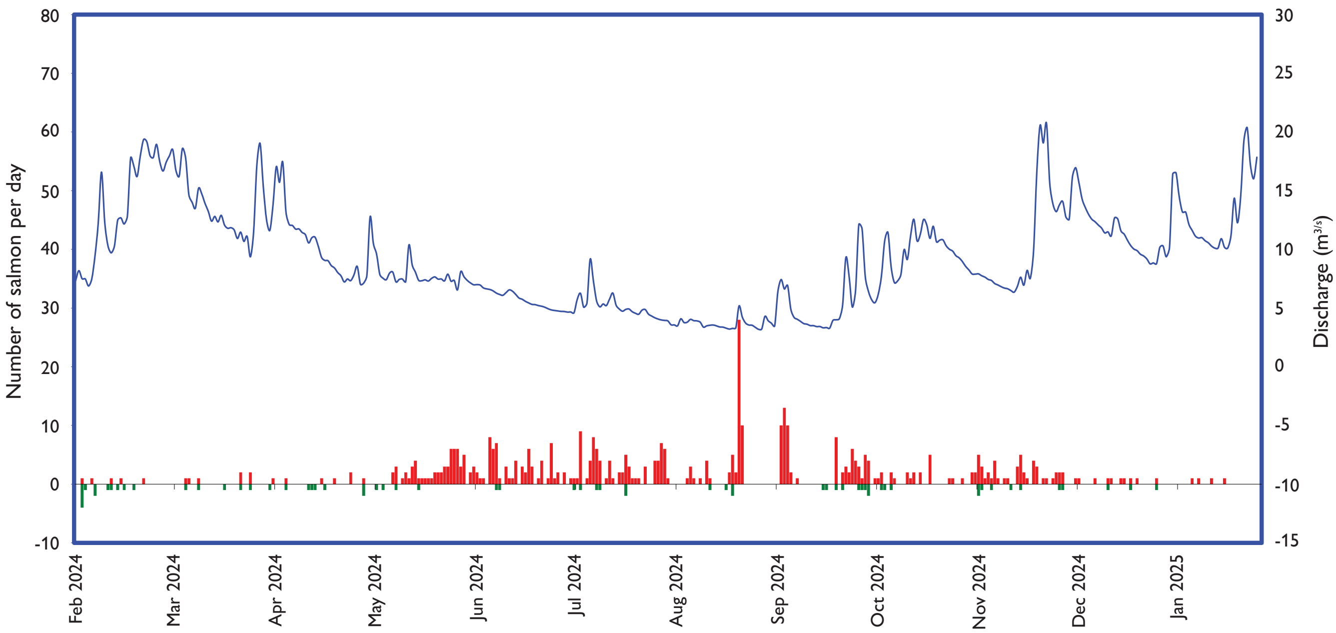


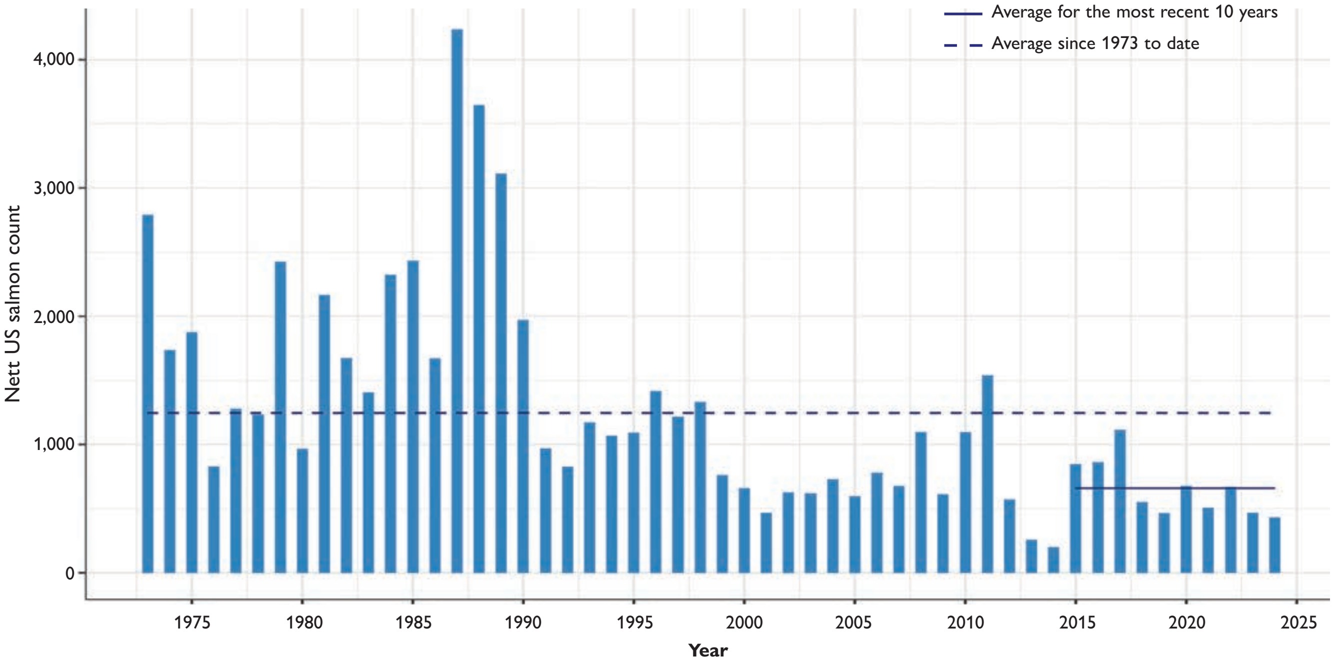
TABLE 2

Monthly movement of returning adults measured by the counter and tracer

2024	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan '25	Total
Gross U/S	5	7	8	59	70	76	65	64	31	47	14	4	**450**
Gross D/S	12	4	8	4	2	6	4	5	7	6	5	0	**63**
Nett U/S	3	3	8	55	68	70	61	59	24	41	9	4	**405**

Figure 9

The long-term annual nett upstream movement of adult salmon. The dark blue horizontal line indicates the average for the last 10 years. The dark blue dashed horizontal line indicates the mean since 1973 to 2024. Prior to 1985 the counter did not take downstream movement into account, and this has been corrected in this figure (see methods p16). Low numbers shown in 2013 and 2014 are minimum numbers of salmon returning because of mechanical problems with the counter



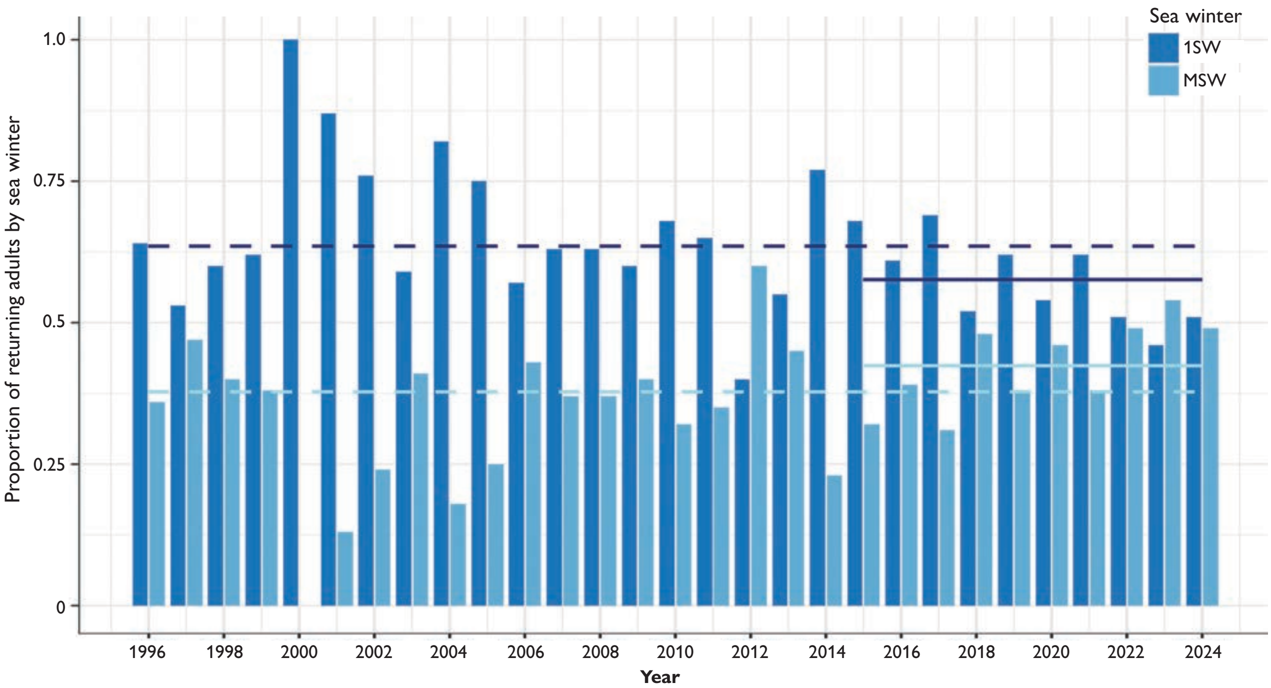
Fish size and sea age

Due to poor water clarity from continued high rainfall in 2024, video images recorded at the fish counter enabled us to estimate the length of just 92 (21%) adults registered on the counter in 2024. The largest 2024 salmon recorded was 110cm with a mean MSW size of 86cm (SD ±10cm), whereas the 2024 grilse mean size was 62cm (SD ±7 cm).

