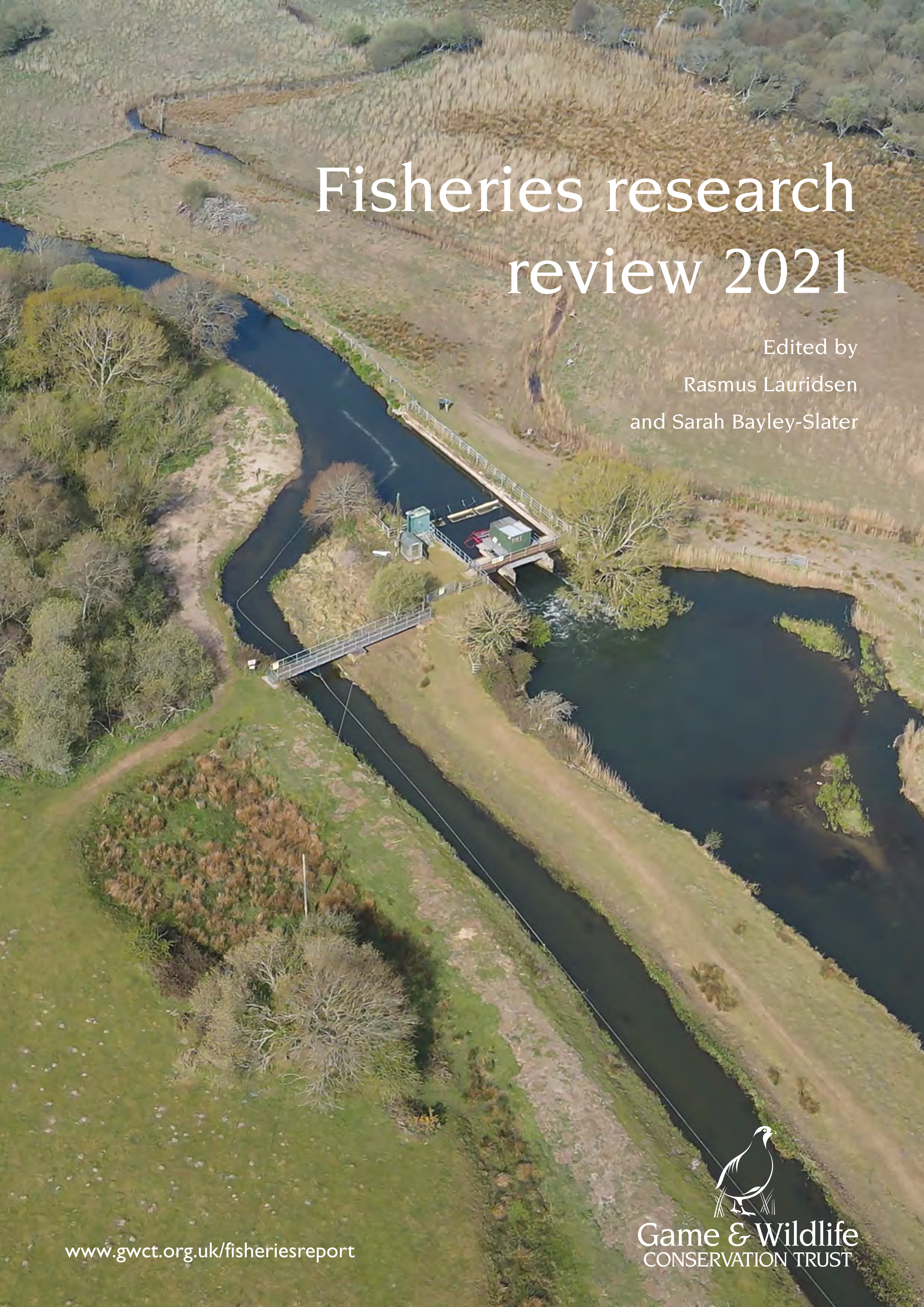


Fisheries research review 2021

Edited by
Rasmus Lauridsen
and Sarah Bayley-Slater

www.gwct.org.uk/fisheriesreport

Game & Wildlife
CONSERVATION TRUST

Acknowledgements

The GWCT would like to acknowledge the financial support for all of the fisheries projects from the Environment Agency, Cefas, EU Interreg Channel VA Programme, The Missing Salmon Alliance, The Grayling Research Trust, Horizon 2020, Wessex Water, The Piscatorial Society, The Valentine Trust, The Alice Ellen Cooper Dean Charitable Foundation, G & K Boyes Trust, Mr Anthony Daniell, Jean and Keith Howman, Winton Capital, NERC FRESH-DTP programme, Swedish Research Council for Sustainable Development, Queen Mary University of London, University of Southampton, Bournemouth University, University of Exeter and Cardiff University.

We would also like to thank all the riparian owners along the River Frome and other areas for access to the rivers. Without their permission our work would not be possible.

The GWCT Fisheries team who contributed to work in this *Review* in alphabetical order:
C Artero, S Bayley-Slater, WA Beaumont, WRC Beaumont, S Gregory, R Lauridsen, T Lecointre, J Marsh, D Osmond, D Roberts, L Scott and O Simmons.

The Salmon School art installation conceptualised by artist Joseph Rossano, and brought to COP26 Glasgow by the Missing Salmon Alliance and a global collective of salmon conservation organisations. © Ben Etridge

Contents

Foreword

David Mayhew

Chairman of the GWCT Fisheries Research Steering Committee

Well, 2021 began with yet another Covid lockdown. Fortunately, the team were still able to complete the fieldwork to catch and tag 55 sea trout kelts on the River Frome in January. This marked the completion of the sea trout kelt tagging programme with a total of 315 kelts tagged between the Rivers Tamar, Frome and Bresle over the winters of 2018/2019, 2019/2020 and 2020/2021. This work has been a mammoth effort by the team, often working over their Christmas holidays to ensure that they were on the river, at the right time to catch the kelts. Now the work begins to unravel the mysteries of sea trout behaviour and survival at sea, held within the 75 recovered tags.

The smolt population estimate on the Frome in spring 2021 was modest at 6,635 which is nearly 30% down on the 10-year average. However, the numbers of parr observed during our September parr tagging programme was encouraging, so hopefully the 2022 smolt run will be better. The estimated number of adult salmon that returned to the Frome in 2021 was 459 which is 20% down on the 10-year average.

2021 was also another busy year for the Missing Salmon Alliance (MSA) (GWCT being a founding member). This culminated with a partnership between the MSA and artist Joseph Rossano's 'Salmon School', which was installed at the COP 26 UN Climate Change Conference 2021 in Glasgow to highlight the plight of our wild Atlantic salmon as well as their Pacific counterparts, and the pressures which climate change is putting upon them. Our message was that salmon need cold, clean water and this was expressed with a stunning display of 350 one-metre long, hand blown glass salmon, hanging from the ceiling above the COP26 delegates (see left).

David Mayhew (right) with Dylan Roberts.

Finally, I would like to commend the team for their efforts in writing up their research in 2021. If it's not published, it hasn't been done. It was a record year for the fisheries team with nine peer-reviewed scientific papers in 2021. Happy reading.

The River Frome at East Stoke. © Revelstoke Films

River Frome salmon population

The GWCT fisheries research group is based at East Stoke on the banks of the River Frome in Dorset, and the Atlantic salmon population in the River Frome is at the core of our work. For nearly 50 years, the number of adult salmon returning to the River Frome has been quantified and over the years of studying this population, we have built up an unparalleled monitoring infrastructure at East Stoke and elsewhere in the catchment (see Map 1). Like many rivers feeding the North Atlantic, the number of adult salmon returning to the River Frome showed a marked decline in the early 1990s (see Figure 1).

Because this collapse was observed in rivers across the salmon's distribution, the consensus opinion is that the decline is caused by problems in the marine environment, such as warmer sea temperatures. However, this highlighted the importance of being able to separately analyse the changes affecting survival that occur in freshwater and those that occur at sea.

Only by monitoring both smolt output (freshwater production) and returning adults (marine survival) are we able to separately analyse the two components of the salmon life cycle. Estimating the density of juveniles and the number of emigrating smolts on a catchment scale is difficult. However, it is possible to estimate population size by marking a proportion of the population and then resampling the population at a later time and seeing what proportion of the individuals captured on the second sampling are marked.

At the beginning of the millennium the fisheries group decided to take advantage of developments in Passive Integrated Transponder (PIT) tag technology and use these tags (microchips) to obtain population estimates at the catchment level for juveniles, smolts and returning adults. Whereas conditions at sea are impacted by global activities, managing the freshwater and coastal environments is much more tangible, and optimising the number and the quality of smolts output from freshwater will help to offset a lower marine survival rate and hopefully boost the population.

Each PIT-tag contains a unique code, hence our PIT-tag systems not only provide us with population level data, but also life history data of individuals. Using PIT-tags, we can quantify and compare parameters such as growth and survival in different parts of the catchment, as well as the latent impact of the freshwater phase on their probability of marine survival. Hence, we can identify environmental drivers of changes within the population. It is exactly this knowledge that can inform us how best to manage the river catchment to optimise the output of smolts. The relationship between the freshwater production of smolts and returning adults enables us to quantify the marine

KEY FINDINGS

- The estimated smolt output from the River Frome in 2021 was down nearly 30% on the 10-year average, largely owing to recruitment failure in the upper catchment from the 2019 spawning.
- The number of adult salmon returning to the River Frome was more than 20% below the 10-year average. The number of returning 1 sea-winter fish was particularly disappointing given the large smolt output the previous year.
- The density of parr encountered during the 2021 PIT-tagging was good, indicating strong recruitment from the 2020 spawning.

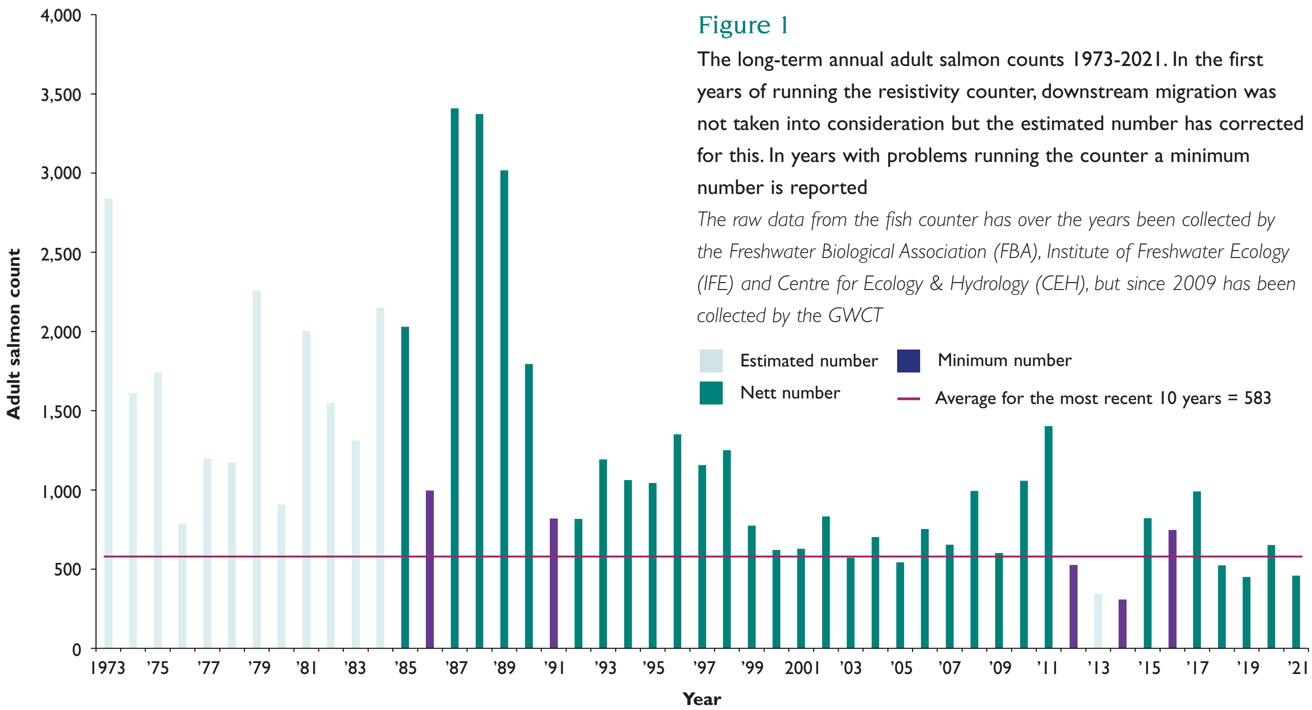


Figure 1

The long-term annual adult salmon counts 1973-2021. In the first years of running the resistivity counter, downstream migration was not taken into consideration but the estimated number has corrected for this. In years with problems running the counter a minimum number is reported

The raw data from the fish counter has over the years been collected by the Freshwater Biological Association (FBA), Institute of Freshwater Ecology (IFE) and Centre for Ecology & Hydrology (CEH), but since 2009 has been collected by the GWCT

survival of separate smolt cohorts. The combination of adult 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.

