Game & Wildlife Conservation Trust 2022 River Frome Salmon Monitoring Report

Produced by GWCT's Salmon & Trout Research Centre

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This monitoring is part of the SAMARCH project and is part-funded by the EU's Interreg VA Channel Programme, **www.samarch.org**

Contents

Cover photograph: GWCT fisheries team electrofishing the River Frome.

The GWCT measures annually the juvenile and adult salmon population in the River Frome in Dorset.

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 2022 salmon year (1st February 2022 to the end of January 2023), followed by the methods used, which change minimally between years.

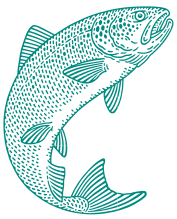
The nett upstream adult count of salmon for 2022 from the East Stoke resistivity counter was 628 fish, which is 8% up (575) from the last 10-year average (2013-2022), but down from previous 10-year averages (see Figure 1). The three largest salmon recorded by the video at the resistivity counter were all 100cm. The 2022 run of adult fish was dominated by 2-Sea Winter (2SW) fish from a large 2020 smolt cohort. Based on the individuals captured by the video we estimated that 37% of the 2022 adult run consisted of 1-Sea Winter (1SW), which is much lower than the 10-year average of 66%. As a result of the high proportion of Multi-Sea Winter (MSW) fish in the adult run, the estimated egg deposition was nearly double the conservation limit for the River Frome, boding well for recruitment from the winter of 2022/23.

Based on the detection of Passive Integrated Transponder (PIT) tagged returning adult salmon, the marine return rate of 1SW fish was 1.7%, which is well below the long-term average (2.8%). However, the return rate of MSW fish was 2.5% which is higher than the 10-year average (2.1%) (see Table 1).

We estimated that there was just over 99,000 salmon parr (0+) in the River Frome catchment in September 2021 which is 9% above the 10-year average (see Figure 2). Our 2022 salmon smolt estimate was 10,430 ± 1,320 (95% confidence interval), which is 10% above the 10-year average (see Figure 3). As a result of the 2022 smolt estimate, a good adult return from the 2022 smolt cohort is expected in 2023 and 2024.

HIGHLIGHTS

- The nett upstream adult count of salmon for 2022 from the East Stoke resistivity counter was 628 fish, which is 8% up on the last 10-year average (2013-2022), but down from previous 10-year averages.
- There has been an increase in MSW salmon (up 0.4% from the 10-year average) returning, but a decrease in 1SW salmon (down 0.6% from the 10-year average).
- Salmon parr (0+) in the River Frome catchment in September 2021 was 9% above the 10-year average.
- Prolonged low flows during March and April meant that most salmon smolts left the river two weeks later than usual between early and mid-May and largely during the daytime.
- The estimated number of salmon smolts at East Stoke in 2022 was 10,430 with a confidence interval of ± 1,320 (see Figure 3). This is 10% above the 10-year average (9,456).



The nett upstream adult count of salmon for 2022 from the East Stoke resistivity counter was 628 fish, which is 8% up on the last 10-year average (2013-2022), but down from previous 10-year averages

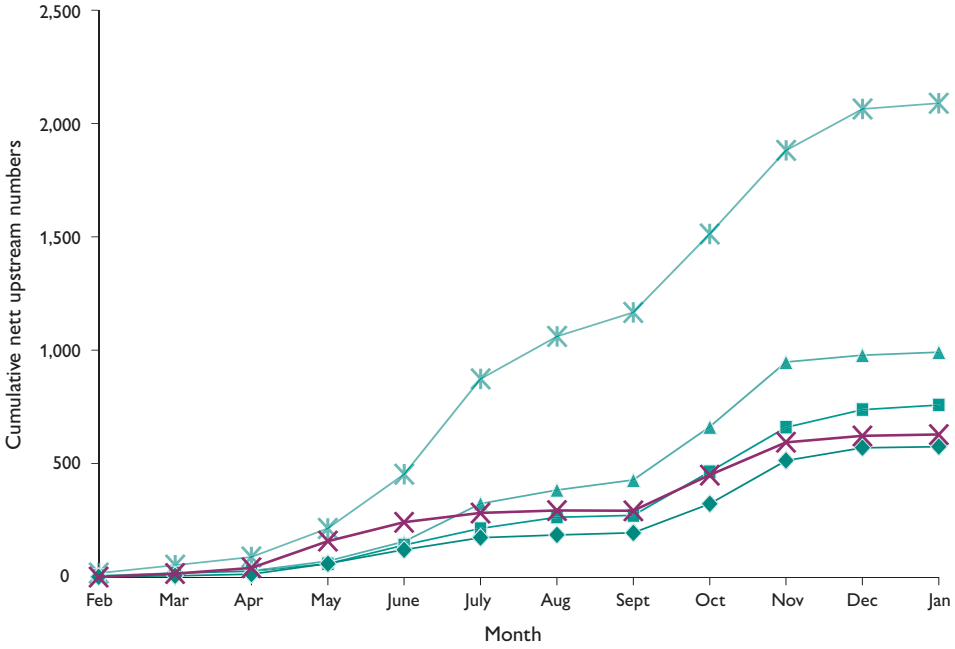


Figure 1
Cumulative nett upstream adult salmon count for 2022 and the average for the most recent 10 years recorded by the resistivity counter at East Stoke

MONTH	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	TOTAL
2022	0	15	25	118	83	41	11	-1	157	145	28	6	628
10-year average	1	4	7	47	61	53	12	9	128	191	57	5	575

TABLE 1

Marine return rates of River Frome salmon for individual smolt cohorts as reported to the International Council for Exploration of the Seas (ICES)

Smolt cohort	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average since 2011
1SW	1.2	3.1	1.5	2.0	5.9	4.4	2.6	1.6	4.7	2.2	1.7	2.8
MSW	1.6	2.0	2.3	2.6	2.8	2.0	1.9	2.0	1.8	2.5	N/A	2.1
Combined	2.8	5.1	3.8	4.6	8.7	6.4	4.5	3.5	6.5	4.7	N/A	5.1