The 10-year average for MSW salmon is 84cm (±8 SD), and 60cm (±7 SD) for grilse. Based on the 92 adults where we estimated length from the video image, 51% of the 2024 run were 1SW salmon, and 49% were MSW salmon (see Figure 10).

Figure 10

The annual proportion of 1SW and MSW salmon detected from video images over the resistivity counter. The light blue line indicates the average proportion of MSW salmon detected in the last 10 years and the dark blue line indicates the average proportion of 1SW salmon detected



Conservation limit

The conservation limit for the River Frome is the deposition of 1.50 million eggs (the very minimum number of salmon eggs required to ensure a viable population as estimated by the Environment Agency (EA)). In 2024, the egg deposition estimate calculated by the EA was 1.39 million eggs, based on the adult run estimate from the resistivity counter, the size distribution and sea age of returning salmon, along with potential natural and fishing mortality. The estimate for 2024 is therefore only 93% of its conservation limit (see Figure 11). The 10-year average for the River Frome is 126.68% of its conservation limit, with six years falling below the conservation limit in this 10-year period.

River discharge

During 2024, the River Frome discharge at East Stoke continued to be well above 1970 to 2023 quartiles throughout much of the year, illustrating another wetter than average year (see Figure 12). Towards the end of 2023, a breach in the riverbanks downstream of the Fluvarium caused water to back up the Millstream producing erroneous discharge values. Discharge data on the Mill Stream at East Stoke were therefore imputed using rainfall data and discharge data from Louds Mill gauging weir as a proxy for ground water sources.

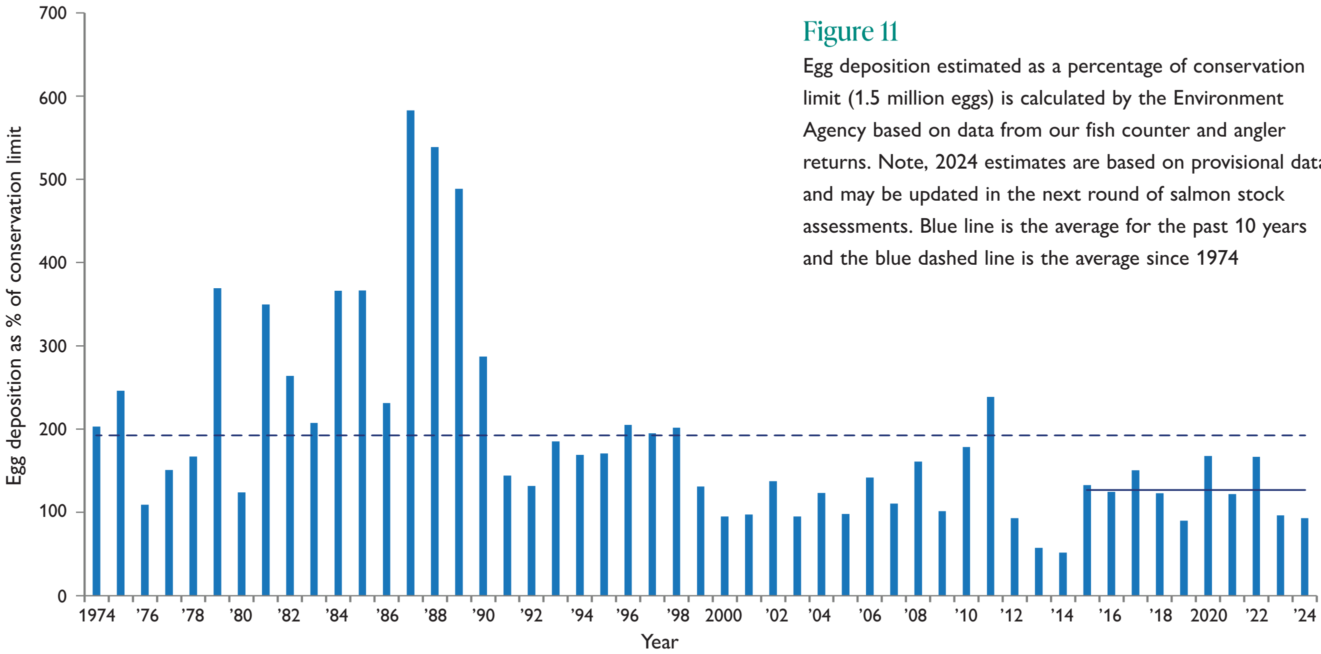
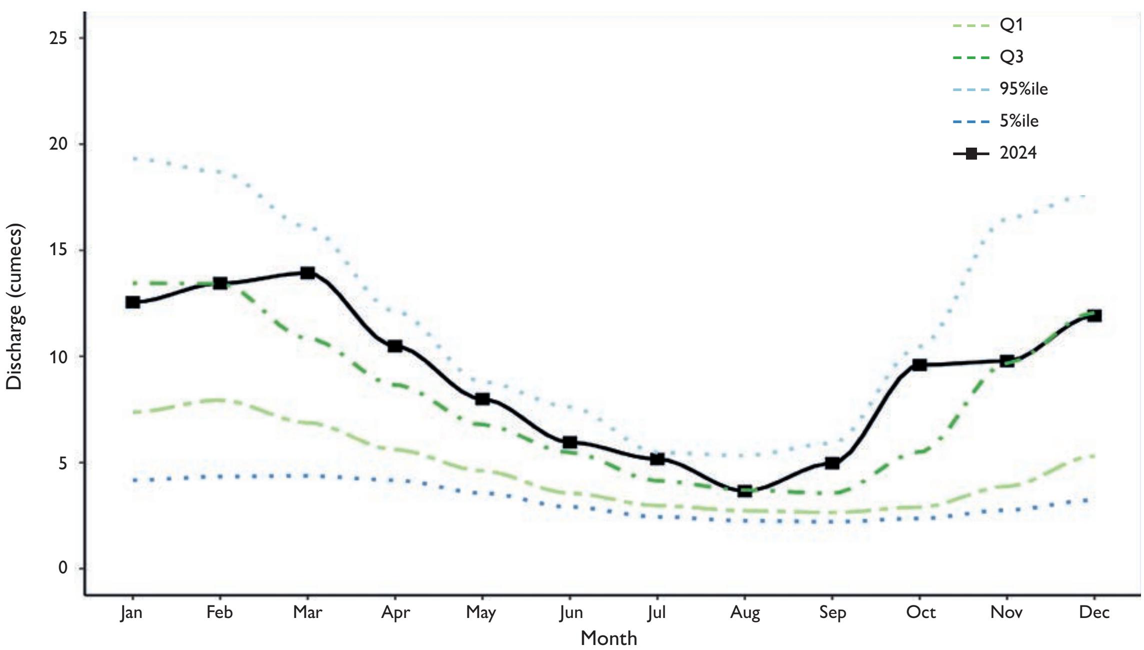


Figure 11

Egg deposition estimated as a percentage of conservation limit (1.5 million eggs) is calculated by the Environment Agency based on data from our fish counter and angler returns. Note, 2024 estimates are based on provisional data and may be updated in the next round of salmon stock assessments. Blue line is the average for the past 10 years and the blue dashed line is the average since 1974

Figure 12

Mean monthly discharge data (in cubic metres per second (cumecs)) for 2024 relative to the long-term average 5 percentile (5%ile), 25%il (Q1), 75%ile (Q3) and 95%ile discharge data for the period 1966-2022. Values represent the proportion of time that discharge has historically been above the stated value (i.e., for the 5%ile, values have only been above this level for 95% of the time and for 5%ile, discharge was above this value for 95% of the time (since 1966)). All data are collated and calculated from Environment Agency records



The conservation limit for the River Frome is the deposition of 1.50 million eggs (the very minimum number of salmon eggs required to ensure a viable population as estimated by the Environment Agency)

4. Methods

This section has been written to reflect the long-term methods used to survey salmon on the River Frome.