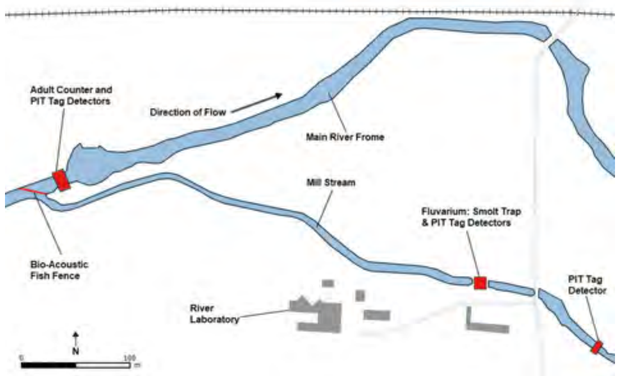
Adult salmon estimate

We estimate the number of returning adults using a resistivity counter that detects the change in the electrical resistance of the water caused by a salmon swimming over the counter. As well as providing population data, the adult counter provides information on migration timing and the environmental factors that influence this. For individuals captured by the video attached to the counter, it also provides estimates of adult fish length, enabling us to look at changes in marine growth over time.

A large part of the effort in running the East Stoke adult counter is focused on verifying and matching the 'counts' from the monitoring equipment. Counts generated by the resistivity counter are identified and verified by a combination of trace waveform analysis and video analysis. An additional estimate of the adult return is made from the PIT-tag data obtained from tagged adults as they migrate back into the river.

With the help of our SAMARCH project, our fish counter at East Stoke had a new fibreglass base with new electrodes installed at the bottom of the river in 2019. In 2021 the refurbishment of the resistivity counter at East Stoke continued with the installation of new electronics for detecting fish movement from the electrical signal detected by the electrodes at the bottom of the river. The old system has served us well for more than 30 years but is proving increasingly difficult to maintain as we can no longer obtain replacement parts. The new electronics were installed in parallel to our old system, enabling us to use the data collected in 2021 to calibrate the two systems. The new system has been developed by the Environment Agency; it provides more flexibility when analysing the data and it enables us to store the electronic signal from the electrodes in perpetuity. This enables us to re-analyse the data retrospectively as we hone the settings over time.

Our preliminary estimate or returning adult salmon for 2021 is low at 459 (see Figure 2). This is more than 20% below the 10-year average (583). The number of returning 1 sea-winter (grilse) fish was average at best, which is disappointing as these fish originated from a very large smolt run in 2020 (see Figure 3).



Map 1

Site plan of the counting equipment at the Salmon & Trout Research Centre at East Stoke.

PIT-tagging of juvenile salmon

In September each year since 2005, we have electric-fished and marked approximately 10,000 juvenile salmon (8-15% of the juvenile salmon population in the catchment) with PIT-tags. These small tags (just 12mm long x 2mm in diameter) are inserted into parr and enable us to identify

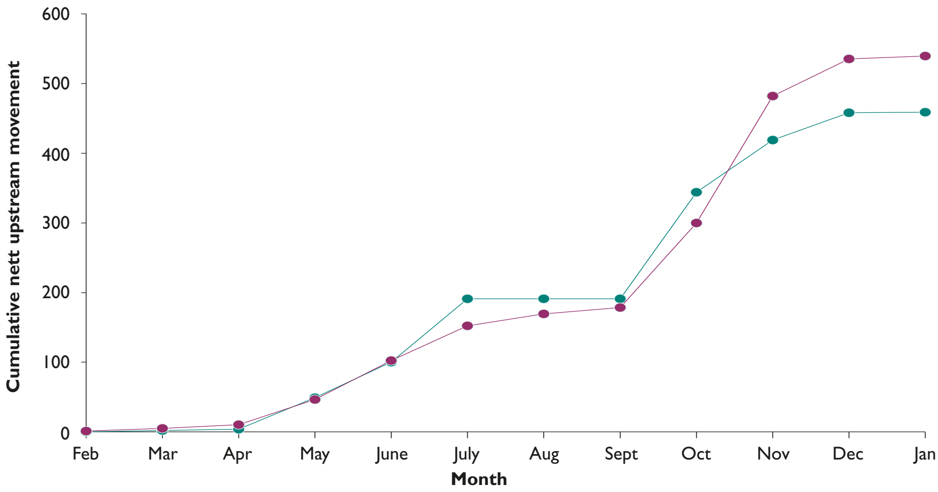


Figure 2

Cumulative nett upstream adult count for 2021 and the average for the most recent 10 years recorded by the resistivity counter at East Stoke

Cumulative 2021

Average for the most recent 10 years

As a result of intermittent technical issues with the resistivity counter, prior to its refurbishment, we have used estimates for total run reported in Figure 1 for some years. This results in a small difference in the 10-year average reported in this figure with the one reported in Figure 1 (583)

MONTH	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	TOTAL
2021	0	2	2	45	51	91	0	0	153	75	39	1	459
10-year average	1	4	5	36	56	50	17	9	121	182	53	4	539*

individual fish when they swim past our detector antennae. The PIT-tag stays with the fish for life and the passage of tagged fish out to sea, and any fish returning from the sea, are recorded by the tag detecting equipment installed throughout the catchment.

To deploy 10,000 PIT-tags across the catchment requires a concerted effort lasting three to four weeks involving all GWCT fishery staff, many students and other volunteers. As such, this is an annual event that staff look forward to with excitement to see if recruitment from spawning the previous winter has been good, but also with slight trepidation in the knowledge of the marathon ahead. In 2021 the first day of the campaign was a baptism of fire as recruitment had been very good at the chosen site and we PIT-tagged more than 1,000 salmon. Recruitment had been good throughout most of the catchment and the river upstream of Lower Bockhampton was back on track, contributing a more 'normal' 13% of the deployed salmon PIT-tags.

Smolt estimate

During the smolt run we normally install a device called a Bio-Acoustic Fish Fence (BAFF) consisting of bubbles with sound entrained, to divert the fish from the main River Frome into the Millstream at East Stoke (see Map 1). However, in 2021 heavy rain in March and April resulted in high river levels at the start of the smolt run. Consequently, we were unable to deploy our BAFF before commencing trapping on 25 March. In place of the BAFF we installed a deflection system consisting of bubbles with a set of four underwater speakers attached to mimic the effect of the BAFF. A couple of weeks into the smolt sampling we were able to install the BAFF system, but the system of the bubbles with speakers looks

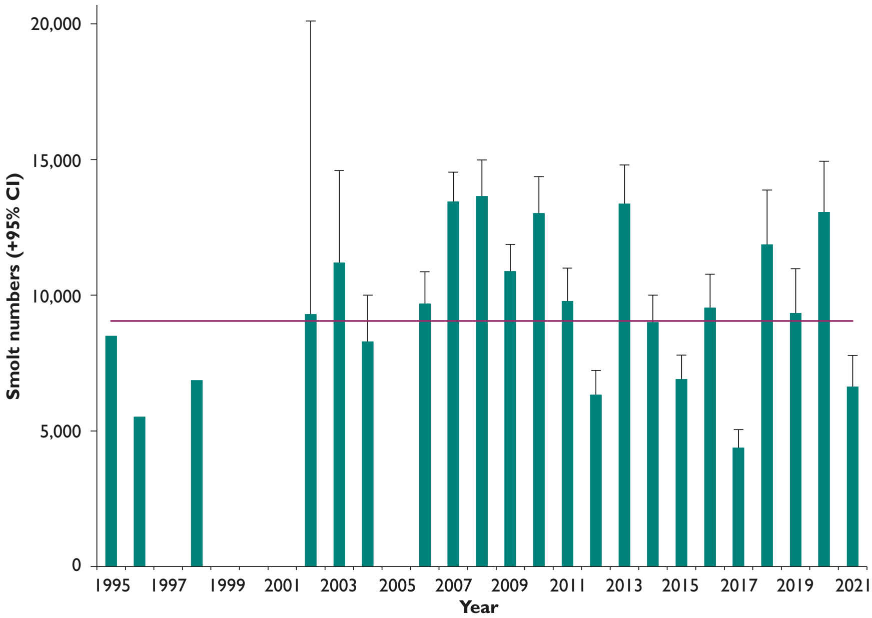
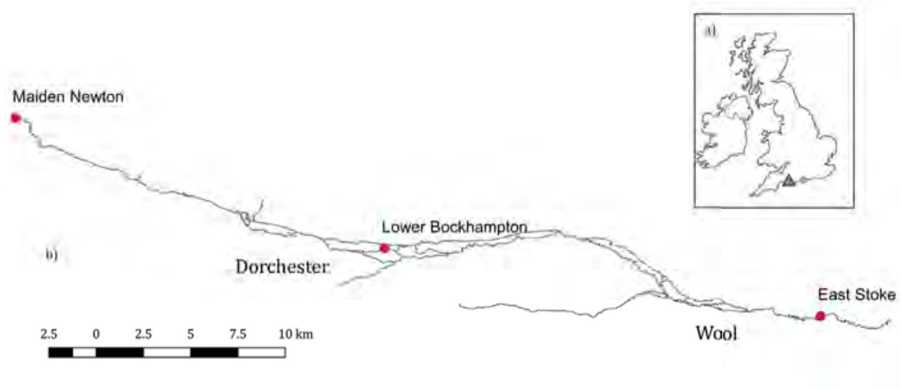


Figure 3

Estimated spring smolt population with 95% confidence intervals 1995-2021

Average for the most recent 10 years = 9,046



Map 2

The River Frome catchment highlighting East Stoke, Lower Bockhampton and Maiden Newton which is normally the upstream limit of salmon spawning.

like a promising alternative for deflecting smolts down the Millstream. In the Millstream, a proportion of the deflected fish are trapped using a rotary screw trap.