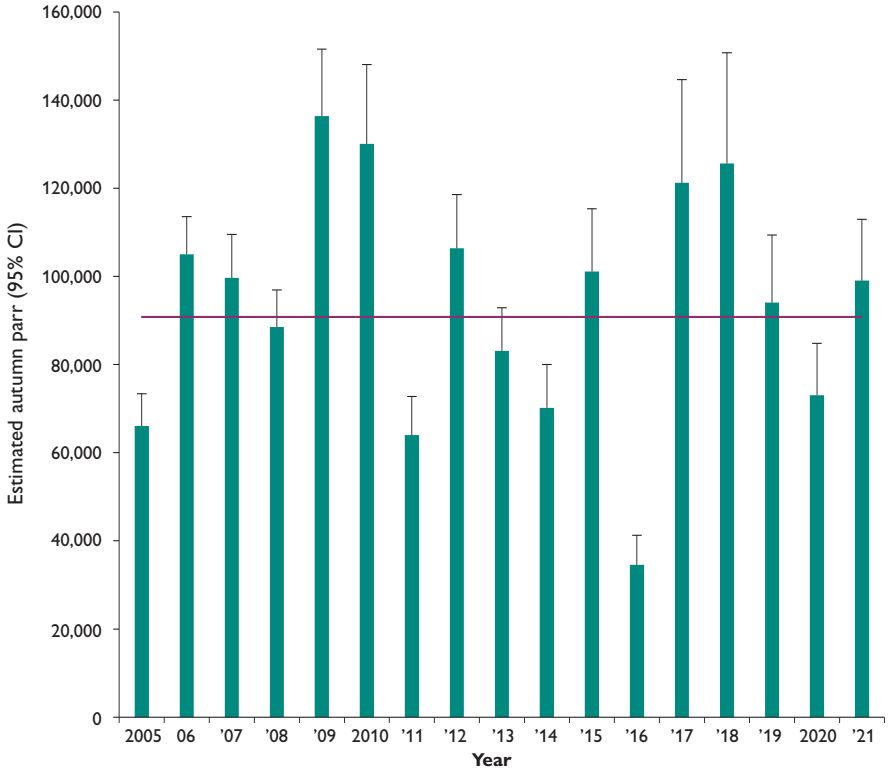


Figure 2

Estimated number of salmon parr (0%) in the Frome catchment in September with 95% confidence interval 2005-2021

Average for the most recent 10 years = 90,819

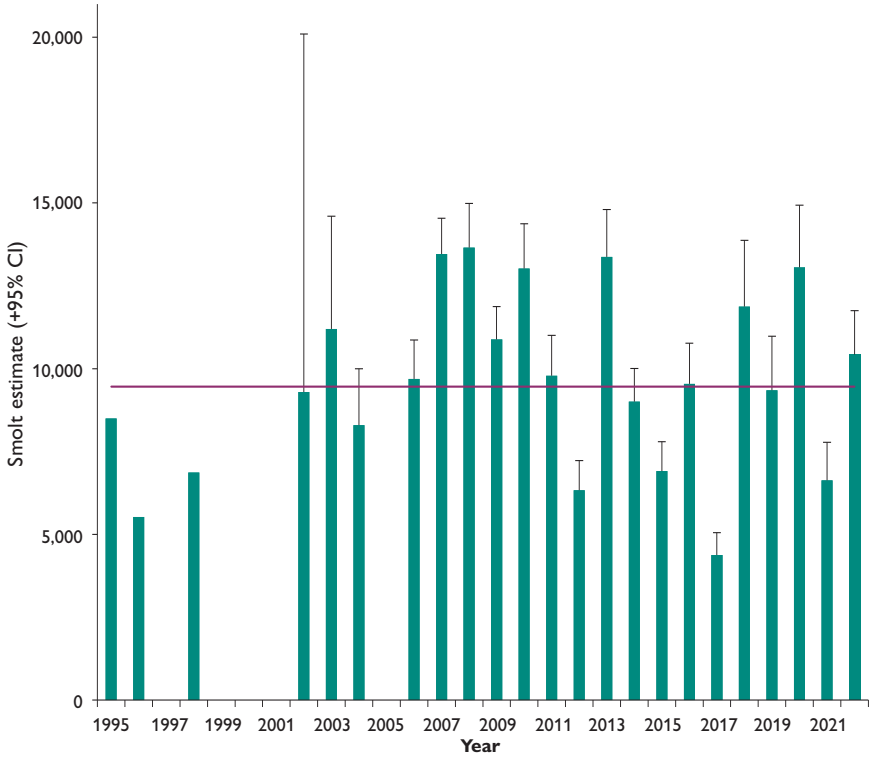


Figure 3

Estimated spring smolt population with 95% confidence interval 1995-2022

Average for the most recent 10 years = 9,456

These studies form part of the EU SAMARCH project part-funded by the Interreg Channel VA Programme via the European Regional Development Fund.

Full river coverage PIT-tag antenna readers are installed on the River Frome at four locations.

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 timing, which we relate to environmental factors (eg. 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 in the River Frome. These antennae, in conjunction with the annual parr tagging programme, enabled us to quantify the number of juveniles in the catchment, and the smolt output (eg. 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 (eg. 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 equipped with PIT-tag antennae (see Figure 5).

The combination of the adult resistivity counter and PIT-tag data offer a unique opportunity to answer questions about salmon life history that would be difficult to repeat on other rivers. The adult counter data gives us a long-term view of spawning migration timing, which can be related to its dependence on environmental conditions. The PIT-tag data enables 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 4