Parr tagging

Towards the end of August to mid-September, since 2005, we electric-fish and mark approximately 10,000 juvenile salmon, representing 8-15% of the juvenile salmon population in the catchment, with 12mm full duplex PIT-tags. PIT-tagging sites are spread throughout the catchment upstream of East Stoke. During the tagging process, we also record length, weight, and take a scale sample of each individual, before returning them to the same 100 metre reach from where they were captured. The PIT-tags (12mm long x 2mm in diameter; see Figure 13) are inserted into the peritoneal cavity of the parr and enable us to identify individual fish when they swim past our detection antennae. Nearly all PIT-tags will stay with the fish until at least their first spawning. Passage of tagged fish out to sea, and fish returning from the sea, are recorded by the PIT-tag antennae installed throughout the catchment (see Figures 5-6).

Catchment parr estimate

Trying to estimate the total number of parr in a whole catchment is difficult. However, it is possible to estimate population numbers (see Figure 3) by marking some of the population and then sampling that population later to see what proportions are marked. On the River Frome, we use a variation of this method to determine the number of both parr and smolts in the catchment. To estimate the number of parr we divide the number of parr tagged in August and September by the proportion of the population that is tagged in the following spring. We obtain a measure of the proportion of the population that is tagged by quantifying the proportion of tagged to non-tagged smolts captured in our smolt trap at East Stoke the following spring.

Smolt trapping and estimate

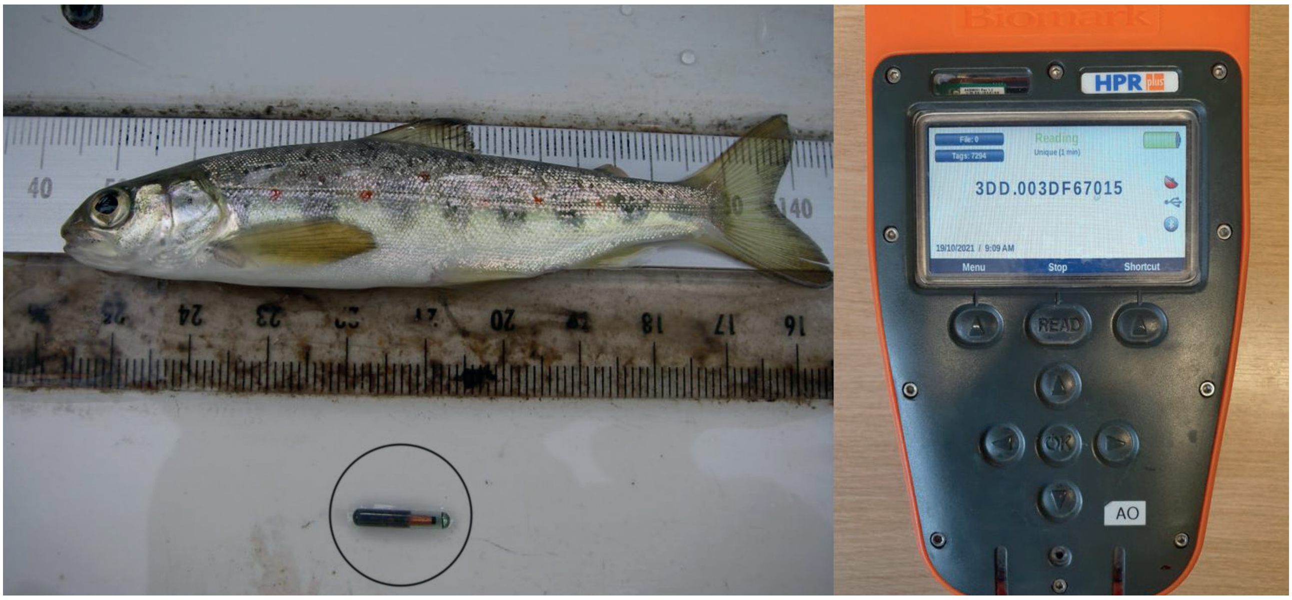
We have estimated the number of smolts emigrating from the river since 1995. Since 1996, we have used a BAFF to divert the smolts down the Millstream at East Stoke, where we now have our smolt trap. In the Millstream, the smolts pass through the Fluvarium channels where PIT-tag antennae detect the tagged smolts. On leaving the Fluvarium they encounter the Wolf trap (prior to 2024 the RST) where a proportion of the smolts migrating down the Millstream are intercepted.

In most years the BAFF and the RST/Wolf trap are operational from the 25 March until the smolt run ends sometime in early to mid-May. The trap is operated most days throughout the trapping season with day and night shifts. When in operation, we check and empty the trap every 30 minutes. Biometrics of all intercepted smolts are recorded and we take a scale sample of a stratified subset of smolts. Smolts without an adipose fin have their PIT-tag scanned before recording biometrics and taking a scale sample. After processing, all intercepted smolts are released downstream of the trap.

The smolt estimate is derived from the number of PIT-tagged smolts detected at East Stoke and Bindon during the

Figure 13

Salmon parr and PIT-tag (circled). During tagging the PIT-tags are scanned by a reader and their individual IDs are stored against information on tagging location and fish biometrics



smolt run window (1 March to the 31 May) and the efficiency of the PIT-tag antennae (calculated from multiple antennae and the number of tagged smolts intercepted by the smolt trap). Because of the unknown efficiency of the main river antenna (next to the counter), we use detections from the Bindon antenna (set up in 2012) to estimate the main river antenna efficiency, including a survival parameter between Bindon and East Stoke (see Figure 4). More accurate smolt estimates have therefore been made since 2012. These annual tagged smolt estimates at East Stoke are then divided by the ratio of tagged to untagged smolts captured in the trap.

Adult estimate from the resistivity counter

The resistivity counter at East Stoke has been recording fish movement since 1973, and over the years the counter has been operated by several organisations: Freshwater Biological Association (1973-1989), Institute of Freshwater Ecology (1989-2000), and Centre for Ecology & Hydrology (2000-2009). In April 2009, the GWCT took over the running of the counter at East Stoke.

Currently, data are collected by the EA's Conductance sensor resistivity counter connected to three stainless steel electrodes mounted 45cm apart on the EA venturi gauging flume at East Stoke (NGR SY 867868). The counter works by constantly measuring the electrical resistance of the water. When a fish of sufficient size (larger than 45cm) passes over the electrodes the electrical resistance changes, which is registered as an event on the counter (see Figure 14-15).

Adult salmon data are presented for the period from the 1 February to the 31 January the following year. Past data and video observations indicate that most of the upstream movement of salmon on the Frome in January are spawning fish, and not fish from a new cohort that will be spawning later that year. Data are collected for both gross up- and down-stream events. The gross upstream number is the total number of fish moving upstream over the weir and the nett upstream number is the gross upstream number minus the gross downstream number. However, during January, February, March and April this year (2024), the downstream counts are not subtracted from the upstream numbers as a high percent-

Figure 14

Screen display from the computerised video verification system. The image shows a 78cm salmon ascending the weir