Smolt trapping commenced the last week of March and continued into May. An estimated 6,635 (95% CI ±1148) salmon smolts left the River Frome in 2021, nearly 30% down on the 10-year average (9,046, see Figure 3). This is the third lowest estimate recorded since we started quantifying emigrating smolts in 1995. During parr tagging in 2020 we encountered a low number of salmon parr particularly in the upper river where recruitment had nearly completely failed, despite a reasonable redd count in the upper river. Only 1% of the 2020 salmon PIT-tags were deployed above Lower Bockhampton (30 km upstream of the tide. See Map 2) compared with an average of 16% in previous years. As a result, only 3% of the PIT-tagged salmon smolts detected at East Stoke in 2021 were from upstream of Lower Bockhampton, whereas the average contribution from this part of the river in previous years was 24%. Hence the low number of migrating smolts was largely down to the lack of recruitment in the upper river from the 2019 spawners.

Estimate of juvenile salmon

We determine how many juveniles there were in the catchment at the time of tagging from the number of tagged juveniles and the proportion of PIT-tagged smolts the following spring. As such the juvenile estimate is always from the previous calendar year. The estimated juvenile population in the catchment in 2020 was 73,022, which is nearly 20% down on the 10-year average (87,311, see Figure 4).

Rasmus Lauridsen is head of GWCT Fisheries Research. He primarily researches the migration strategy of young salmon and trout, and the drivers and consequences of different life history choices.

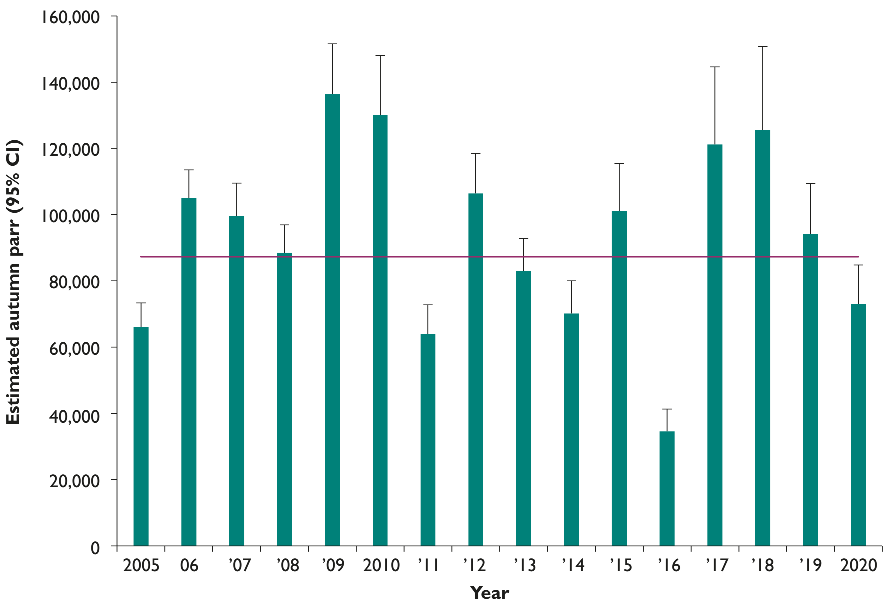


Figure 4

Estimated number of salmon parr in the Frome catchment in September with 95% confidence intervals (2005-2020)

Average for the most recent 10 years = 87,311

Salmonid Management Round the Channel 2017-2023 (SAMARCH)

Migratory salmonid populations have declined drastically in the last four decades. Multiple freshwater factors have been associated with this trend, along with a marked decline in marine survival. Reasons for the decreasing marine return rates are yet to be fully understood, thus leading researchers, like those in the SAMARCH project, are engaging in more detailed studies of the estuarine and marine phase of the salmonid's life cycle.

Led by the GWCT, SAMARCH includes 10 partners, five in England and five in France, who are involved in scientific research and fisheries management. The partners are working together on four work packages to gather new knowledge on the biology and ecology of salmonids, to improve policy and management guidance for salmonids in estuaries and coastal areas.

FUNDING & PARTNERS

The SAMARCH project is part-funded by the EU Interreg VA France (Channel) England Programme. SAMARCH aims to improve the management of salmon and sea trout in the English Channel in order to protect and increase their populations.

SAMARCH project partners:

UK – Game & Wildlife Conservation Trust, University of Exeter, Environment Agency, Salmon & Trout Conservation, Bournemouth University.

France – INRAE, l'insitut Agro Rennes Angers, Office Francais de la Biodiversité, Seine-Normandie Migrateurs, Bretagne Grands Migateurs.

Work Package T1 – Tracking salmonid use of and mortality rates in transitional, coastal and marine waters

WP-T1 used acoustic tags to track Atlantic salmon and sea trout smolts during their migration through four estuaries and into the marine environment, in order to describe their migration route, behaviour and survival, and the potential factors impacting on their survival. Furthermore, sea trout kelts (post-spawning) were tagged with a combination of tags to provide novel information on the whereabouts of sea trout in the English Channel, causes of mortality and behaviour eg. swimming depths (see page 12).

Sea trout from the River Bresle, France, and the recovered data storage tag.

Work Package T2 - Developing novel genetic tools for managing migratory fish in coastal and transitional waters

WP-T2 seeks to use genetics to discover more about the marine phase of the sea trout life cycle. The project has built a genetic database incorporating DNA profiles of trout populations from almost all rivers flowing into the English Channel area. This database will enable fisheries managers to:

1) Determine the region, and potentially the river, of origin of adult sea trout from the English Channel area;
2) Understand how far sea trout travel from their natal river;
3) Identify the marine landscape (seascape) parameters that impact the movement of sea trout between rivers;
4) Risk assess the potential of bycatch of sea trout from specific rivers in commercial fisheries (see page 10).

Work Package T3 - Stock Assessment Data & Models

WP-T3 Salmon populations are assessed and managed using stock assessment models. The models for salmon rely heavily on data from key stages within their life cycle. SAMARCH scientists are providing new data and updating existing parameters for the stock assessment models such

We sample the adult sea trout caught by fishermen at sea for genetic analysis.

as the sex ratios, fecundity and rod (angler) exploitation rates of salmon in rivers. In addition, this WP is studying long-term changes in the marine growth and survival, and the impacts of these changes on salmon populations.

Research outputs

Research results from Work Packages T1-3 are being published during the course of the project, in scientific journals (see page 26 and **gwct.org.uk/fisheriespapers**), the *Fisheries Research Review* and presented at conferences. The final SAMARCH conference will take place in March 2023.

Work Package T4 – Training, stakeholder engagement and policy delivery

Training: To date more than 60 undergraduate students, 20 MSc students and two PhD students have received practical training and research opportunities as part of SAMARCH. They have gained experience from working with the project partners in a variety of areas, from tracking salmon smolts using acoustic telemetry technology, salmon stock assessment research and data management, to communications and organising and speaking at public events.

Stakeholder engagement: The project is engaging with relevant stakeholders from various sectors, to disseminate the project's results through workshops and conferences to deliver policy recommendations on both sides of the Channel.

Policy delivery: As the project approaches its final year, the focus of WP-T4 is to develop policy recommendations to be considered by the regulatory bodies, based on current best practice and the project's research findings. The dedicated SAMARCH policy group will deliver these recommendations during 2022/23 and the group has already started engaging with regulatory bodies.

Sarah Bayley Slater is our fisheries communication officer, who works with our partners in the UK and France to help disseminate the findings and results of the SAMARCH project.

Students have been assisting the GWCT Fisheries Team collecting and tagging salmon and trout parr.

At-sea sampling for migratory trout, using local netsmen at four locations in southern England.

Identifying the natal region of migratory trout

To effectively manage trout populations, accurate information on life history and migration patterns is needed. For many rivers, through the work of organisations such as the GWCT, the Environment Agency and various Rivers Trusts, we now have a good idea of their population size, location of spawning areas and potential threats (ie. habitat and water quality, location of barriers to fish movement etc). In-river trout populations can be managed taking this information into account. However, for migratory trout there is an extra dimension that has to be considered, one that is not so easily incorporated into management plans, and this is the marine environment.

Migratory individuals spend a significant proportion of their life at sea but, for such an iconic fish, relatively little is known about the marine phase of their life cycle. That they go to sea is known, but once in the marine realm they mostly seem to disappear. This lack of knowledge makes conserving migratory trout stocks all the harder. How can we work to conserve something if we don't know where they it is? Traditionally, various physical tags

KEY FINDINGS

- English Channel trout populations have strong genetic structures enabling sea trout caught in marine and estuarine environments to be assigned to 11 distinct groups of rivers.
- There is evidence of mixed stocks of sea trout in several areas of the English Channel and southern North Sea.
- Some trout migrate more than 800km from where they were born.

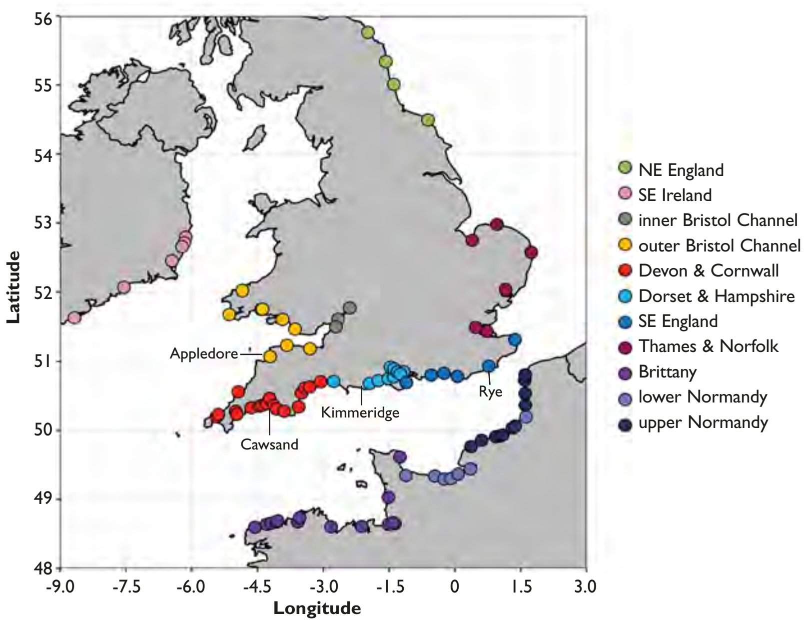


Figure 1
Map showing the location of the 103 UK, Irish and French rivers sampled for the SAMARCH genetic baseline. Symbol colour indicates to which of 11 distinct genetic groups each river belongs. Approximate location of the four netting locations (Appledore, Cawsand Bay, Kimmeridge Bay and Rye Harbour) are shown in text boxes

Interreg
France (Channel Manche) England
SAMARCH
SAlmonid MAnagement Round the CHannel
European Regional Development Fund

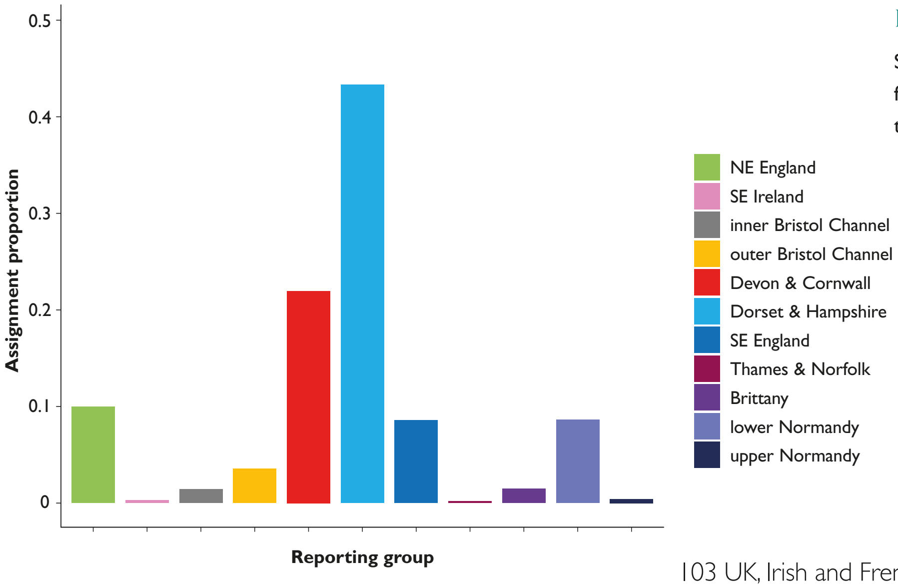


Figure 2

Stock composition of sea trout sampled from Kimmeridge Bay, Dorset showing the proportion of fish assigned to each of 11 distinct genetic groups

(ie. carlin or coded-wire tags) have been used to determine the marine spatial distribution of different fish stocks and tag returns suggest that many migratory trout stay close to their natal river, while a minority can move considerable distances. While tagging approaches are 100% successful in assigning recaptured tagged fish back to their river of origin, such studies typically involve fish from only a small number of rivers and generally suffer from low levels of recapture, despite the often large numbers of fish tagged.