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

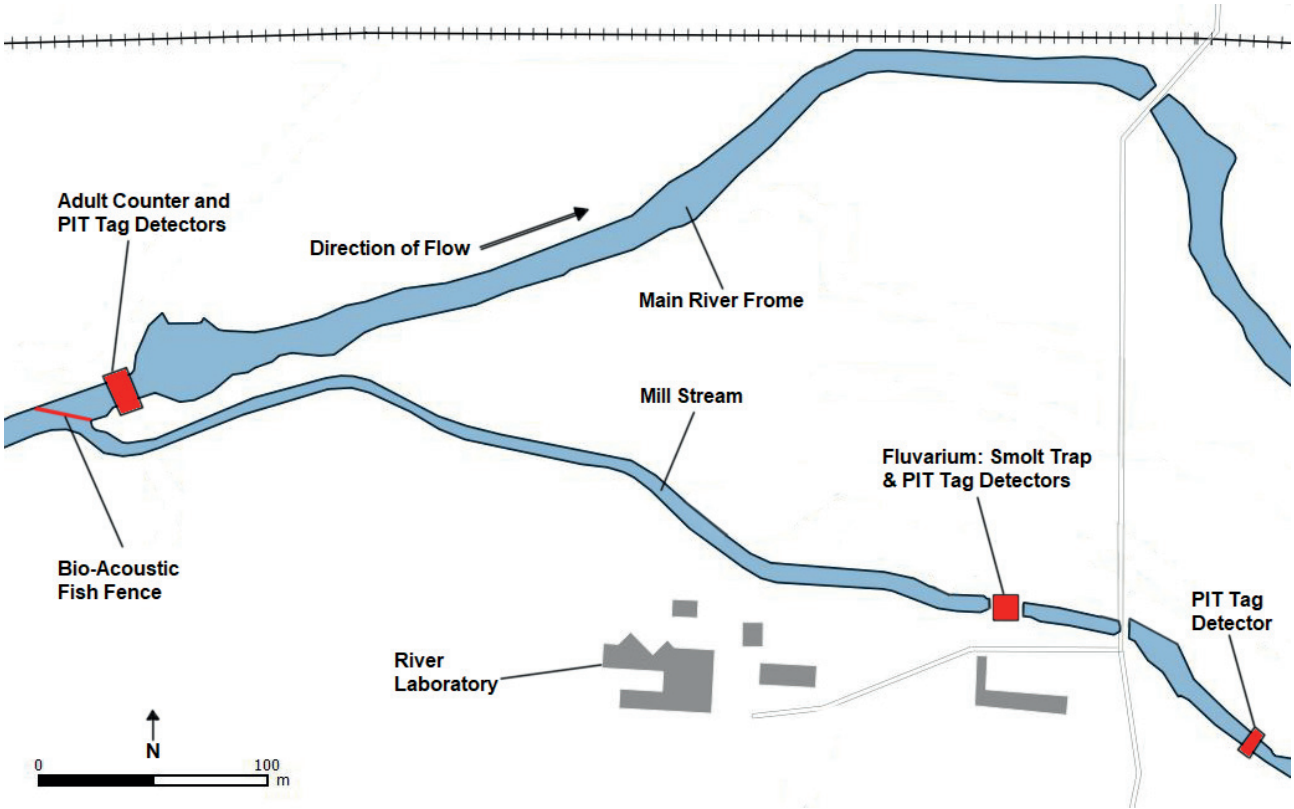
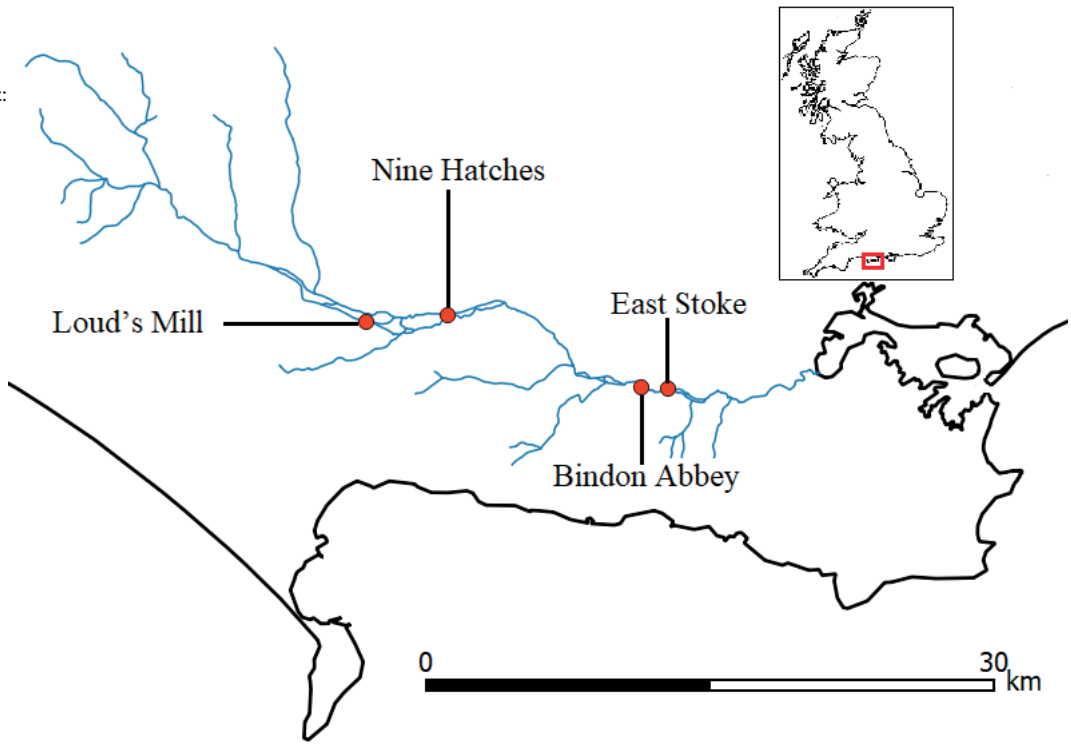


Figure 5

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



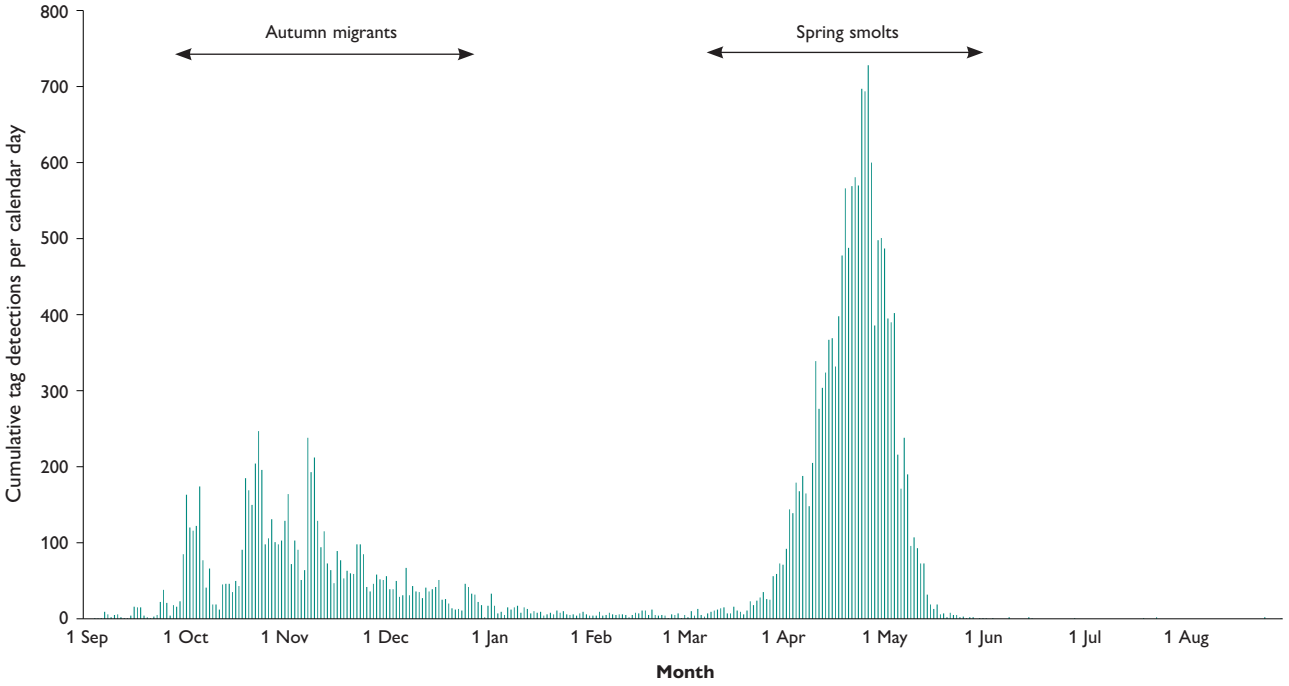
10,000 juvenile salmon are measured, weighed and PIT-tagged each September on the River Frome.