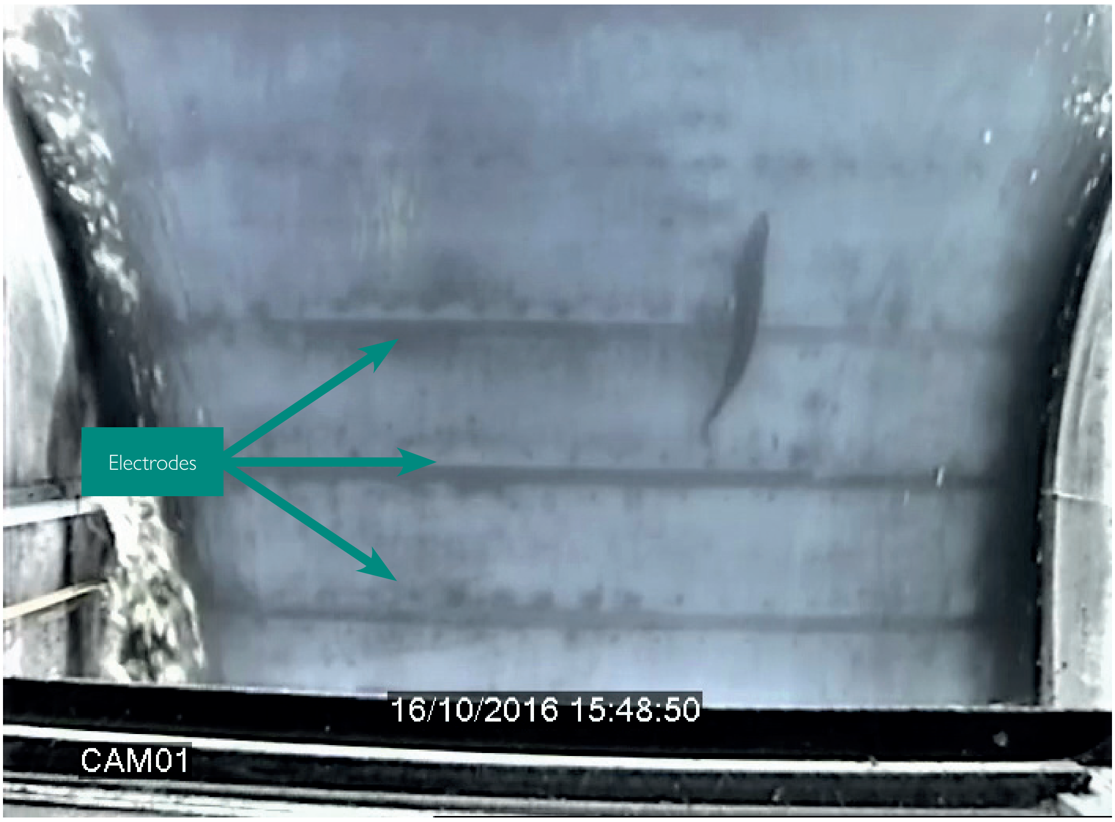


Figure 15

Change in electrical resistance of the water recorded by the trace computer during the event of an upstream migrating salmon

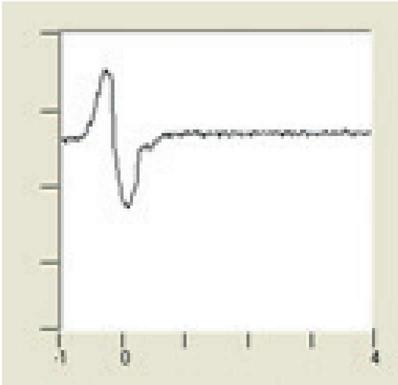


Figure 16
Two Atlantic salmon smolts of contrasting sizes

age are caused by downstream moving kelts (post-spawning individuals). Some kelts, however, carry out repeated up and down movement over the weir, and if down-numbers are not subtracted this can lead to over-estimating the number of upstream migrating fish. Therefore, where up counts have been caused by kelts, these are subtracted from the totals.

Until 1984, only gross upstream events were collected. These gross upstream numbers for the early years have since been adjusted by the relationship between nett and gross upstream numbers from subsequent years so that the presented data represent a nett upstream estimate.

Data verification

To ensure that the data collected from the resistivity counter are ecologically meaningful each recorded event must be verified and at GWCT, large resources are allocated to verify the data from the East Stoke resistivity counter. The data from the resistivity counter are verified by a combination of computer trace analysis (change in electrical resistance) and digital video image analysis.

Raw data events recorded by the resistivity counter are verified by first assessing the shape and magnitude of the waveform trace generated by the computer interpretation of the change in resistance of the water (see Figure 15) followed by viewing the corresponding video records (see Figure 14). In 2016, we upgraded our Video Home System (VHS) to a Digital Video Recorder (DVR) timelapse that allows us to store all the images we record from the counter.

There are multiple reasons for triggering a raw data event (e.g., salmon, sea trout, other fish, or anything more or less conductive than the water), so using the two methods above enables us to assign each event to a category. For example, during periods when the computer trace data are not operational, counts are assessed by direct examination of the video records, whereas the event evaluation is based on the trace signal analysis only during periods when the turbidity is too great to use the video records.

Assigning sea age contribution to adult run

We use the video images of upstream migrating fish to estimate their length (see Figure 15). These length estimates (±5cm) are used to estimate the proportion of 1SW and MSW salmon among the upstream records (see Figure 10). It is not possible to accurately distinguish 2SW fish from 3SW fish using these images hence we refer to them as MSW. Further, we are only able to record the lengths of fish when the water is sufficiently clear. Due to high discharge and turbidity in 2024, the number of lengths recorded was lower than usual.

Historically, we used 74cm as the upper size limit of returning 1SW salmon. However, in recent years we, and other researchers (e.g., Trehin et al., 2021), have observed that the minimum length of returning adult salmon appears to be getting smaller. As a result, in 2018, we adjusted the upper size limit of 1SW salmon to 72cm. Since 2014, we have included data from fish (identified as salmon) larger than 45cm, whereas in earlier years only fish larger than 49cm were included. We are continuously assessing the upper size limit of 1SW fish from the scales of returning salmon.

Marine return rates

We have reported the marine return rates to the International Council for the Exploration of the Sea (ICES) since we first started quantifying the number of emigrating smolts. From the installation of PIT-tag antennae (see Figure 5) at Bindon Abbey in 2012, marine return rates have been estimated from the detection of PIT-tagged adults. The total number of returning PIT-tagged fish is estimated using a mark-recapture calculation from detections made at East Stoke and then Bindon Abbey. To estimate the total number of returning adults, the estimate of returning PIT-tagged adults is divided by the proportion of tagged smolts in the given smolt cohort based on data from the smolt trap.

Conservation limit

The EA produces an annual egg deposition estimate for all the 42 principal salmon rivers in England. This egg deposition estimate is based on the estimated number of salmon returning to the individual rivers, their sea age distribution, the proportion of females and their estimated fecundity. For most rivers this information is deduced from declared angling catches but on the River Frome, and other rivers with fish counters or adult traps, the calculation is based on the fish counter data. The egg deposition estimate is used to evaluate if the salmon stock in the river is reaching its conservation limit or not. The conservation limit for the River Frome is set at 1.5 million eggs.

Collection of environmental data

In conjunction with data on the salmon population, daily rainfall and 15-minute water and air temperature readings are collected using purpose-built instrumentation at East Stoke.

Figure 17
Floating PIT-tag antennae are part of the PIT-tag systems on the River Frome at East Stoke

Game & Wildlife CONSERVATION TRUST

THE MISSING SALMON ALLIANCE

Acknowledgements

We would like to thank the Environment Agency and the Missing Salmon Alliance for its financial support to the data collection, and Cefas for its continued contribution to the River Frome PIT-tagging programme. We would also like to thank organisations previously in charge of running the resistivity counter for the use of the early data and all the land and fisheries owners in the catchment for giving us access to their land enabling our work to continue. We would like to thank the trustees of the Valentine Trust and The Alice Ellen Cooper Dean Charitable Foundation for the continued support of our work.

The River Frome counter which was installed in 1970.

5. Automating fish detection on salmon counters

The GWCT's fisheries team have begun trialling deep learning modelling methods to process our resistivity counter data more accurately and efficiently. We use these counter data to count fish in the river. Deep learning models are a type of machine learning which uses artificial neural networks to perform computations on large amounts of data. As fish pass over the resistivity counter large amounts of trace waveforms are produced for which salmonids can be identified from the specific waveforms produced. The team also collects large amounts of video data to help confirm waveform identifications and narrow down this identification to a species level (salmon or trout) when the image is clear enough. Various deep learning models have been used to facilitate automated identification of salmonids (Atlantic salmon and sea trout), and to estimate their length. The new method is being compared with traditional salmon estimates with exceptional results.

On the River Frome, in Dorset, we have been collecting data on adult Atlantic salmon returning from the sea since 1973. Various pieces of equipment have been used to collect and interpret these data, notably the use of a resistivity counter which produces trace waveforms and video recordings, when fish swim past our counter. From the resistivity counter, passing salmonids (salmon and trout) can be identified from distinctive waveform signals as they pass over the electrodes (see Figure 1). To date, to obtain estimates of the number of passing Atlantic salmon, hundreds of hours of staff time has been required to manually examine 1,000s of waveform signals and their associated video images. Salmon identification is then based on existing knowledge of salmon migratory periods and their body length and shape at the time of migration.