Increasingly, DNA markers are used in fisheries research as an alternative to traditional physical tags. This approach has the advantage that all fish can potentially be included, as any marine-caught trout can be screened with genetic markers. Extensive DNA baseline databases now exist for genetic stock identification of Atlantic salmon and North Sea populations of trout.

Initially, genetic data must be obtained for trout populations from potential home rivers of the sea-caught migratory trout. For the SAMARCH project, this has involved collecting samples from juvenile trout from both UK and French rivers flowing into the English Channel, as well as rivers from north-east England, the Bristol Channel and south-east Ireland (see Figure 1). The final genetic baseline comprises nearly 3,000 trout sampled from 103 UK, Irish and French rivers which have been genotyped using a suite of 94 genetic markers. Initial findings indicate significant genetic structuring across the region, with the identification of 11 distinctive genetic groups (see Figure 1).

Using the genetic data from the juvenile trout, we have a foundation to look at the origins of migratory trout caught in marine and estuarine waters. As part of the SAMARCH project, we have undertaken a programme of at-sea sampling, utilising local netsmen at four locations around southern England (Appledore, Cawsand Bay, Kimmeridge Bay and Rye Harbour). In addition, migratory trout have also been obtained from commercial fisheries along the East Anglian coast and the Rhine/Meuse estuary, as well as from trout caught in estuarine areas of the Taw/Torridge, Tamar and Sussex Ouse Rivers.

Preliminary results suggest that each of our marine sampling locations represent mixed stocks of migratory trout. For instance, as might be expected, the majority of fish sampled from Kimmeridge Bay in Dorset assign to Dorset and Hampshire rivers (see Figure 2). However, fish from Devon, Cornwall and south-east England were also identified in the waters of Kimmeridge Bay. There is also a suggestion that French migratory trout (from lower Normandy rivers) are present along the Dorset coast. Interestingly, several fish from north-east English rivers were caught at Kimmeridge, representing a migration distance in excess of 800 kilometres from their natal rivers. The apparent mixing of trout stocks in the marine environment must be taken into account when managing commercial fisheries, as well as other marine activities, to effectively protect and manage trout stocks.

Collecting material from a sea-caught migratory trout.

Andrew King is working on the SAMARCH project at the University of Exeter. He is interested in using genetic techniques for the conservation and management of salmon and trout populations.

Tags from migratory sea trout found around the English Channel and in the North Sea

As part of the SAMARCH project, the GWCT has annually (2018-2021) captured post-spawning sea trout to track their journey at sea. To identify their migration path, we used data storage tags (DST; see Figure 1), a little electronic device which records temperature and pressure every two minutes for up to a year. By comparing the temperature recorded by the tag and the temperature of the ocean, we can reconstruct the migration path of tagged individuals. However, DSTs are not transmitting devices so they need to be retrieved to get the data. That is why we embedded the tag in an orange float, making the tag buoyant and a message was inserted on the tag with our email and phone number along with a notification of a £50 reward for people to contact us if they found a tag.

Figure 1

The Data Storage Tag is inserted in an orange float to make it buoyant

KEY FINDINGS

- Twenty-four percent of the deployed sea trout tags have been recovered.
- Sixty-seven percent of the recovered tags were found by beach walkers, which demonstrates great participation of the public in our research project.
- Tags were found in every country with a coastline in the English Channel or southern North Sea.

Tagged sea trout recaptured in the Gunnislake trap on the River Tamar after a few months at sea. Note the red floy tag in the dorsal fin.

Figure 2

Map showing the location of the rivers in which sea trout kelts were tagged and where the data storage tags were found

Tagged sea trout returning to the river after spending a few months at sea. Note the scar from the tag insertion.

During the project a total of 314 sea trout were tagged in three rivers around the English Channel (Rivers Tamar and Frome in southern England and River Bresle in northern France). So far 76 DSTs have been recovered; 25 (33%) from individuals recaptured after returning to their natal river to reproduce, and 51 (67%) which were discovered by beach walkers. If the fish died or expelled its tag at sea, the tag's orange float would have taken the tag to the surface. Marine currents then directed its movements until the tag beached itself where people found it.

We have been contacted by people finding our tags in England, France, Belgium, Holland, Germany and Denmark. The recovery locations do not indicate where the fish went, but where the currents pushed the tags after the fish died. Most of the tags have been recovered east of the tagging location, which is indicative of the general marine currents in the English Channel (see Figure 2). Some tags were found 950 kilometres from the tagging location, quite an adventure for a little orange tag.

Analysis of the data collected by these tags is ongoing, but from the preliminary analysis it is already clear that this data will provide novel information on sea trout marine behaviour, migration routes and causes of mortality at sea. All this new information will provide a better understanding of the ecology of this migratory species during the marine stage of its life cycle. As part of the SAMARCH project we are working with regulators to incorporate our discoveries into the management of sea trout populations around the English Channel, to better protect this iconic species and improve stocks.

Céline Artero has a PhD in fish ecology and conservation and is a marine biology and ecology specialist. Prior to joining the GWCT, Céline worked at the French Institute of Research for Exploitation of the Sea (Ifremer).

Sea trout smolt productivity potential

Sea trout are a crucial resource providing economic and ecological services to both marine and freshwater systems; as well as this they have an important place in social and cultural heritage. Sea trout, also known as anadromous brown trout, undergo several long and arduous migrations during their life switching between fresh and saline environments multiple times. During the autumn/winter spawning, adults lay dozens to thousands of eggs depending on their size. After the eggs hatch the following spring, the fry stay in the natal river for one to three years before they either undergo smoltification and migrate to sea as sea trout or they remain in the river as resident brown trout for life.

To ensure a healthy and sustainable adult sea trout population, enough smolts need to survive the journey to sea. Once there they face many challenges in the harsh marine environment and only a few will make it back to contribute to the next generation. But what dictates how many sea trout smolts a river produces? This project hopes to shed some light on the relationship between smolt output and habitat from multiple sites across Europe. Working in collaboration with ICES (the International Council for Exploration of the Sea) the research spans five countries and the length of the native latitudinal range (see Figure 1). The River Frome in Dorset is one of these study sites, where the GWCT has been studying salmonids for decades, and monitoring of both Atlantic salmon and sea trout populations is conducted every year.

KEY AIMS

- Assess smolt output and habitat quality for a multitude of rivers.
- Develop a universal smolt productivity potential model for sea trout rivers.
- Promote the model to be used for management and directing restoration efforts.

Figure 1

Map of all the river sites included in the study

Trout inhabit a wide range of habitats (see Figure 2) and many features such as hydrology, geography and biotic interactions are likely to be important for determining what constitutes a good sea trout river. For example, sea trout researchers are increasingly highlighting the importance of the presence of woody debris and in-river plants in systems as a shelter for juveniles from competition with other trout, as well as refuge from predators such as pike, perch and fish-eating birds. In this study the vast array of factors at play will be scored using the Trout Habitat Index (see Box below) and combined with smolt density data to create a productivity model. The aim is to produce a simple tool to assess smolt productivity potential in any given sea trout system. This will be invaluable for targeted restoration and informed management of key sea trout rivers.

The model relies on two pieces of information, habitat quality and smolt density. Detailed habitat mapping will be conducted along the entire river stretch to generate a Trout Habitat Index. During the following spring migration season, smolt traps will be operated to quantify the number of downstream migrating trout smolts.

TROUT HABITAT INDEX

- Each habitat feature is scored, the scores are then combined to calculate a 'Trout Habitat Score'.
- Habitat features used will include elements such as width, depth, substrate and connectivity.
- Sites are categorised into discrete habitat categories. The best ranked category will serve as a reference for the maximum density of smolts.

Figure 2

Examples of how diverse the habitat is in sea trout rivers/streams

Both habitat mapping and smolt trapping will be undertaken at multiple sites across the sea trout's native range to develop the model.

This universal model will help us to predict how many sea trout smolts any river is likely to produce by mapping the habitat and inputting the data into the tool. In terms of management, it could be used to target systems with a high productivity potential as areas of interest or pinpoint habitat features that could be altered to boost productivity. With sea trout inhabiting a wide range of river types, many of which have been affected by human activity, it is vital to understand the link between habitat and smolt production to best protect the species.

GÖTEBORGS UNIVERSITET

Game & Wildlife CONSERVATION TRUST

Madeleine Berry is a PhD student at the University of Gothenburg working closely with the ICES working group on trout to better develop a model to predict trout production potential from stream habitat data.

Genetic divergence in metal-impacted trout populations

The pollution of our waterways has been hard to ignore over the last year, with much public discussion and Government debate. However, the footprint of how human activities influence rivers has a much longer history, stretching back to the early Bronze Age. With 9% of rivers in England and Wales impacted by heavy metal pollution as a legacy of mining activities, how do species survive or even thrive in a toxic environment?

The brown trout (hereafter trout) is a ubiquitous and highly genetically diverse species, occupying a broad range of habitats, including catchments polluted by heavy metals. Earlier work has indicated that trout living in metal-polluted rivers in Cornwall, are genetically distinct from nearby populations, and are unstressed by water chemistry that would be fatal to metal naïve trout. We have been seeking to understand whether these patterns of genetic distinction are more widely seen in metal-impacted trout populations across the UK. Using whole genome sequencing, we are investigating if this is indicative of genetic drift driven by reproductive isolation or unique genetic adaptation by metal-impacted trout populations.

Since the *2020 Review*, we have received results from high coverage whole genome sequencing (see page 17) from five representative trout from west Wales, and developed bioinformatic pipelines to interrogate these. We have used this whole genome data to identify over four million high-confidence single nucleotide polymorphisms (SNPs; single letter changes to the genetic code which are used as markers of variation between populations). We have also identified 1,800 high-confidence large structural variants (larger changes to the genome whereby whole genes or clusters of genes are moved around within the genome. Results from recent studies imply that such structural changes play a significant role in modifying and adapting genes. With a relatively small sample size, these data alone are not sufficient to allow us to draw firm conclusions, but they do give us a high-confidence dataset with which to compare and quality control a subsequent lower-coverage sequencing dataset across a broader, more representative set of samples.