Juvenile movement patterns

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 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 significant downstream movement of juvenile salmon occurs during autumn and early winter in the River Frome (see Figure 6). Although this phenomenon had been reported before, the subsequent migration and life-history choices of juvenile salmon are less well understood. We undertook a detailed study of these autumn migrants, which indicated that this movement is an active decision to move downstream (ie. the fish are not just passively drifting downstream; Pinder et al., 2007; Ibbotson et al., 2012). 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. From the PIT-tag data, we have since recorded many returning adults that were autumn migrants, so we know that these fish do survive and contribute to the adult spawning population.

Figure 6

Records from more than 22,0000 PIT-tagged juvenile salmon detected at East Stoke between 2005-2022



3. Results

Autumn parr estimate

From the number of PIT-tags deployed the previous autumn and the ratio of tagged to untagged smolts intercepted by the smolt trap the following spring, we can estimate the number of salmon parr (0+) in the catchment at the time of tagging. The estimate for September 2021 is 99,037 (95% Confidence Intervals (CI) 88,188-112,930). This is 9% above the 10-year average (90,876; see Figure 2).

Smolt estimate

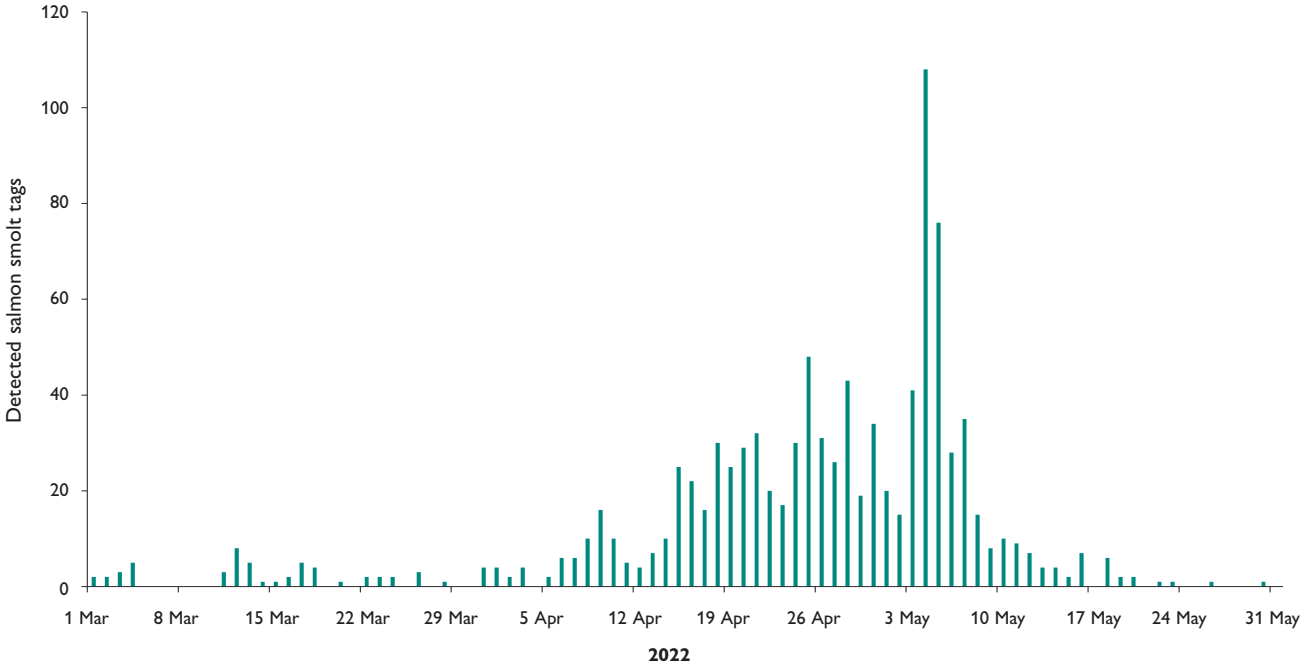
In 2022 we continued testing and optimising our in-house made Bio-Acoustic Fish Fence (BAFF), which diverts the smolts from the main river to the Millstream, where we have our smolt trap (Figure 4). Our in-house made BAFF is made up of two porous hoses which are laid on the riverbed and through which air is pumped, creating a curtain of bubbles. Six underwater speakers have also been attached to the hoses emitting a sound at 150 hertz (Hz). The combined system of the porous hoses and underwater speakers deflects more smolts down the Millstream than would have naturally taken this route. The preliminary results indicate that the deflection rate from this system is nearly as efficient as the commercial BAFF previously used and has cost-saving and logistical advantages as no diver is required for the installation enabling the system to be installed regardless of flow conditions.

The daily detection pattern of salmon smolts at East Stoke during 2022 is shown in Figure 7. In the second half of April, we only recorded 15mm of rainfall at East Stoke and, as a result of the low rainfall, there were no discharge events to trigger the smolts to leave the river during the main migration window between late April-early May. The peak of the smolt migration took place in the first week of May when increasing water temperatures incentivised the smolts to leave. As previously reported, when the average daily water temperature exceeds 12°C more smolts migrate during the daytime, and the warm temperatures in 2022 provided a good example of this. Fifty-six percent of the recorded tagged smolts were detected moving during the daytime, which is much higher than the 10-year average (25%).

The estimated number of salmon smolts at East Stoke in 2022 was 10,430 with a confidence interval of ± 1,320 (see Figure 3). This is 10% above the 10-year average (9,456), hence we are expecting; comparable with recent years a good adult run of one sea winter salmon (grilse) in 2023 and a good run of two sea winter salmon in 2024 from the 2022 smolt cohort if marine survival remains stable.

Figure 7

Daily numbers of PIT-tagged salmon smolts detected at East Stoke during spring 2022



Adult estimate

In late 2021 we installed new electronics for the resistivity counter, 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 14 for methods). Daily gross upstream and downstream counts together with mean daily discharge 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 cumulative monthly data (see Figure 1) for 2022 shows that there was a strong and early run of MSW salmon. By the end of May, we had recorded 158 MSW salmon, which is more than the 10-year average (59) for this period. These MSW salmon primarily originate from a large 2020 smolt cohort.
The return of grilse (1SW) fish from this cohort, in 2021, was disappointing. However, they returned as MSW fish in 2022. The number of 1SW salmon recorded was below average in 2022 but these came from a very small 2021 smolt cohort (see Table 2). The total annual estimate of 628 was 5% above the 10-year average (596; see Figure 9). With a high proportion of the 2SW salmon being female (Trehin et al., 2021) and, as the number of eggs per female is strongly related to body size, we expect this to result in an above-average egg deposition. Therefore, although the total number of adult salmon returning to the River Frome in 2022 was only average, the high proportion of 2SW salmon provides hope for strong recruitment from winter 2022/23.