Within the fisheries team, we have implemented a series of deep learning models to automate identification of salmonids from these waveform and video images (see Figure 1 and 2). Although this work is not yet complete, our results have led to an increased number of returning salmon identified compared with the traditional method.

Specifically, from the trace data, we were able to detect 43% more salmonids (Atlantic salmon and anadromous brown trout) waveforms than the traditional method (with some 7% more salmonids >30cm, since the new method can also process juveniles). The modelling method to detect Atlantic salmon from video data correctly identified salmon with 81% accuracy and measured the lengths of >20% more returning adults than traditional methods. This new method also far outpaces traditional counting methods in terms of time taken. Beyond identifying salmon, we are also able to identify other species, with a confidence estimate attached to each. Over the coming year we hope to have completed this work and gained increased accuracy for species identification, abundance and length estimates.

The team are working with the Environment Agency (EA) to be able to trial these techniques on another salmonid river for validation. Initial exploration has shown that, because of better quality images on other rivers (the River Frome's water is quite murky), more accurate identification should be achieved. It is hoped that, with the support of the EA, we will be able to roll this out at a national level. ■

Figure 1

Examples of data generated by the resistivity counter on the River Frome. The characteristic waveform data generated by (a) a salmonid, and (b) background noise (note different y-axis)

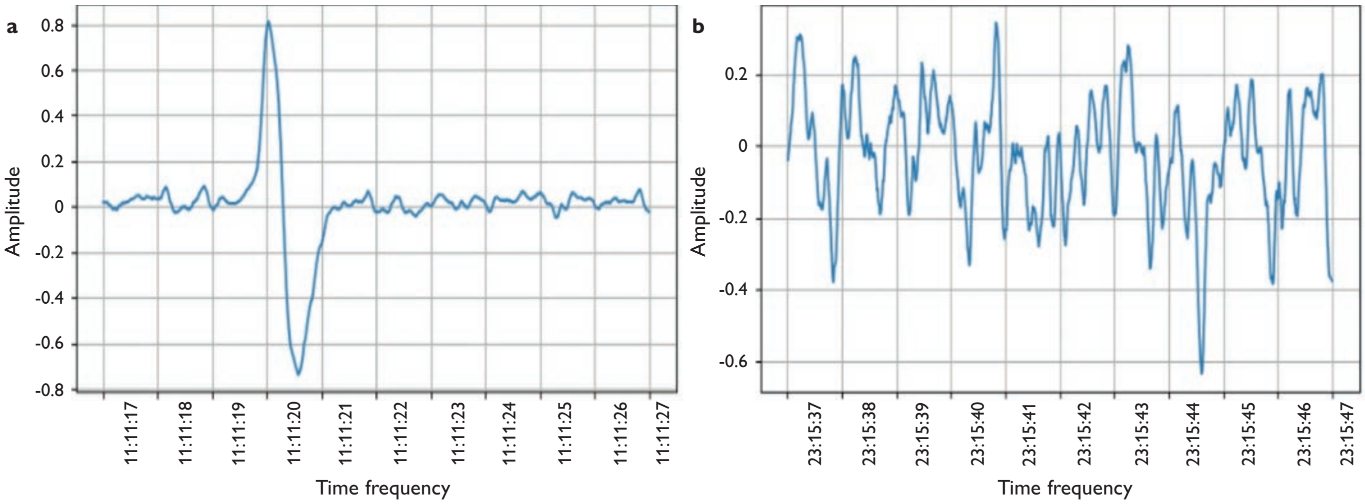


Figure 2

Automated fish identification from deep learning modelling techniques on the River Frome using video data with individual species identification confidence (between 0 and 1). (L-R) Eel, salmon and mullet

KEY FINDINGS

- Deep learning models are being used to support salmon abundance estimates, using the River Frome's resistivity counter and video data.
- Although the complete dataset has not been analysed, we are able to detect more returning adult Atlantic salmon using these models compared with estimates from experienced fisheries scientists.
- Specifically, the new waveform part of the deep learning model was able to detect 43% more salmonid waveforms than the traditional method was able to detect (with some 7% more salmonids >30cm, since the new method can also process juveniles).
- The deep learning video analysis models were able to detect salmon with 81% accuracy from testing data and measure the lengths of >20% more returning adults than traditional methods.
- These methods are currently being expanded to identify other endangered diadromous fish (eg. the river and sea lamprey, and European eels).

Sophie Elliott & Keerthan Boraiah

Grayling and brown trout on the River Wylye

The European grayling is a member of the salmonid family, found in the UK and central and northern Europe. It is typically a freshwater species which, owing to its distinctive large and iridescent dorsal fin and streamlined body-shape, is affectionately known as the 'Lady of the Stream'. The Wylye Grayling and Trout Study (WGTS) has been monitoring European grayling and brown trout since 1996 on the River Wylye, a tributary of the Hampshire Avon. This makes the dataset one of the longest continuous time series of a European grayling population.

Since 1996, European grayling and brown trout have been monitored on the River Wylye, a tributary of the Hampshire Avon (see Figure 1). The annual fishing survey, which is supported by the GWCT, the Grayling Research Trust, and the Piscatorial Society, takes place each autumn. Survey methods have evolved with improvements to telemetry technology and increased capacity. Six sites have been continuously monitored since 1996, and from 2009 onwards, have been quantitatively electro-fished (ie. multiple fishing passes) to collect data on numbers of grayling and brown trout, as well as morphological data, such as length and weight. Additionally, since 1999, all caught grayling are tagged so that we can monitor movements, growth, and survival of recaptured individuals.

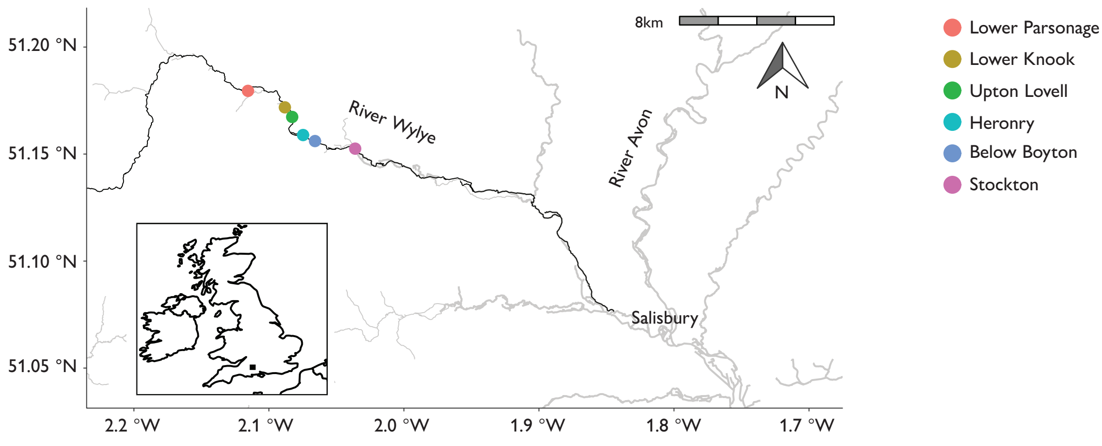
Long-term monitoring is a powerful tool in the management and conservation of species. Only with consistent surveying of populations can we build up time series data to be able to detect trends over time. Grayling abundance, while fluctuating between years, appears to have declined over time, with the mean number of newly caught grayling in a single fishing pass since 2018 (ranging from nine to 18) consistently below the long-term average (n = 34) (see Figure 2a). Similarly, mean abundance of small trout (≤ 150mm in length) caught in a single fishing pass has declined from 69 to 29 between 2018 to 2024 (see Figure 2b). Comparatively, mean abundance of larger trout (> 150mm in length) caught in a single fishing pass appears to have increased over time, from 63 to 84 between the first half (1996 to 2010) and second half (2011 to 2024) of the time series (see Figure 2b).

Detecting trends is an essential first step in understanding the status of a population; determining what is driving trends is often more difficult as the availability of covariates describing potentially influential biological and environmental factors is often limited and generating robust estimates of population structure can require bespoke analysis. Nonetheless, previous GWCT studies using these grayling data (see *Review of 2018,* pp.32-33 and *Review of 2020*, pp.58-59) have identified several factors considered detrimental to both survival and growth of grayling at various life-stages. These include low flow and high temperature events during summer and increased macrophyte cover. In June this year, these findings were presented to members of the Trout and Grayling Group (Environment Agency and Natural Resources Wales), in discussions shaping the group's future grayling research priorities at a meeting hosted by the GWCT and the Piscatorial Society on the banks of the River Wylye.