Summer 2021 saw us travel across the British Isles to collect further samples by electric-fishing (see Figure 1). The first of these trips took us to the River Hayle in Cornwall, to collect tissue to produce a new reference genome of the brown trout. This reference genome, from a close relative to our populations of interest, will allow us to more accurately pinpoint variable genomic regions in our populations. This will give better confidence in the implications of any variation we discover

KEY PROGRESS AREAS

- Field work collecting samples for genetic analysis has been completed; with catchments sampled in western Wales, south-east Ireland, north-east England and Cornwall.
- Results from the individuals sequenced using high coverage revealed high-confidence variants. This paves the way for the analysis of the individuals which are currently being sequenced.
- Initial analysis using a small number of genetic markers suggest that genetic differentiation exist between trout from heavily metal-impacted streams and trout from neighbouring streams in the same catchment with relatively low metal input.

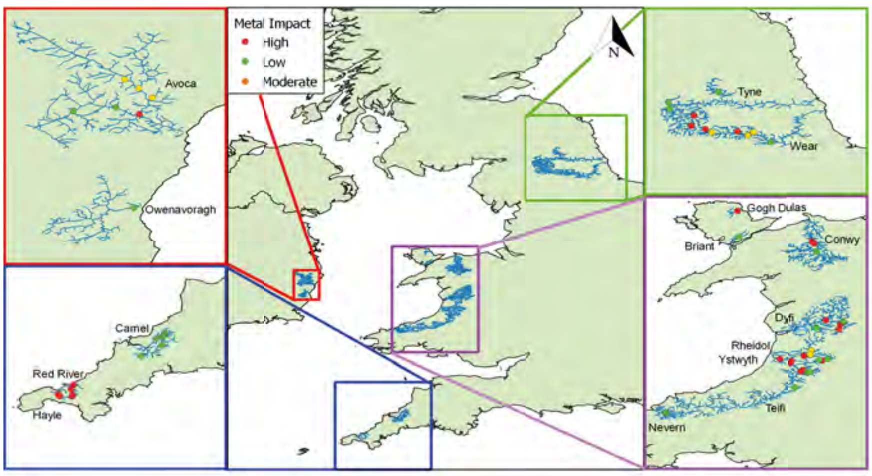


Figure 1

Sampling sites across the British Isles, spread across four regions with historic mining activity. For each region the relative level of metal impact is given, with heavily-impacted sites red, moderately-impacted orange and relatively low-impact as green

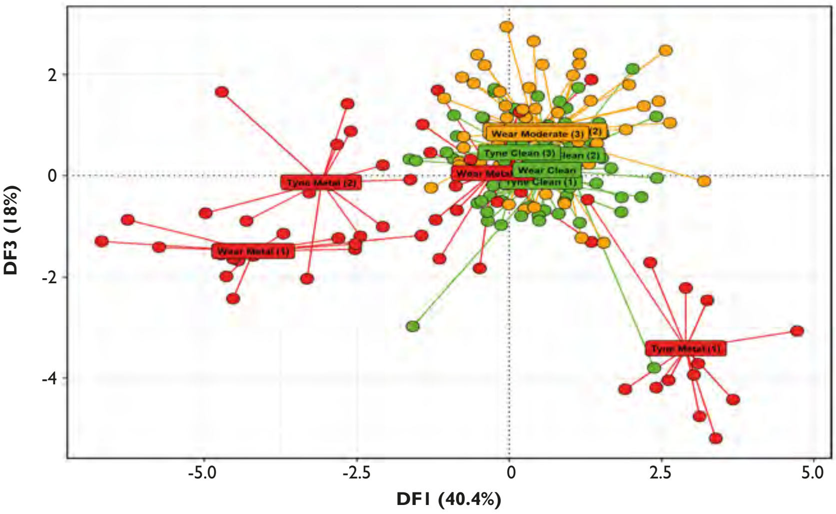


Figure 2

Discriminant Analysis of Principal Components (DAPC) plot of trout sampled from the Rivers Wear and Tyne. Each point represents the genotype of an individual fish, with centroids for each site labelled in boxes. The level of metal impact at each sample site is given by the colour of the points and centroids, with high metals in red, moderately-impacted in orange and relatively clean in green

in metal-impacted trout. We then travelled to north-east England to collect samples from the Rivers Tyne and Wear, both catchments having been impacted by historic lead mining in the Pennines. Our final journey took us to County Wexford, Ireland, to sample trout from the River Avoca. This catchment appeared to contain pristine headwater streams, dense with *Ranunculus,* but also had telling signs of metal impact on the river ecology downstream of the historical copper mines.

We have produced a set of 95 SNP markers, which are very good at identifying and characterising genetic diversity and structure within and between populations of trout. We used this assay to have a first look at our sampled populations from across the British Isles, and to identify which populations appear to merit further investigation using whole genome sequencing. This first look has revealed reduced genetic variation within some of our metal-impacted populations, and genetic distinction of some metal-impacted populations from populations elsewhere in the catchment despite no obvious physical barrier to movement (see Figure 2).

At present, we have sent 12 trout individuals for medium-coverage whole genome sequencing, and 140 for low-coverage whole genome sequencing, with paired samples from relatively clean and metal-impacted sites from the sampled catchments across the British Isles. This will give us a representative sample to analyse for genetic diversity and to identify areas of the genome that are under selection. Using trout from across the British Isles with a different phylogenetic history improves our ability to disentangle existing differences between populations and those potentially driven by metal adaptation. This will give us a clearer picture to answer the questions that arose from the previous study of trout in Cornwall; specifically, whether or not the genetic differences are a result of metal adaptation, and if there are convergent responses in populations across the British Isles where metal pollution impacts rivers.

What is whole genome re-sequencing?

Genome: The full sequence of genetic material for an individual, consisting of genes, regulatory regions and 'neutral' regions, that is responsible for biological function.

Sequencing coverage: Genomes are too long to sequence in a single chain, so many short fragments are read and then assembled. The number of times each individual unit of the genome is read during sequencing determines the accuracy of the assembly. High, medium and low coverage refers to the number of times each unit of the genome is read.

Dan Osmond and Jamie Stevens electric-fishing for samples on the Avoca catchment, Ireland. © Charlie Ellis

Dan Osmond is a PhD student working with the GWCT, University of Exeter and Cardiff University, studying evolutionary adaptation of trout to metal pollution.

Game & Wildlife CONSERVATION TRUST

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

UNIVERSITY OF EXETER

Mature male pink salmon. The species is also known as humpback salmon and is easily identifiable from the black oval spots on the tail fin, small scales and the lack of dark spots on the gill covers. © Eva Thorstad

Impact of invasive pink salmon at sea and in rivers

Pink salmon is the smallest, most abundant and the most adaptable of the Pacific salmonid species, with one of the fastest oceanic growth rates. They typically have a two-year life cycle with separate populations reproducing in odd and even years. Between 1956 and 1999 they were deliberately stocked in rivers in the White Sea region by the USSR/Russia to establish a commercial fishery. For almost seven decades, irregular records of mainly single fish were reported from the UK and other countries, with the highest numbers reported from northern Norway. However, 2017 saw a substantial expansion of the species and pink salmon were observed in rivers across the British Isles, and in many countries for the first time, including Denmark and Germany. Large numbers of mature pink salmon were observed spawning in rivers in Scotland (especially the Rivers Dee, Spey and Ness) and were caught by net fisheries between the Scottish border and east Yorkshire coast. This phenomenon has raised concerns among scientists, conservationists and anglers, about the potential negative impact of this non-native species on stocks of native Atlantic salmon. As the population established in Europe comprises odd-year spawning fish, adult pink salmon entered British rivers again in 2019 and 2021.

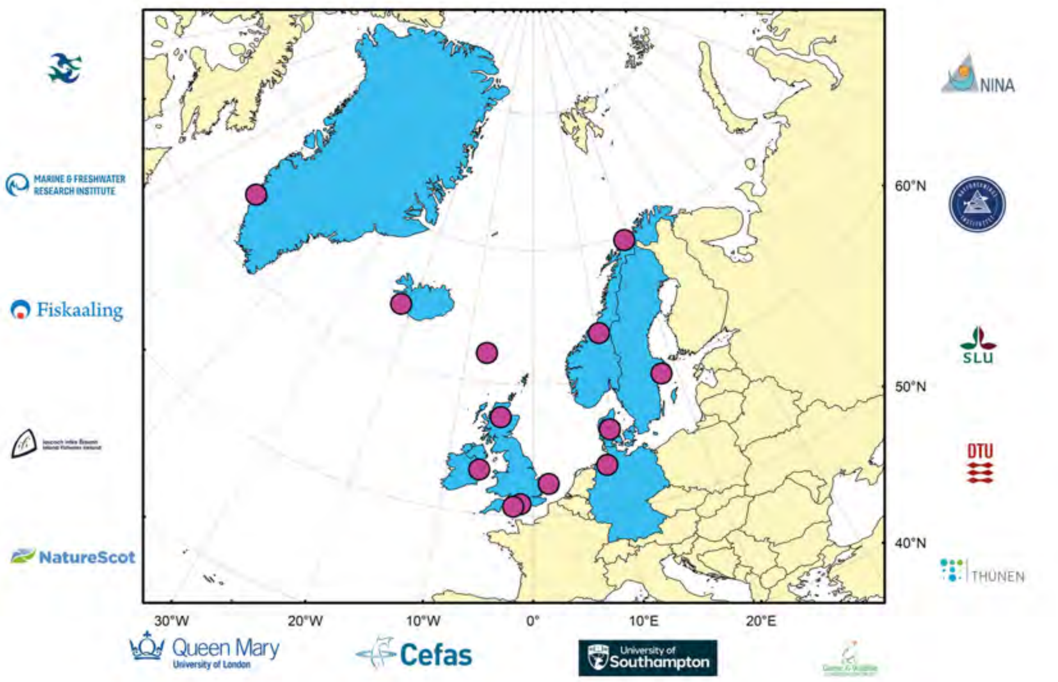
In their native range in the Pacific, pink salmon deplete marine food and compete with other salmonids. The marine feeding grounds of this new arrival in the North Atlantic and the extent to which pink salmon compete with native European fishes at sea is unknown. Moreover, around the Atlantic basin their ecological role during the freshwater phases of their life cycle remains unknown.

In 2021, a study was launched with the aim of assessing the present and future impacts of pink salmon at sea and in recently invaded rivers. This study will include mapping the distribution of pink salmon feeding grounds in the NE Atlantic, determine the extent of co-occurrence, and potential competition between pink and Atlantic salmon in ocean waters. The thermal sensitivity of pink and Atlantic salmon will be determined from field metabolic rates and used to assess the impact of climate warming on the future distribution of pink salmon in the NE Atlantic (see page 19). The study will also establish the ecological role of pink salmon fry in recently invaded rivers. These activities are being carried out under the 'PinkSIES' (Pink Salmon Invasion of the North Atlantic: Evaluation of Stable isotopes as a method to detect potential impacts) project at Queen Mary University of London (QMUL) and the Centre for Environment, Fisheries and Aquaculture Science Centre (Cefas). The project has the support of the GWCT and collaborators throughout the Atlantic (see Figure 1) including support from institutions such as the Environment Agency, NatureScot, Caithness District

KEY AIMS

- Mapping the distribution of pink salmon feeding grounds in the NE Atlantic, determining the extent of co-occurrence and potential competition between pink and Atlantic salmon in ocean waters.
- Determine the thermal sensitivity of pink and Atlantic salmon to assess the impact of climate warming on their future distribution, using field metabolic rates.
- Establish the ecological role of pink salmon fry in recently invaded rivers.