Figure 8

Daily gross up-stream (green bars) and downstream (orange bars) counts for 2022 and the associated daily mean river discharge (purple line)

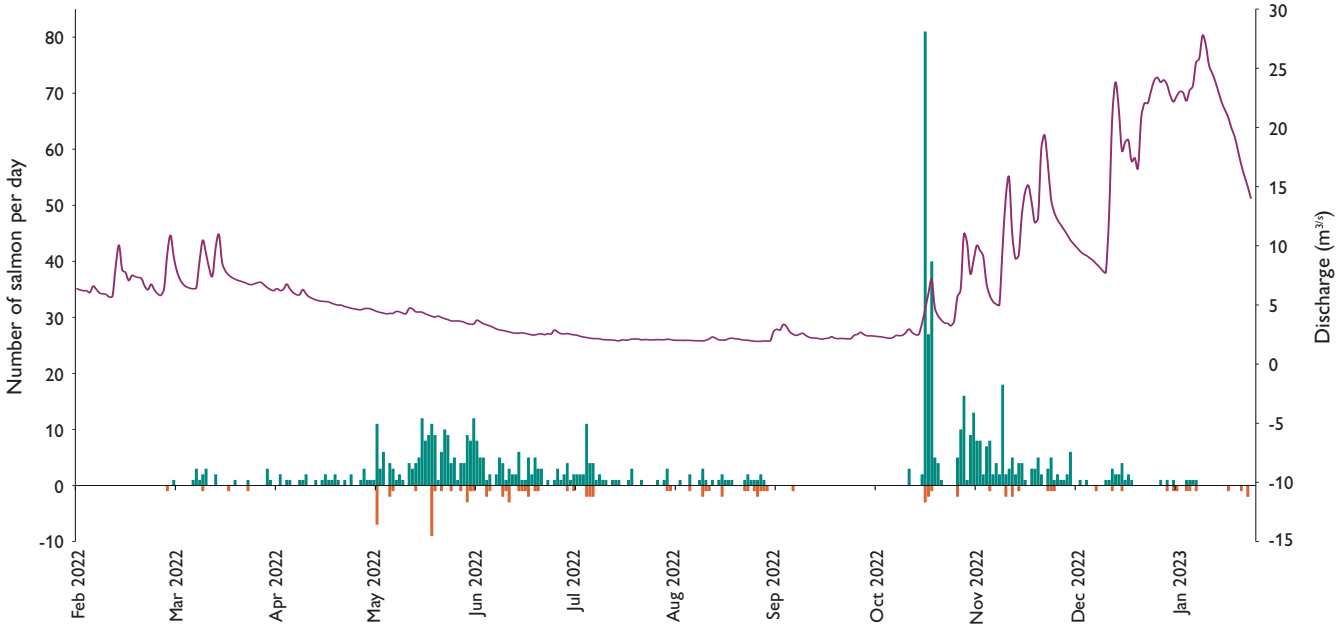


TABLE 2

Monthly salmon data: Note that the data from January to March are corrected so as not to include kelts vacillating on the weir

2022	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan '23	Total
Gross U/S	0	15	25	142	104	49	25	3	163	155	32	7	**720**
Gross D/S			0	24	21	8	14	4	6	10	4		**91**
Nett U/S		15	25	118	83	41	11	-1	157	145	28	6	**628**