The 2024 survey was successfully completed despite challenging field conditions following the unusually wet spring and summer months. We caught a total of 127 grayling and a total of 949 trout. Grayling body length ranged from 106 to 416mm with a mean length of 265.5mm and the length of trout ranged

Figure 1

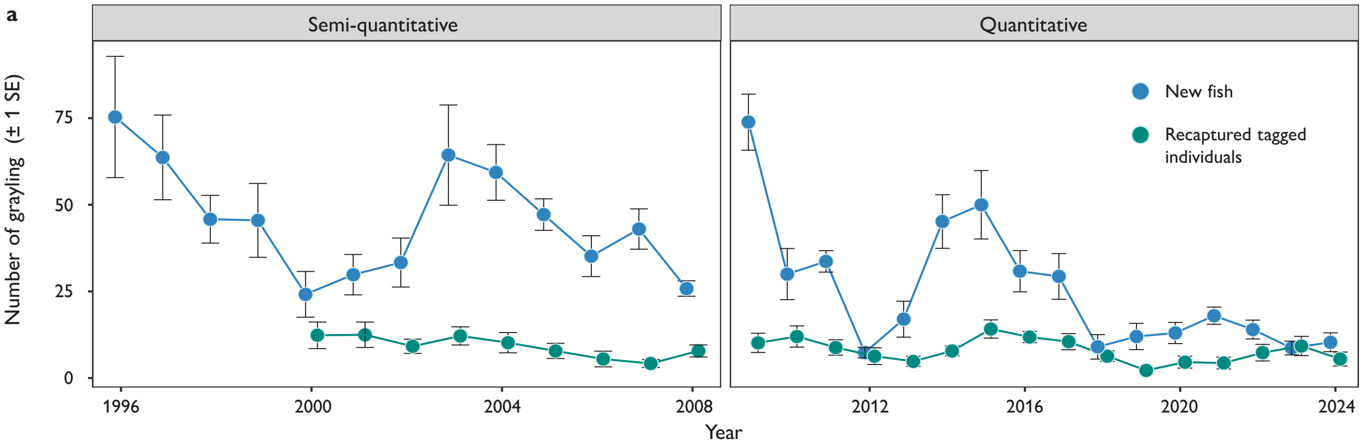
Location of the six long-term monitoring sites on the River Wylye (main channel shown in black) and its situation within the Hampshire Avon catchment, and the location of the Hampshire Avon (black rectangle) in the UK (inset map)

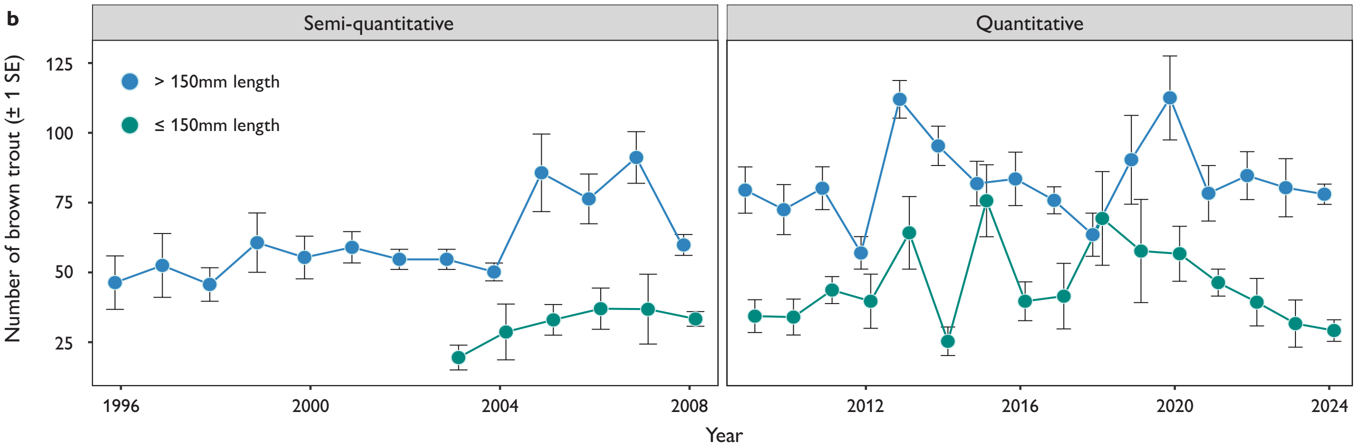


from 68 to 408mm with a mean length of 184.3mm. Of grayling caught in the first fishing pass, the percentage of age 0+ grayling was lower (11.8%) than the long-term average (30.8%) and the percentages of ages 1+, 2+, 3+ and 4+ were higher (42.2%, 25.5%, 12.7%, and 7.8%, respectively) than the long-term averages (33.4%, 19.9%, 10.1%, and 4.1%, respectively). We always aim to review and improve our sampling methods for the benefit of the study species as well as the data collection. This year we trialled a new tagging method for grayling older than 0+, reducing the amount of processing time and thus, the time that the fish spent out of the water. We have also expanded the data collected on trout to include weight, a useful metric for assessing condition of individuals. Next steps for the Wylye study will be to understand better the drivers of changes in grayling population dynamics, particularly under predicted climate change scenarios, and to begin to use this valuable dataset and the research to date, to implement and monitor management actions that aim to improve habitat conditions for this iconic species. ■

Figure 2

The mean number of a) grayling and b) brown trout caught during electro-fishing on the River Wylye over time. Grayling are categorised as newly tagged fish or recaptured tagged individuals, and trout are classified by length: > 150mm and ≤ 150mm. Panels indicate the change in electro-fishing methods over time from semi-quantitative (single-pass fishing, 1996 to 2008) to quantitative (depletion electro-fishing, 2009 onwards)





KEY FINDINGS

- 2024 marked the 29th year of data collection for European grayling on the River Wylye.
- Since 2018, the mean number of newly caught grayling in a single fishing pass (ranging from nine to 18 between years) has been consistently lower than the long-term average (n=34) and well below the peak in 1996 (n=75). Similarly, mean abundance of small brown trout (≤ 150mm in length) caught in a single fishing pass has declined from 69 in 2018 to 29 in 2024.
- In contrast, mean abundance of larger brown trout (> 150mm in length) caught in a single fishing pass appears to have increased across the time-series, from 63 (1996 to 2010) to 84 (2011 to 2024).
- In the 2024 survey we caught 127 grayling and 949 brown trout.

Jessica Marsh

Beaver dams and brown trout

The return of Eurasian beaver to large areas of Europe represents a conservation success with the current European population estimated to be around 1.2 million individuals. Beaver reintroduction to many areas, including Great Britain, has been controversial in some cases. Despite numerous documented benefits for biodiversity, concerns related to localised flooding, adverse impacts on land use and engineered structures (eg. culvert blockage), and disease spread have been raised. An important concern is the influence of beaver habitat modifications on fish that need to migrate up and down rivers. This is particularly important in relation to the migratory behaviour of economically important salmonids such as brown trout and Atlantic salmon, the latter now classified as endangered in Britain.

We investigated the impacts of a series of four beaver dams on the upstream movement of brown trout during the spawning period (October to December) at a field site in Scotland, quantifying the possible impact of beaver dams on the movements of brown trout (hereafter trout). Individual motivation was assessed through movement patterns based on telemetry data with some individuals displaying highly motivated movements, while others showed no movements during the study period. The study site comprised two streams entering a common loch, one modified by a series of four beaver dams, the other remained unaltered (see Figure 1).

Electro-fishing was used to capture trout in both streams and the loch from autumn 2014 to autumn 2016. Trout were anaesthetised, fork length and weight were recorded, and trout greater than 80 millimetres (mm) were PIT-tagged (n = 701). To establish if passage success was related to flow conditions, rainfall data were obtained from a local weather station six kilometres from the site.

PIT telemetry antennae were installed below and above each dam to monitor the passage of trout during the monitoring period. This included trout spawning movements in 2015 (high flows) and 2016 (low flows).