Figure 1
Collaborating organisations involved in the PinkSIES project



Salmon Fishery Board, Kyle of Sutherland District Salmon Fisheries Board and others.

To date, biological material from 500 adult pink salmon (otoliths, muscle tissue and scales) has been collected from locations across the North Atlantic region for analysis of stable isotopes to identify the feeding grounds and any potential competition with Atlantic salmon during the marine phase. The fish were caught offshore, in coastal waters as well as in rivers. In addition to the analysis of material from adult fish, sampling of juveniles from recently invaded rivers took place in spring 2022. The first results from the project will be available later this year.

In 2021, at an international seminar on pink salmon held in Finnmark (Norway), Norwegian scientists reported a 10-fold increase in the number of returning pink salmon in some rivers between 2019 and 2021. Additionally, the number of spawning adults in Russian rivers was the highest ever observed. Provided no excessive in-river mortality of juveniles and that there is no severe food limitations at sea, the wave of invaders entering rivers around the North Atlantic, including the UK, will likely be larger than ever in 2023.

What is field metabolic rate?

Field metabolic rate is a measure of the total energy expenditures of an organism. Energy costs include: sustaining life, storage, growth, hunting and predator avoidance. Higher values indicate a fast-growth rate likely associated with good food availability, whereas low rates might be associated with periods of food deficiency. In this project we will use otoliths (ear-stones) to determine field metabolic rate.

Michał Skóra is based at QMUL with a secondment to Cefas. He works at the University of Gdańsk, Poland. Prior to his academic work, he worked on a range of anadromous species in the Department of Migratory Fishes of the Inland Fisheries Institute (Poland).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101026030.

Two Atlantic salmon smolts of contrasting sizes.

Pre-smolt overwinter growth, smolt phenology and size related marine survival

The Atlantic salmon is a species of immense commercial, recreational and cultural importance. Native to rivers on both sides of the North Atlantic basin, this species has experienced dramatic population declines since the 1970s. The reasons are likely to be complex and due to many factors. Understanding factors affecting salmon survival, as well as other important aspects of their life cycle such as growth rates and migration phenology, is crucially important.

It has long been hypothesised that juvenile body size is an important driver of life-history events, as body size may be a proxy for overall fitness and can affect growth rates, migration timing, and survival between different life stages. The main aim of this work was to test the hypothesis that juvenile body size is a key determinant of success for later life events using a long-term Capture-Mark-Recapture (CMR) dataset of salmon in the River Frome, where every year since 2005 approximately 10,000 juvenile salmon (known as 'parr') have been captured throughout the catchment using electric-fishing. The body length of all individuals is measured, and each fish is fitted with a Passive Integrated Transponder (PIT) tag. Each PIT-tag has a unique code that enables each individual fish to be re-identified. In the spring, the parr metamorphose into 'smolts' and migrate downstream, where a subset of the PIT-tagged individuals are resampled. Approximately 1.5-6% of previously PIT-tagged individuals are trapped, measured again, and released to continue their migration. PIT-tagged individuals that successfully complete their marine migration and return to the river as adults (known as the 'marine return rate') can be redetected a final time by PIT-tag antennae in the river.

KEY FINDINGS

- Small juvenile salmon grow more during the winter than expected given their initial size.
- Large salmon smolts migrate earlier than small salmon smolts.
- Large salmon smolts are more likely to survive their marine migration and return to the River Frome as adults than small ones.

Four studies were conducted to address the main aims:

1: **Assessing how body size and environmental variables affected overwinter growth rates:** Small individuals grew more during the winter than expected given their initial autumn body size, and cohorts that experienced warm winters, with more variation in daily water temperatures, had the highest growth rates.

2: **Assessing what factors affected variation in smolt migration timing:** Relatively large smolts migrated earlier than relatively small smolts, and that while water temperature and discharge affected migration timing, the importance of these effects varied throughout the migration period. Smolts were more likely to migrate in schools later in the migration period, and during the daytime instead of at night.

3: **Assessing factors that affected marine return rates, with an emphasis on conditions experienced by smolts during the early part of their marine migration:**

Smolt body size was the most important determinant of the probability of an individual surviving and returning as an adult, although water temperature and the presence of piscine predators may also have played a role (see Figure 1).

4: **Combining the River Frome dataset with smolt data from six other European rivers with PIT-tag programmes to assess whether smolt body size was an important determinant of marine return rates across a substantial portion of the salmon's European range:** The results suggest that, as on the River Frome, smolt body size was an important determinant of marine return rates across Europe, with large smolts more likely to return as adults than small smolts.

These results are important for conservation efforts attempting to bolster numbers of salmon. Instead of focusing predominantly on increasing the number of juvenile salmon in the river, in the hopes of increasing the number that return to reproduce as adults, efforts should also be made to ensure excellent growth conditions, as this study established that juvenile body size plays an important role in subsequent survival.

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

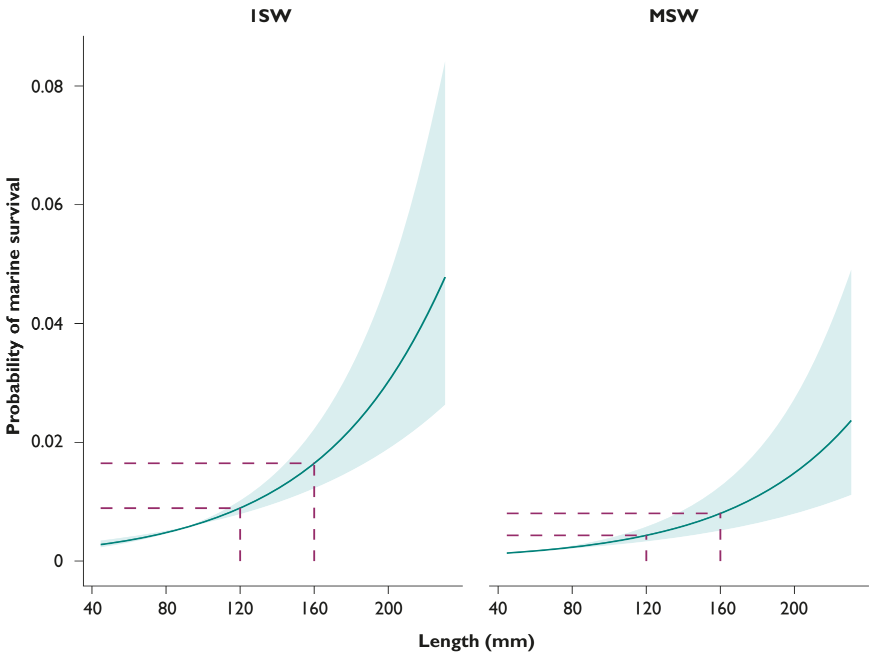


Figure 1

The predicted probability of survival for salmon on the River Frome after spending one year at sea (1SW) and after spending multiple years at sea (MSW) as a function of its body length as a smolt. The dashed lines show the marine return rate for a 120mm and 160mm smolt, respectively. These are two body lengths within the range of smolt body lengths commonly observed on the River Frome. The pale shaded area represents the 95% credible interval

Game & Wildlife CONSERVATION TRUST

Interreg France (Channel Manche) England SAMARCH SAlmonid MAnagement Round the CHannel European Regional Development Fund

Bournemouth University

Olivia Simmons is a PhD student working with the GWCT and Bournemouth University studying juvenile Atlantic salmon size and behaviour on their seaward migration and subsequent sea survival.

We are looking at the timing of the smolt migration and subsequent ocean productivity and feeding opportunities. © Ken Whelan

The Likely Suspects Framework

The Missing Salmon Alliance is developing its Likely Suspects Framework programme. This is a new approach that considers the whole life cycle, to understand changes in salmon survival; forecast stock prospects; and suggest a framework to guide management decisions. To advance the programme and demonstrate the relevance of the whole life cycle approach to the salmon management community, the team is developing an implementation study.

We are all too familiar with the trend of reduced marine survival of Atlantic salmon over the past decades, and recognise that this is linked to wider changes in oceanic conditions and their impact on salmon growth. The consensus view is that most of the marine mortality and between year fluctuation is likely to take place during the first few months at sea. During this phase the post-smolt actively migrate north to their feeding grounds (see Figure 1), they are small and potentially most vulnerable to predators and variations in food availability.

The Likely Suspects Framework implementation study focuses on using a sub-set of salmon rivers from the southern part of their European distribution, where high-quality data on marine return rates has been collected for decades, to develop a new salmon-focused angle to existing ocean datasets. The study aims to examine patterns in marine conditions during the early marine migration phase for the past decades and relate these to fluctuations in marine survival of salmon. It will then evaluate the strength of these past correlations between environmental conditions and marine survival of salmon, to develop predictors of future marine survival of this iconic species.

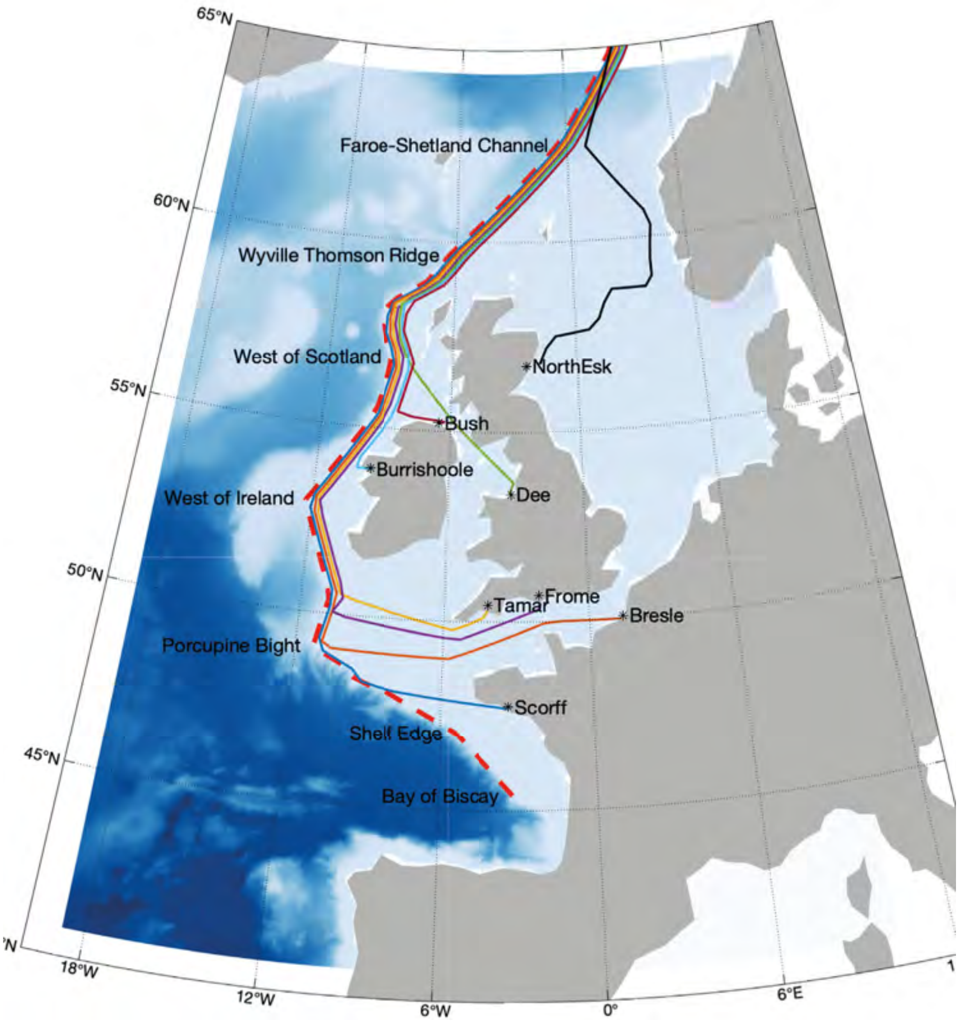
This implementation study began in the latter half of 2021 and the initial work has re-synthesised new salmon focused outputs from two oceanographic models, enabling the description of how ocean conditions have changed over the last 20 years at small scale resolutions (see Figure 1).