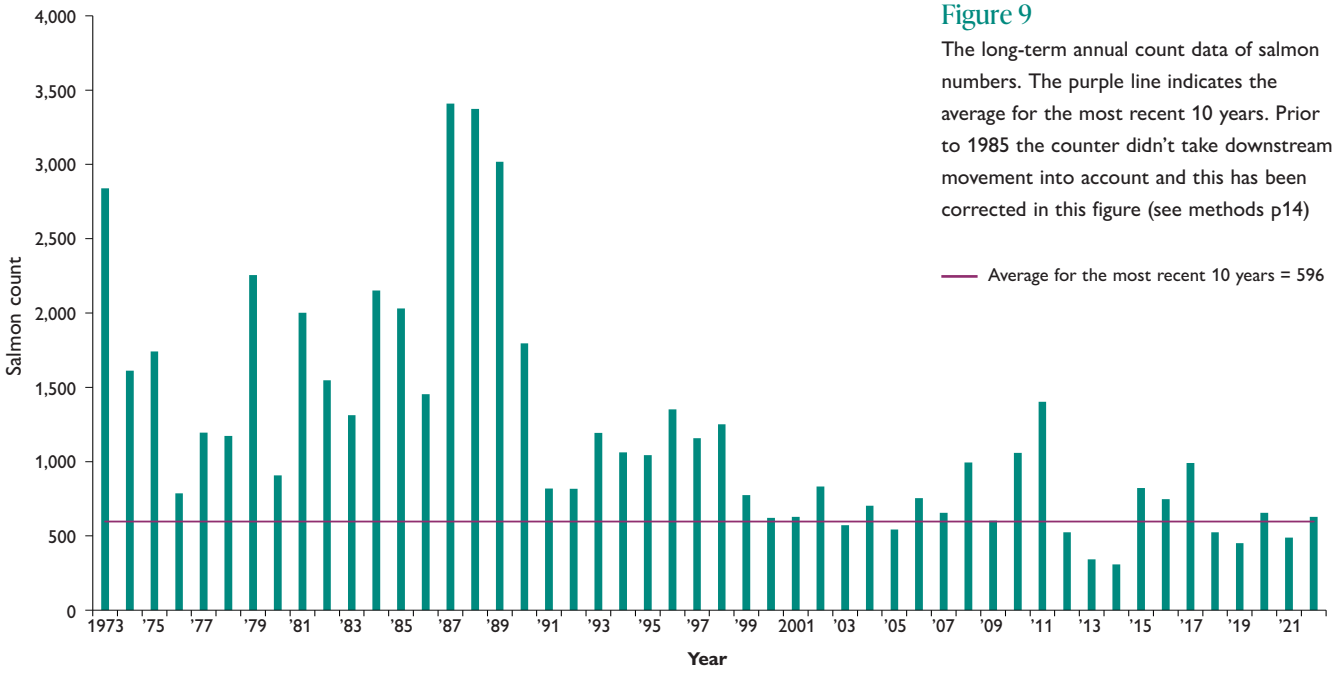


Figure 9

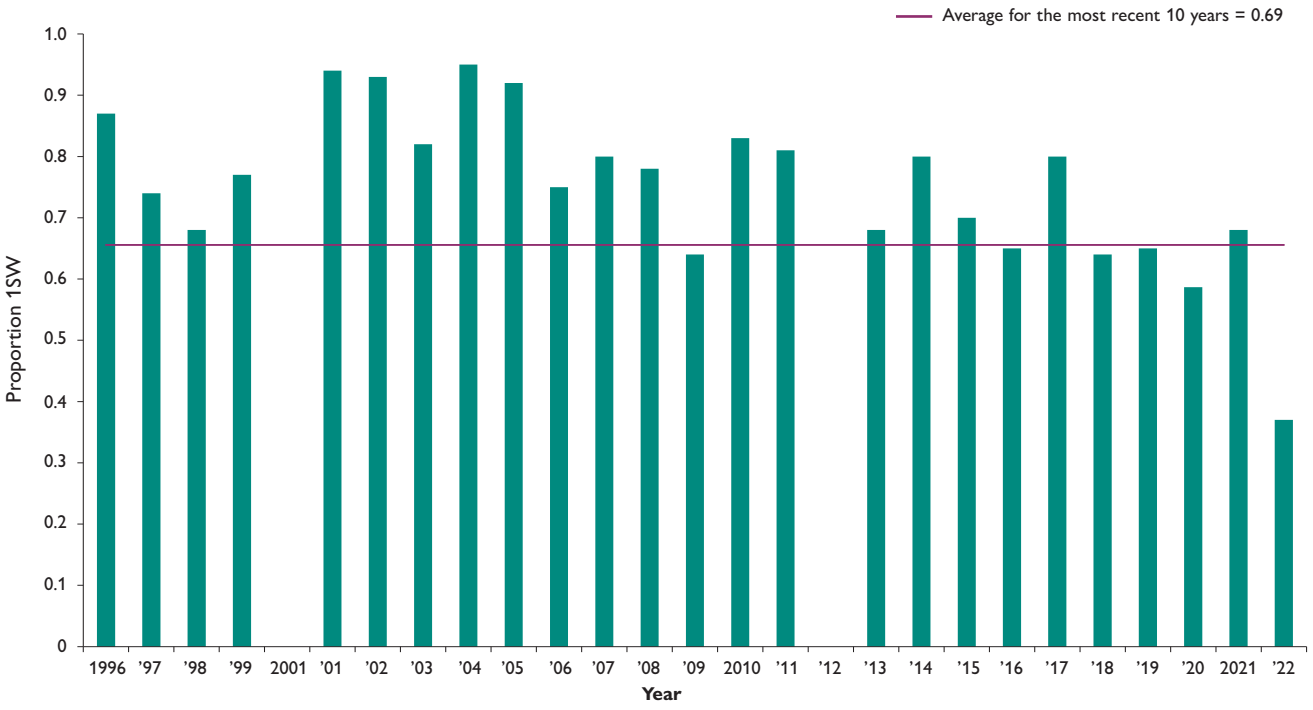
The long-term annual count data of salmon numbers. The purple line indicates the average for the most recent 10 years. Prior to 1985 the counter didn't take downstream movement into account and this has been corrected in this figure (see methods p14)

Fish size and sea age

The video images recorded at the fish counter enabled us to estimate the length of 354 adults registered on the counter in 2022. In 2022 we were, therefore, able to estimate the size of more than half of the run. The three largest recorded fish were all 100cm. Length data from the video records are used to calculate the proportion of 1SW and MSW fish returning to the river. Based on the 354 adults, where we estimated length from the video image, an estimated 37% of the 2022 run were 1SW salmon (see Figure 10). This is well below the 10-year average proportion of 66% 1SW fish.

Figure 10

Annual percentage of 1SW salmon estimated from lengths obtained from the video image from the resistivity counter. The purple line indicates the average for the most recent 10 years. Missing bars indicate years when the resistivity counter was not working



Conservation limit

The conservation limit for the River Frome is the deposition of 1.5 million eggs (the very minimum number of salmon eggs required to ensure a viable population as estimated by the Environment Agency). In 2022 the egg deposition estimate calculated by the Environment Agency was 2.7 million eggs based on the adult run estimate from the resistivity counter, the size distribution of returning salmon, and potential mortality from fishing. The estimate for 2022 is therefore up 177% of its conservation limit (see Figure 11). The 10-year average for the River Frome is 119% of its conservation limit, with only three years falling below the conservation limit in this 10-year period.

River discharge

Similar to most of England, the first 10 months of 2022 were very dry in Dorset and as a result, the River Frome discharge at East Stoke was low at the outset of the year and dropped well below the 95th percentile during the summer months (see Figure 12). The combination of low discharge and very high temperatures in late summer was the cause of some concern for the welfare of juveniles as well as returning adults.