There was a distinct difference in passage success between years, with high flows (using prior rainfall as a proxy measure) and larger fish size being important positive predictors of upstream passage success. A combination of environmental (prior rainfall and water temperature) and biotic (fish size) factors influenced passage success with high flows being a significant factor at all four dams used to define trout passage dynamics. This provided the best explanation for fish passage at two of the four dams. Survival analysis and associated modelling indicated that migratory delay was inversely related to previous passage success (see Figure 2), while motivation was also a determinant of success, with the highest probability of passage in highly motivated trout. Beaver dams may pose a greater challenge in the future due to shifting climatic conditions if periods of warmer and drier weather persist and coincide with peak migratory movements of fish. ■

Figure 1

Study site where the movements of brown trout were investigated in response to fluvial landscape modification by Eurasian beaver. The map illustrates the modified stream post-beaver modification and the surrounding landscape and habitat types. The inset map illustrates an overview of the site, with the loch in the north and control stream to the east of the modified stream. The position of beaver dams, passive integrated transponder (PIT) loops (to monitor fish movement), and water data loggers (to monitor depth and temperature) are indicated

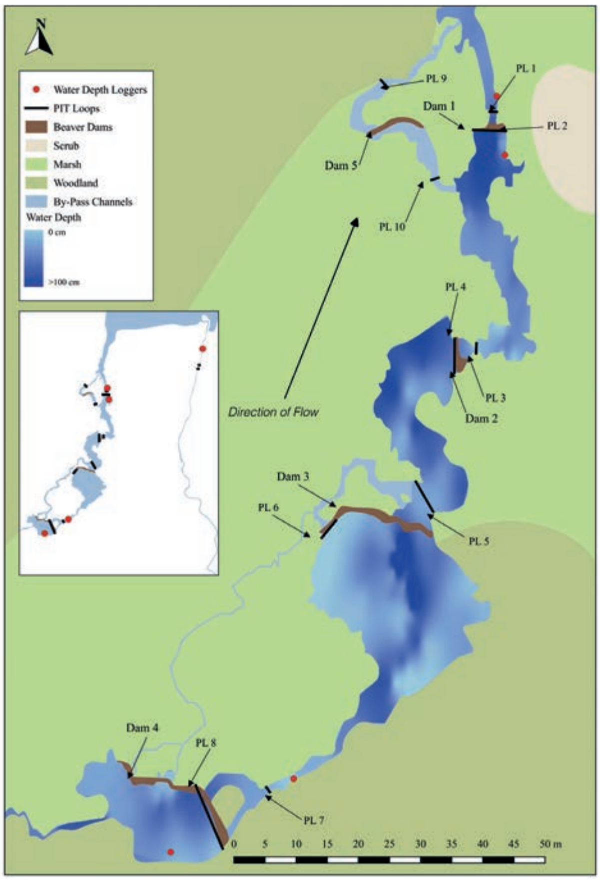
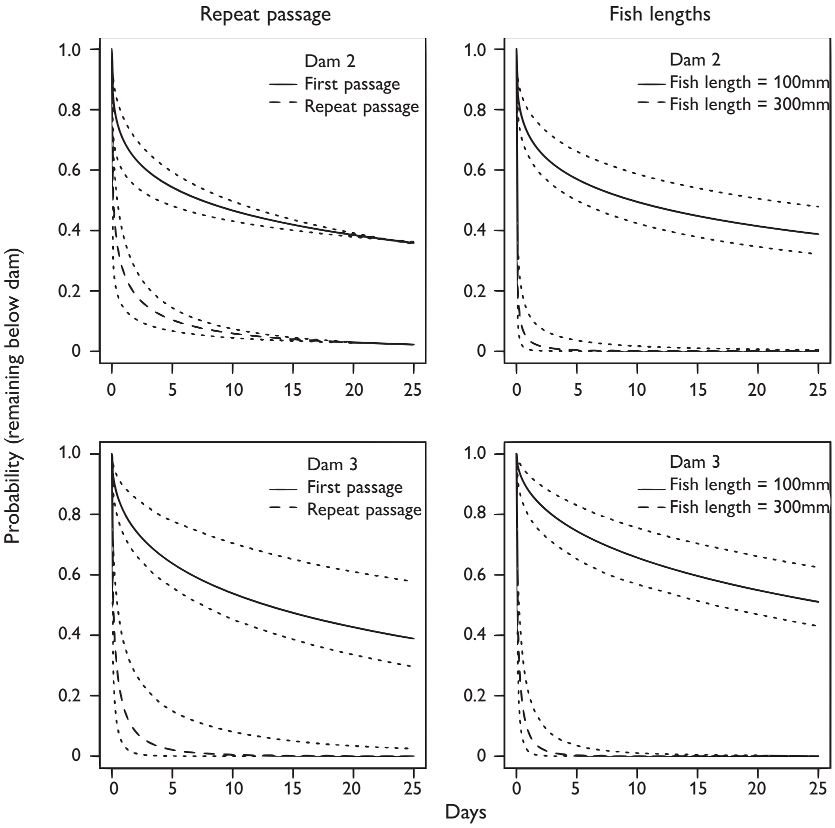


Figure 2

Passage prediction plots, illustrating how the probability of remaining below a dam (ie. failing to pass a dam) is affected by two fish characteristics. 1. Whether a fish was attempting their first passage or whether this was a repeat passage; 2. Fish size fork length of 100mm versus fish with fork lengths of 300mm. The solid and dashed lines represent estimated proportion remaining, and the dotted lines indicate 95% prediction intervals



PIT telemetry antennae were installed above and below each dam to monitor the passage of trout.

KEY FINDINGS

- Given the right environmental and biotic factors, brown trout are capable of passing beaver dams.
- Under certain conditions, beaver dams can impede the movement of brown trout.
- The barrier effects of beaver dams are exacerbated under low flow conditions.
- Shifting climatic conditions may result in beaver dams presenting a greater challenge at times of peak migratory movements of fish in future.

Robert Needham

Eels are caught at night using a special net.

DID YOU KNOW?

Eels can take on oxygen and survive both under water and on land. They have gills like other fish but can also use their mouth and gills as a rudimentary lung which allows them to survive out of water.

Slippery work – the mysterious lives of eels

Eleanor Williams reports on a challenging new project for the fisheries team

For a fish that has been around for millions of years – one that has long been culturally and economically important to us – we know very little about eels.

The European eel has declined by around 90% since the 1980s and is one of only a few UK species considered to be 'critically endangered'. It is disappearing faster from our rivers than any other fish, despite being considered one of the toughest and most resilient of fish species.

Eels hatch in the Sargasso Sea near Bermuda and spend about three years drifting across the Atlantic Ocean on the Gulf Stream. They arrive in Europe as glass eels that then become elvers and swim up rivers and waterways across the continent. They can spend decades living in the riverine environment before they migrate back across the Atlantic to the Sargasso Sea, where they spawn and die.

Eels typically live for 15-20 years, but some are known to live past 80 years. Despite being one of our longest living river inhabitants, little is known about their life and what triggers the start of an eel's migration.

Will Beaumont is leading the fisheries team's latest project which involves tagging eels in a bid to better understand their movements in our river and waterways, and monitor the start of their migration from the UK across the Atlantic Ocean. In June 2024 they caught, tagged and released around 74 eels in the River Frome near Wareham.

The eels were trapped overnight and processed in a mobile riverside laboratory the next day. Each eel was weighed, measured and the smaller ones fitted with a PIT tag – the kind of 'microchips' used in cats and dogs – while the larger eels were fitted with both acoustic and PIT tags.

A second phase will take place this autumn when the team plan to trap and tag mature eels, known as silver eels, as they start their migration. These will be tracked on their way to the sea, and with luck, some way along the channel.

Eel tracking is an entirely new study area for the team, which has been monitoring the wild Atlantic salmon stocks on the River Frome for the past 50 years, as well as carrying out research into many other fish species.

Will is used to putting tags into wild salmon and sea trout, but said: "Tagging eels is a bit of a challenge. They require a lot of anaesthetic to go under, and their skin is pretty tough."

The eels carrying acoustic tags will have to swim within 400 metres of a receiver to be picked up, and the smaller eels need to be caught again in future surveys and scanned. The team have placed 35 receivers along the River Frome and in Poole Harbour. There is also one outside Plymouth and another near the Channel Islands.

The data collected will help researchers see what habitat the eels are choosing and how they move around the river

(Top) Eels are measured and tagged. Usually 45-65cm (18-26in) they rarely reach more than 1.0m (3ft 3in), but can reach a length of up to 1.33m (4ft 4in) in exceptional cases.

The European eel has declined by around 90% since the 1980s and is one of only a few UK species considered to be 'critically endangered'

catchment. It will also give vital information about the transit times through the different environments when they decide to start moving down the river, through the harbour and down the Channel. It can also highlight whether the eels prefer to stay higher up near the surface or lower down near the bottom when migrating and what the survival rates are for different environments.