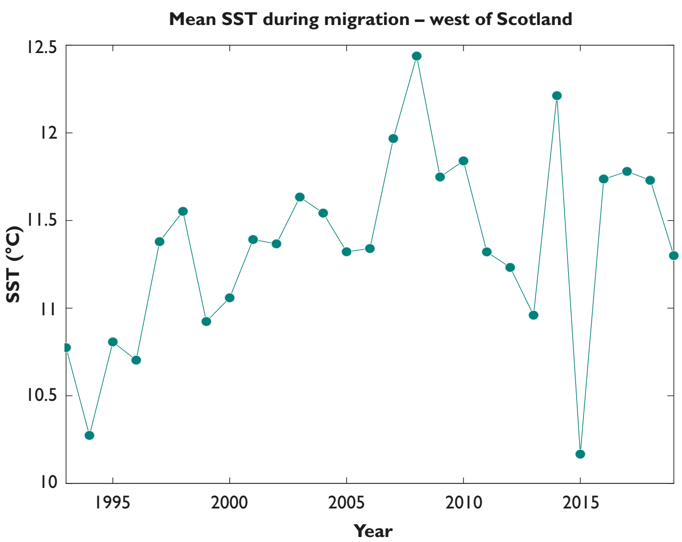
KEY AIMS

- Examine the relative importance of the timing of smolt migration and ocean productivity/good feeding opportunities.
- Develop new indicators of ecosystem health to act as predictors of future salmon marine survival.
- Bring new life cycle knowledge into the development of salmon management decision-support tools.

Figure 1

The indicative salmon post-smolt 'superhighway' for many southern European populations heading northwards along the shelf edge to the west of UK and Ireland (top map). The reconstructed average sea surface temperature (SST) during the migration period, and date of the initiation of marine plankton bloom from an example point (West of Scotland) (re-synthesized from the Scottish Shelf Model Reanalysis Service and the Atlantic Margin Models) are shown in the two graphs below the map





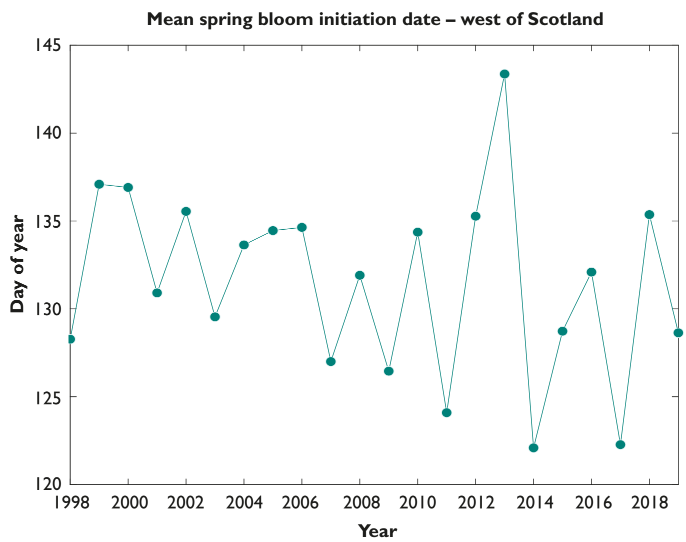
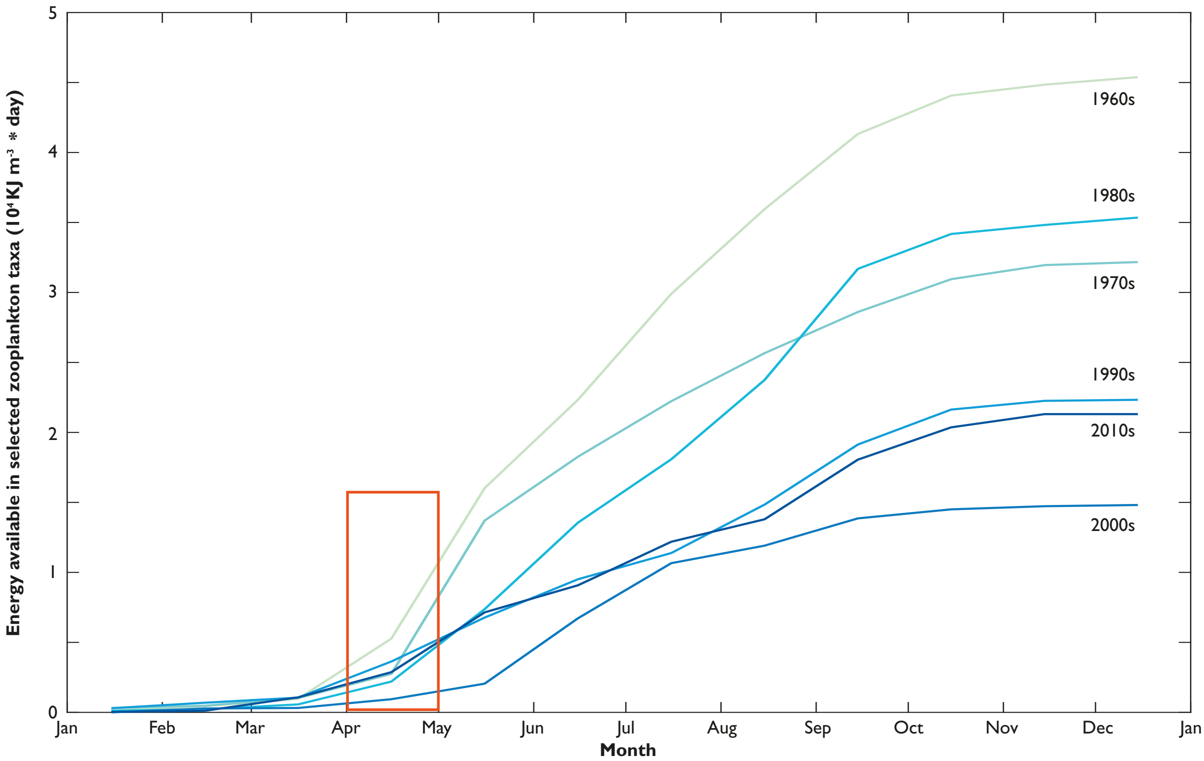


Figure 2

The blue line on the top map shows transects where Continuous Plankton Record data has been collected for decades. Here we focus on the feeding opportunities for salmon estimated from the Continuous Plankton Recorder on the post-smolt migration route west of Scotland and Northern Ireland (red box). In the bottom figure the abundance of all relevant zooplankton taxa were converted to energy content averaged monthly by decade, and cumulatively summed from Jan onwards. The orange box indicates the period when the post-smolts are present off the west coast of Scotland. Forage fish in the present-day ocean do not experience as much opportunity for growth in an entire year as fish in the 1960s would have within April, May, and June alone



The Continuous Plankton Recorder sampler which samples levels of zooplankton. © Marine Biological Association

Concurrently we have begun an examination of extensive plankton time series datasets, describing how particular elements of relevance to salmon diets have changed through time (see Figure 2).

The basic premise for the first part of the study is that post-smolt salmon feed on large zooplankton and small fish during their initial marine migration phase. Identifying signals in these lower trophic levels that relate to past trends in salmon survival might enable development of future indicators or predictors of marine survival of salmon. Possible explanatory variables might include a time lag (ie. conditions experienced by smolts in one year might be determined by ocean conditions the previous year) and include abundance and seasonal timing of plankton, or larval fish that feed on them.

During 2022 the study will:

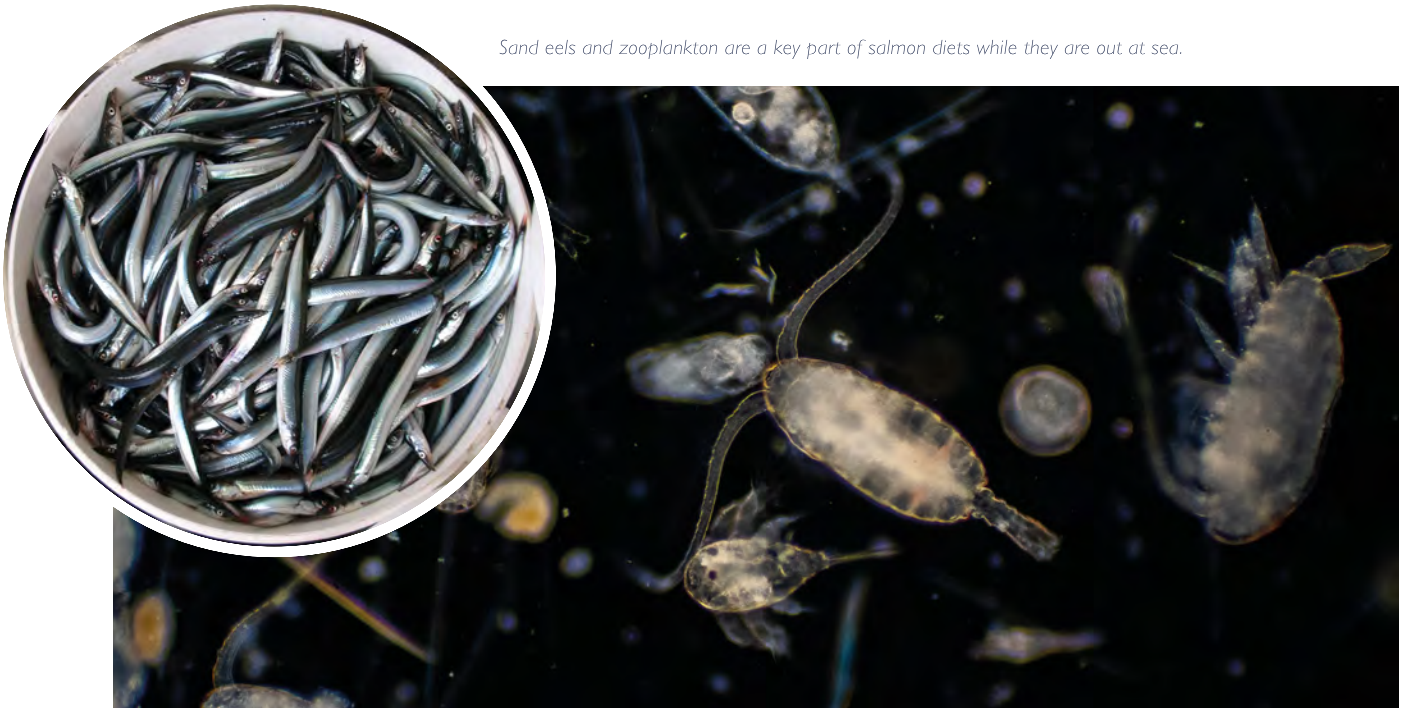
- Identify trends in smolt survival and migration timing among the salmon river groupings.
- Use recently published knowledge on post-smolt migration routes to focus attention on providing accurate reconstruction of conditions at key points and times along a shared migration route (eg. the post-smolt superhighway).
- Develop new indicators of ecosystem state from models and datasets (eg. peak prey timing, abundance and quality).
- Examine datasets for strengths of similarity that may help explain variations in salmon survival trends, primarily via trends in feeding opportunity.