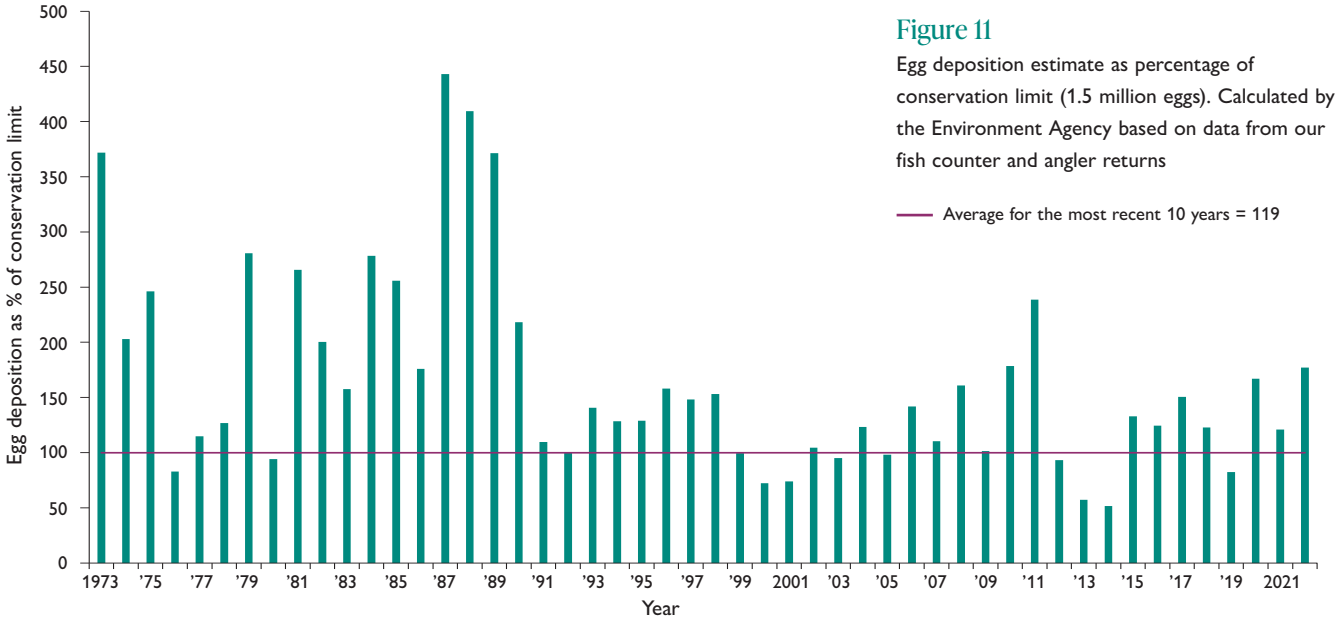
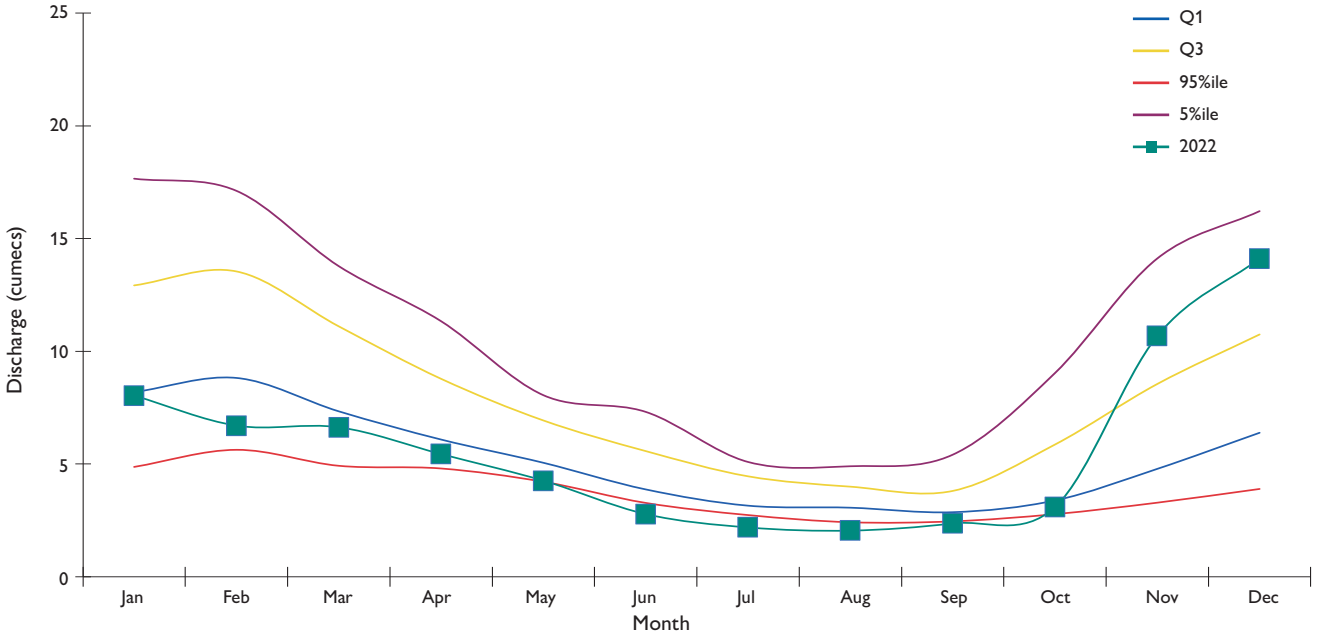


Figure 11

Egg deposition estimate as percentage of conservation limit (1.5 million eggs). Calculated by the Environment Agency based on data from our fish counter and angler returns

Figure 12

Mean monthly discharge data (in cubic metres per second (cumecs)) for 2021 relative to the long-term average 5 percentile (5%ile), 25%ile (Q1), 75%ile (Q3) and 95%ile discharge data for the period 1966-2020. Values represent the proportion of time that discharge has historically been above the stated value (ie. for the 5%ile, values have only been above this level for 5% of the time and for 95%ile, discharge was above this value for 95% of the time (since 1966)). The data are collated and calculated from Environment Agency records



4. Methods

This section has been written to reflect the long-term methods used to survey salmon on the River Frome and as such should not vary from one year to the next

Parr tagging

In September, since 2005, we electric-fish and mark approximately 10,000 juvenile salmon (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 where they were captured. We also remove the adipose fin (the small fin behind the dorsal fin) so that we, and other fishery surveys, can identify tagged fish when they are recaptured. 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 detector 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 Figure 5).

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 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 autumn parr and smolts in the catchment. To estimate the number of parr during autumn tagging we divide the number of parr tagged in the autumn with the proportion of the population that is tagged. We obtain a measure of the proportion of the population that is tagged by quantifying the proportion of tagged smolts among the smolts captured in our smolt trap at East Stoke the following spring. As a result, the estimate of parr in the catchment lags one year behind the smolt and adult data.

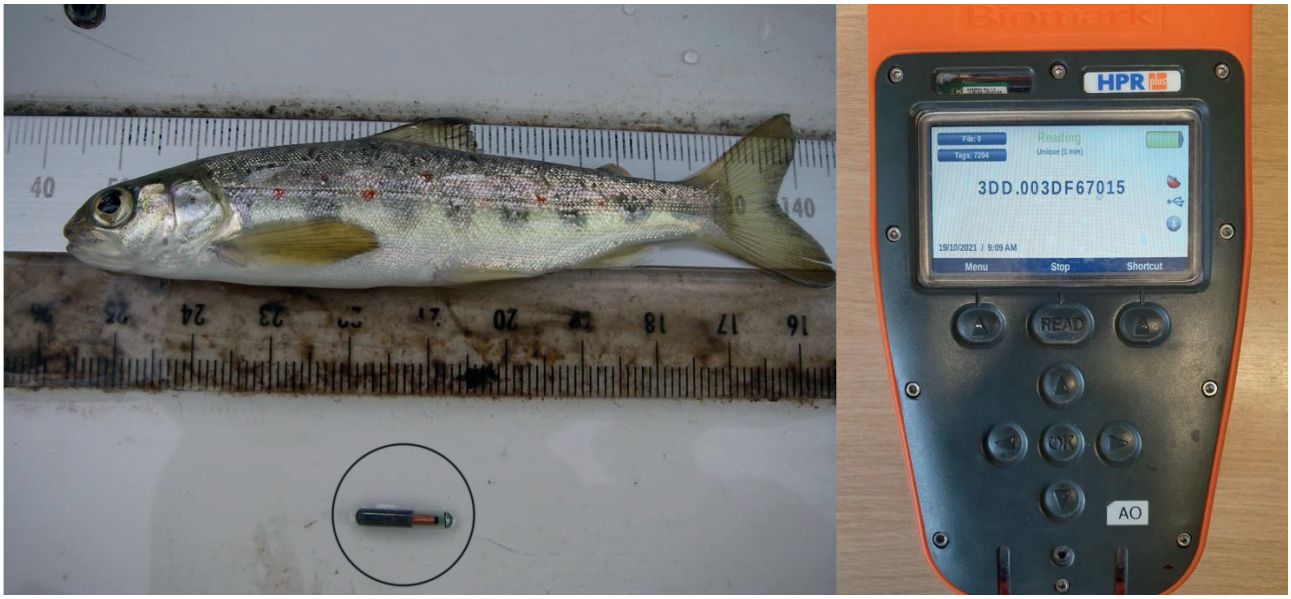
Smolt estimate

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 have our smolt trap (see Figure 4). From detections of PIT-tags in the Millstream and on the main river downstream of the BAFF, we know that deflection efficiency is good, operating at up to 80%. In the Millstream, the smolts pass through the Fluvarium channels where PIT-tag antennae detect the tagged smolts (see Figure 4). On leaving the Fluvarium they encounter the Rotary Screw Trap (RST) where a proportion of the smolts migrating down the Millstream are intercepted.