The decline in the European eel population has been put down to several factors, including a parasitic worm that infests the swim bladder, illegal fishing, water pollution and habitat loss. Will explains: "We do know they are one of the toughest fish species we have, but we still seem to be managing to wipe them out. If we want to save them, it is extremely important we get a better understanding so we know how to stop them from disappearing forever."

The project is a collaboration with the Environment Agency, CEFAS and Bournemouth University. ■

In Brief

CELEBRITY EEL

The oldest ever known European eel was a captive one named Ale that lived in a well in the Swedish fishing village of Brantevik and died in 2014 at the age of 155. Ale had lived in the well ever since he was released into it in 1859 by an eight-year-old boy, Samuel Nilsson.

Life stages of the European eel

- **Larvae *(Leptocephali):*** Eel hatchlings look nothing like adult eels, but more like tiny transparent leaves. They get carried on the Gulf Stream current from the Sargasso Sea across the Atlantic to the European continental shelf.
- **Glass eels:** At the continental shelf the larvae begin developing into glass eels which look like tiny versions of the adults but are still transparent and barely visible except for their backbone, which shows up as a dark stripe through their bodies. They swim to the coast where they find their way to fresh water.
- **Elvers:** The juvenile eels travelling up the rivers. These are often seen trying to climb obstacles in their way, sometimes even vertically, on their journeys up river.
- **Yellow eels:** Adults still growing and maturing while living their lives in the rivers and waterways.
- **Silver eels:** Adult mature eels that are ready to start their migration back to the Sargasso Sea and leave by swimming down river and out to sea.

This piece was first published in the GWCT's member magazine Gamewise Autumn/winter 2024.

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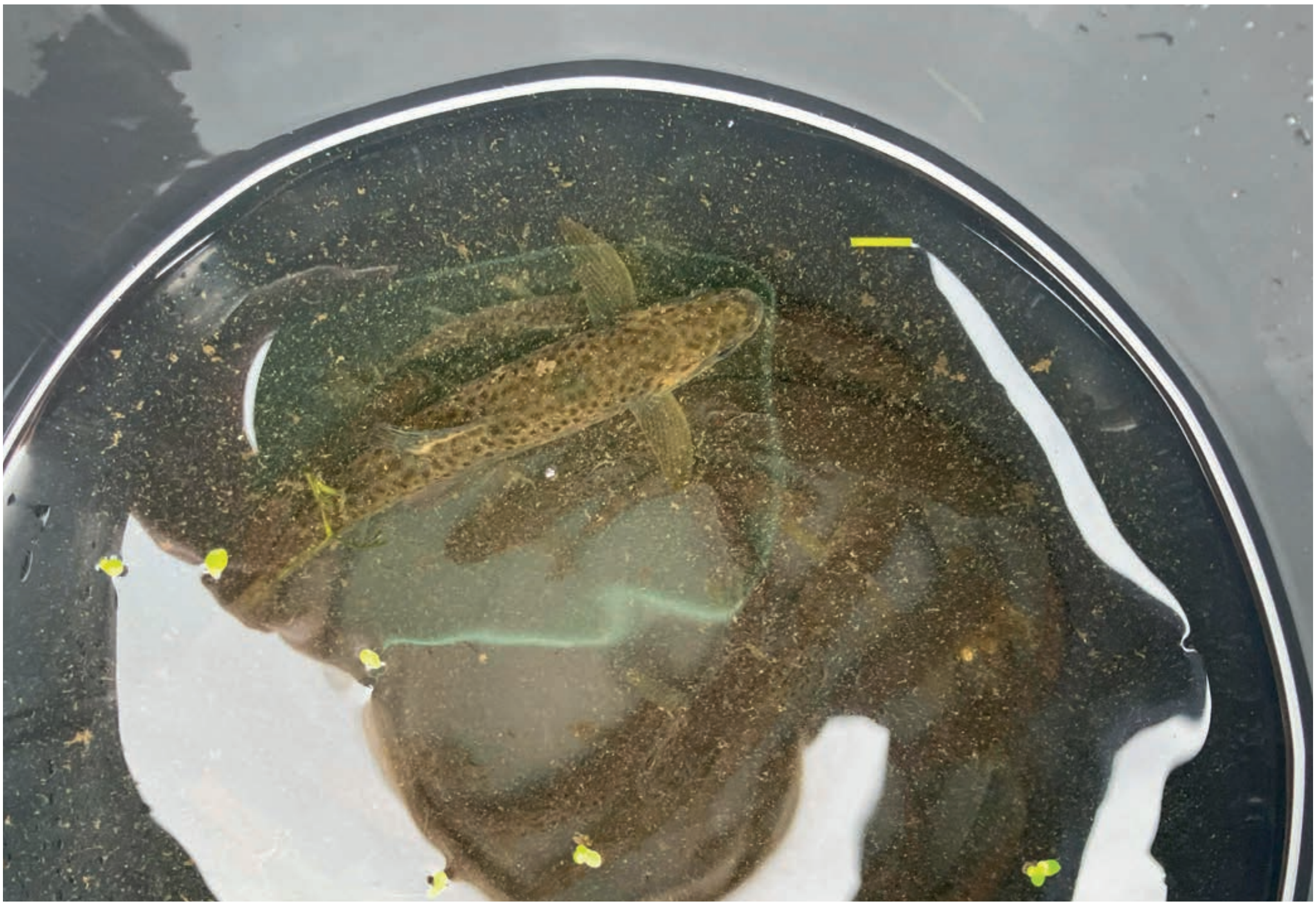

7. Scientific papers

GWCT has published numerous other papers from its salmon research, references from 2024 to 2019 are below. GWCT authors are in bold.

2024

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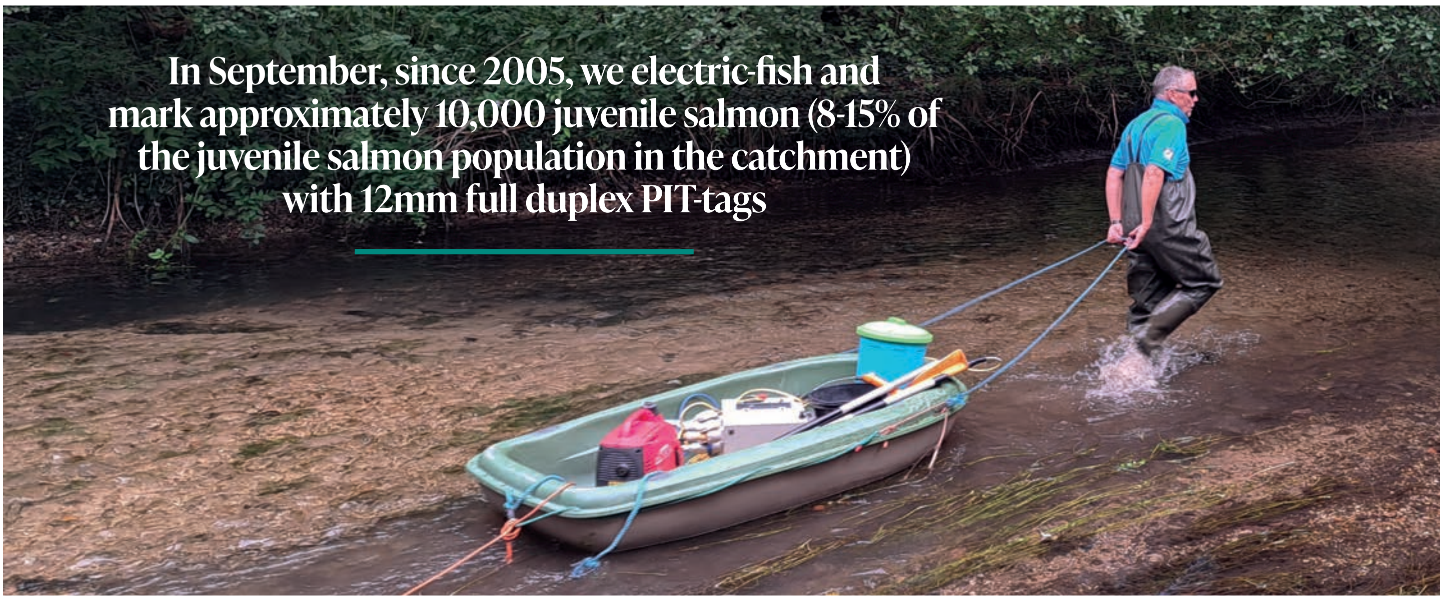

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Design and Layout: Louise Shervington

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