The elements incorporated in this study will provide a 'seascape' describing how the conditions that post-smolts face on route to the Norwegian feeding grounds have changed during the past 20 years. It will provide new insights into the conditions that regulate early marine growth and influence the pattern of survival, enabling the development of better predictors of marine survival. These can then be integrated into a more robust life cycle based guidance for future salmon management activities.

THE MISSING SALMON ALLIANCE

Emma Tyldesley is a Missing Salmon Alliance post-doctoral researcher hosted at the University of Strathclyde. She is leading on the delivery of this work package within the Likely Suspects Framework programme.

Sand eels and zooplankton are a key part of salmon diets while they are out at sea.



© Emma Tyldesley/Choksawatdikorn

The East Stoke resistivity counter and Millstream offtake during the spring smolt migration.

Scientific publications

2021

Ensing, D. (ed), (15 authors), **Gregory, S. D.**, (17 authors) (2021). Working Group on North Atlantic Salmon (WGNAS). *ICES Scientific Reports.* 3:29. 407 pp. DOI: 10.17895/ices.pub.7923.

Rivot, E., Chaput, G. & Ensing, D. (eds), (14 authors), **Gregory, S. D.**, (18 authors) (2021). Workshop for Salmon Life Cycle Modelling (WKSalModel). *ICES Scientific Reports.* 3:24. 20 pp. DOI: 10.17895/ices.pub.7921.

Marsh, J.E., Cove, R.J., Britton, J.R., Wellard, R.G., House, A. & **Gregory, S.D.** (2021) Medium-term environmental changes influence age-specific survival estimates in a salmonid population. *Freshwater Biology.* DOI:10.1111/fwb.13736.

Marsh, J.E., Lauridsen, R.B., Gregory, S.D., Kratina, P., **Scott, L.J.,** Cooling, D. & Jones, J.I. (2021) High summer macrophyte cover increases abundance, growth and feeding of juvenile Atlantic salmon. *Ecological Applications.* DOI: 10.1002/eap.2492.

Marsh, J.E., Lauridsen, R.B., Riley, W.D., **Simmons, O.M., Artero, C., Scott, L.J., Beaumont, W.R.C., Beaumont, W.A.**, Davy-Bowker, J., **Lecointre, T., Roberts, D.E.**, & **Gregory, S.D**. (2021) Warm winters and cool springs negatively influence recruitment of Atlantic salmon *(Salmo salar L.)* in a southern England chalk stream. *Journal of Fish Biology*, **99**, 1125-1129. DOI: 10.1111/jfb.14760.

Needham, R.J., Gaywood, M., Tree, A., **Roberts, D.E.**, Bean, C.W. & Kemp, P.S. (2021) The response of a brown trout *(Salmo trutta)* population to reintroduced Eurasian beaver *(Castor fiber)* habitat modification. *Canadian Journal of Fisheries and Aquatic Sciences* **78**, 1650–1660. DOI: 10.1139/cjfas-2021-0023.

Perkins, D.M., Durance, I., Jackson, M., Jones, J.I, **Lauridsen, R.B.**, Layer-Dobra, K., Reiss, J., Thompson, M.S.A. and Woodward, G. (2021) Systematic variation in food web body-size structure linked to external subsidies. *Biology Letters,* **17**. DOI: 10.1098/rsbl.2020.0798.

Simmons, O.M., Gregory, S.D., Gillingham, P.K., Riley, W.D., **Scott, L.J.**, & Britton, J.R. (2021) Biological and environmental influences on the migration phenology of Atlantic salmon *Salmo salar* smolts in a chalk stream in southern England, *Freshwater Biology,* **66**, 1581– 1594. DOI: 10.1111/fwb.13776.

Simmons, O.M., Britton, J.R, Gillingham, P.K., Nevoux, M., Riley, W.D., Rivot, E., **Gregory, S.D.** (2021) Predicting how environmental conditions and smolt body length when entering the marine environment impact individual Atlantic salmon *Salmo salar* adult return rates. *Journal of Fish Biology*, 1– 11. DOI: 10.1002/JFB.14946.

Trehin, C., Rivot, E., Lamireau, L., Meslier, L., Besnard, A.-L., **Gregory, S.D.**, & Nevoux, M. (2021) Growth during the first summer at sea modulates sex-specific maturation schedule in Atlantic salmon. *Canadian Journal of Fisheries and Aquatic Sciences*, **78**, 659 – 669. DOI: 10.1139/cjfas-2020-0236.

Picken, J. (2021) The effects of low summer discharge on salmonid ecosystems. PhD Thesis, Queen Mary University of London. https://qmro.qmul.ac.uk/xmlui/handle/123456789/72620.

Woodward, G., Morris, O., Barquín Ortiz, J., Belgrano, A., Bull, C., de Eyto, E., Friberg, N. Guðbergsson, G., Layer-Dobra, K., **Lauridsen, R.**, Lewis, H.M., McGinnity, P., Pawar, S., Rosindell, J. & O'Gorman, E.J. (2021) Using food webs and metabolic theory to monitor, model, and manage Atlantic salmon – a keystone species under threat. *Frontiers in Ecology and Evolution*, 9. DOI: 10.3389/fevo.2021.675261.

2020

Gillson, J.P., Maxwell, D.L., **Gregory, S.D.**, (5 authors) (2020) Can aspects of the discharge regime associated with juvenile Atlantic salmon *(Salmo salar L.)* and trout *(S. trutta L.)* densities be identified using historical monitoring data from five UK rivers? *Fisheries Management and Ecology,* **27**, 567-579. DOI: 10.1111/fme.12456.

Gregory, S.D., Bewes, V., Davey, A. J. H., **Roberts, D.E.**, Gough, P. & Davidson, I. C. (2020) Environmental conditions modify density-dependent salmonid recruitment: insights into the 2016 recruitment crash in Wales. *Freshwater Biology,* **65**, 2135-2153. DOI: 10.1111/fwb.13609.

Höjesjö, J. and Walker, A. (ed.) (19 authors), **Lauridsen, R.**, (17 authors) (2020) Working Group to develop and test assessment methods for sea trout populations (WGTRUTTA). *ICES Scientific Reports.* 2:59. DOI: 10.17895/ices.pub.7431.

Marsh, J.E. (2020) The importance of *Ranunculus spp.* for juvenile salmonids in lowland rivers. PhD Thesis, Queen Mary University of London. https://qmro.qmul.ac.uk/xmlui/handle/123456789/68323.

Marsh, J.E., Lauridsen, R.B., Gregory, S.D., Beaumont, W.R.C., Scott, L. J., Kratina, P. & Jones, J.I. (2020) Above parr: Lowland river habitat characteristics associated with higher juvenile Atlantic salmon *(Salmo salar)* and brown trout *(S. trutta)* densities. *Ecology of Freshwater Fish,* **29**, 542-556. DOI: 10.1111/eff.12529.

Nyqvist, M.J., Cucherousset, J., Gozlan, R.E., **Beaumont, W.R.C.**, & Britton, J.R. (2020) Dispersal strategies of juvenile pike *(Esox lucius L.)*: Influences and consequences for body size, somatic growth and trophic position. *Ecology of Freshwater Fish*, **29**, 377-383. DOI: 10.1111/eff.1252.

Simmons, O.M., Britton, J.R., Gillingham, P.K., & **Gregory, S.D.** (2020) Influence of environmental and biological factors on the over-winter growth rate of Atlantic salmon *Salmo salar* parr in a UK chalk stream. *Ecology of Freshwater Fish*, **29**, 665-678. DOI: 10.1111/eff.12542.

Robertson, M. (ed), (14 authors), **Gregory, S. D.**, (18 authors) (2020) Working Group on North Atlantic Salmon (WGNAS). *ICES Scientific Reports.* 2:21. 358 pp. DOI: 10.17895/ices.pub.5973.

Chaput, G. & Ó Maoiléidigh, N. (eds), (3 authors), **Gregory, S.**, (6 authors) (2020) NASCO Workshop for North Atlantic salmon at-sea mortality (WKSalmon, outputs from 2019 meeting). *ICES Scientific Reports*. 2:69. 175 pp. DOI: 10.17895/ices.pub.5979.

Höjesjö, J. & Walker, A. (eds), (17 authors), **Lauridsen, R.**, (17 authors) (2020) Working Group with the aim to develop assessment models and establish biological reference points for sea trout (Anadromous *Salmo trutta)* populations (WGTRUTTA; outputs from 2019 meeting). *ICES Scientific Reports*. Report. DOI: 10.17895/ices.pub.7431.

2019

Gregory, S. D., Ibbotson, A. T., Riley, W. D., Nevoux, M., **Lauridsen, R. B.**, Britton, J. R., Gillingham, P. K., **Simmons, O. M.**, & Rivot, E. (2019) Atlantic salmon return rate increases with smolt length. *ICES Journal of Marine Science*, **76**, 1702-1712. DOI: 10.1093/icesjms/fsz066.

Robertson, M. (ed), (14 authors), **Gregory, S. D.,** (18 authors) (2019) Working Group on North Atlantic Salmon (WGNAS). ICES Scientific Reports, 1: 16. International Council for the Exploration of the Sea. DOI: 10.17895/ices.pub.4978.

Pottier, G., **Beaumont, W.R.C.**, Marchand, F., Le Bail, P.Y., Azam, D., Rives, J., Vigouroux, R., Roussel, J.M. (2019) Electrofishing in streams of low water conductivity but high biodiversity value: challenges, limits and perspectives. *Fisheries Management & Ecology*, **27**, 52-63. DOI: 10.1111/fme.12384.

Soetaert, M., Boute, P.G. and **Beaumont, W.R.C.** (2019) Guidelines for defining the use of electricity in marine electrotrawling. *ICES Journal of Marine Science*, **76**, 1994-2007. DOI: 10.1093/icesjms/fsz122.

Simmons, O., Thorsteinsson, M. & Ólafsdóttir, G.Á. (2019) Trophic dynamics of anadromous brown trout and Arctic charr in NW Iceland and their correlation to salmon lice infection. *Polar Biology*, **42**, 2119-2130. DOI: 10.1007/s00300-019-02586-1.

For a full list of scientific publications please see:
gwct.org.uk/fisheriespapers

Contact us

SALMON & TROUT RESEARCH CENTRE
East Stoke, Wareham,
Dorset, BH20 6BB
Email: fisheries@gwct.org.uk
Tel: 01929 401893

www.gwct.org.uk

RECYCLED
Paper made from recycled material
FSC® C019088
www.fsc.org

Printed on FSC accredited, chlorine-free paper from sustainable forests

Design and Layout: Louise Shervington

Game & Wildlife
CONSERVATION TRUST