In most years the BAFF and the RST are operational from the 25th of March until the smolt run ends sometime in early May. The RST is operated most days throughout the trapping season with a day and night shift. When in operation, we check and empty the RST 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

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



their PIT-tag scanned before recording biometrics and taking a scale sample. After processing, all intercepted smolts are released downstream of the RST.

The smolt estimate is derived from the number of PIT-tagged smolts detected at East Stoke during the smolt run window (1st of March to the 31st of May), the efficiency of the PIT-tag antennae (calculated from multiple antennae), and the proportion of PIT-tagged smolts among the smolts intercepted by the RST.

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 Game & Wildlife Conservation Trust took over the running of the counter at East Stoke.

Data is collected by the EA's Conductance sensor resistivity counter connected to three stainless steel electrodes mounted 45cm apart on the EA venturi gauging weir 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 15).

Adult salmon data is presented for the period from the 1st of February to the 31st of January inclusive. 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 is collected for both gross up- and down-stream events.

Figure 14

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

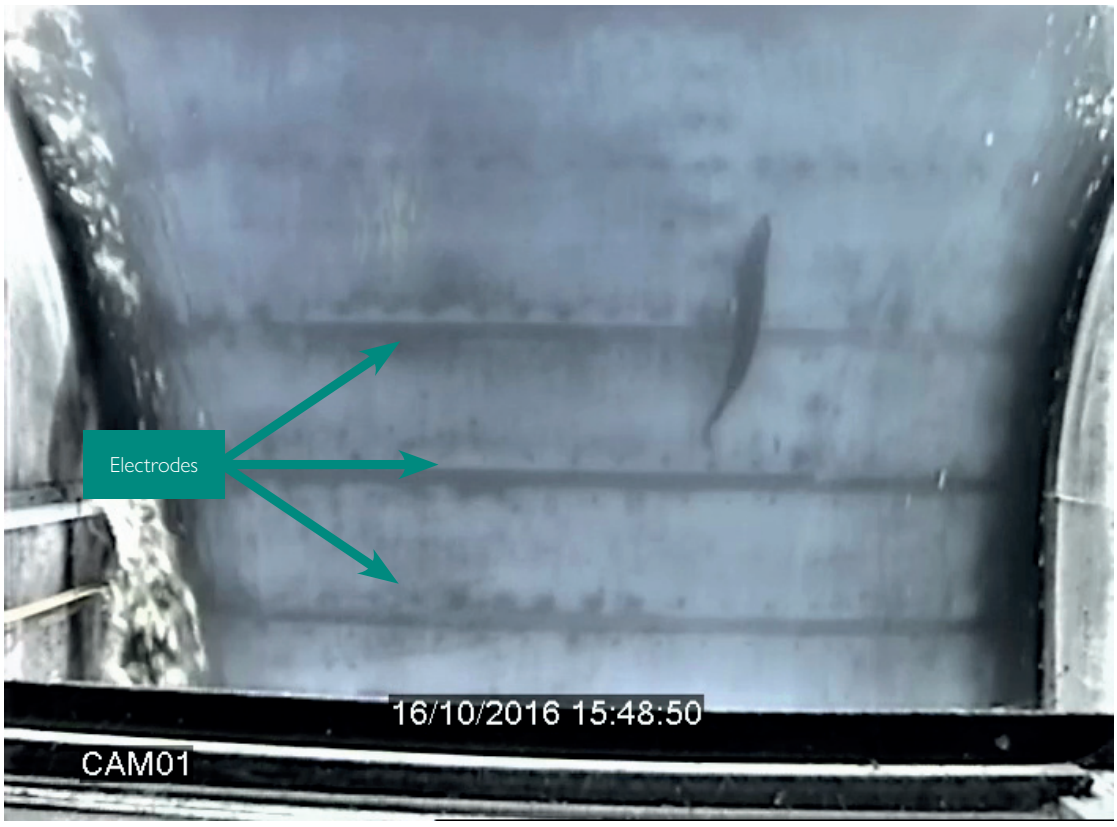


Figure 15

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

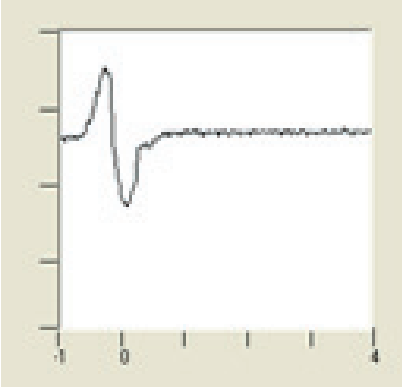


Figure 16
Two Atlantic salmon smolts of contrasting sizes

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, and March the downstream counts are not subtracted from the upstream numbers as a high percentage 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 represents a nett upstream estimate.

Data verification

To ensure that the data collected from the resistivity counter is 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 is 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 can be multiple reasons for triggering a raw data event (eg. salmon, sea trout, other fish, or anything more conductive than the water), so using the two above methods enables us to assign each event to a category. For example, during periods when the computer trace data isn't 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 16). These length estimates are used to estimate the proportion of 1SW and MSW salmon among the upstream records (Figure 10). We are unable to record the length of all adults as migration, especially in the autumn, coincides with high turbidity. Historically, we used 74cm as the upper size limit of returning 1SW salmon. However, in recent years we, and other researchers (Trehin et al., 2021), have observed that the minimum length of returning adult salmon appears to be getting smaller. As a result, we adjusted the upper size limit of 1SW salmon to 72cm in 2018 and 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.

Conservation limit

The EA produces an egg deposition estimate for all the 49 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, and the proportion of females. 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/trap 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.

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. In the early years, this was based on our smolt estimate and adult return estimates from the resistivity counter. However, since the installation of our first PIT-tag antennae (see Figure 17) at Bindon Abbey in 2011, the 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 RST.

Collection of environmental data

In conjunction with data on the salmon population, water temperature, water turbidity, air temperature, and light levels are also collected at 15-minute intervals from 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

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