Fisheries research report 2015

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MorFish
Monitoring for Migratory Fish

Game & Wildlife
CONSERVATION TRUST

www.gwct.org.uk/fisheriesreport

Contents

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Front cover: Sea trout on the River Frome; (above) The fisheries team electro-fishing.

The work of the fisheries department will benefit many salmon rivers with increased focus on managing salmon through estuaries and into coastal waters.

Foreword

Welcome to the GWCT's fisheries department research report for 2015. We hope you find it both interesting and informative. It is now 12 months since I took over the reins of chairing the GWCT Fisheries Research Steering Committee and I am thoroughly enjoying the experience. Thankfully, you will read that the estimated number of adult salmon that entered the River Frome in 2015 increased markedly from 2014, which was a very poor year, and mirrored information from most English rivers which recorded the lowest rod catches of salmon on record. This sparked a 'Salmon Summit' meeting in London in late 2015 resulting in the publication of a five point action plan between the Environment Agency and key players.

The work of the GWCT fisheries department will contribute to many aspects of the five point plan in the coming years and I am glad to see that there is increased focus on managing salmon through the estuaries and into coastal waters. You will notice that the range of projects undertaken by the fisheries team is expanding well beyond the core work of studying patterns in the adult and juvenile salmon population on the River Frome. For example, this report contains results of our work to assess the impacts of hydropower turbines on salmon smolts.

You will also read about how the work of the PhD students that we fund or support, is helping to safeguard and improve salmonid populations such as providing information on the importance of *Ranunculus* for stream biodiversity and salmonid nursing areas in lowland rivers, low flows and management of water resources for salmonid ecosystems and contributions towards the debate on beaver reintroduction.

Funding continues to be a challenge and the team and I are continuously working towards securing the long-term sustainability of our core work. Did you know that the River Frome is the only privately-funded juvenile and adult salmon 'Index' river in Europe? All other index rivers are publicly-funded. With that thought may I wish you an enjoyable read and the anglers amongst you, tight lines for 2016.

David Mayhew
Chairman of the GWCT Fisheries Research Steering Committee

David Mayhew, Chairman of the Fisheries Research Steering Committee.

1. River Frome salmon population

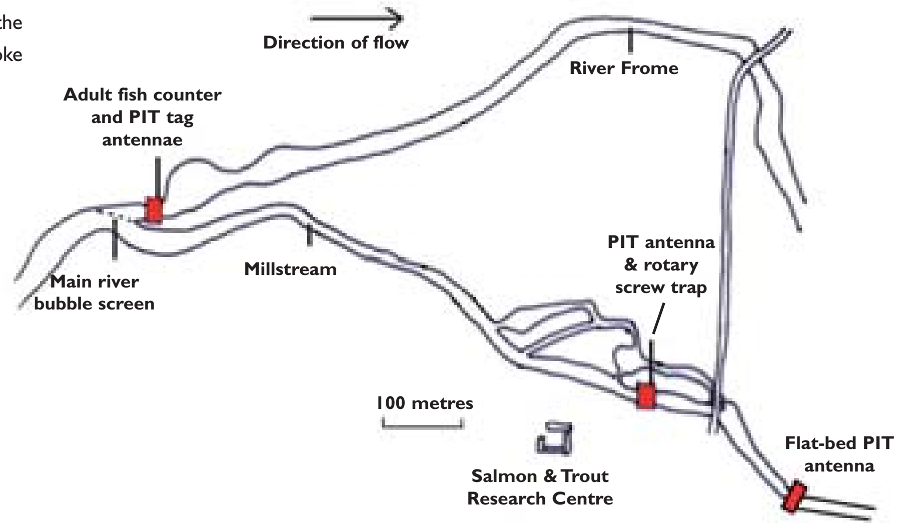
The GWCT fisheries research group is based at East Stoke on the banks of the River Frome in Dorset and the Atlantic salmon population in the River Frome provides the core focus of our work. For the past 43 years we have quantified the number of adult salmon returning to the Frome so that over the years of studying this population we have built up an unparallelled monitoring infrastructure at East Stoke and elsewhere in the catchment (see Figure 1).

Like most rivers feeding the North Atlantic, the number of returning adult salmon to the Frome showed a marked decline in the early 1990s (see Figure 2). Because this collapse was observed in rivers across the distribution of salmon the consensus opinion is that it is caused by problems in the marine environment; such as warmer sea temperatures. However, this highlighted to our fisheries group the importance of being able to separately analyse the changes effecting 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 lifecycle.

Estimating the density of juveniles and the number of emigrating smolts on a catchment scale is very difficult. However, it is possible to estimate population size by marking a proportion of the population and then resampling the population later-on and seeing what proportion 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 different juvenile stages.

Figure 1

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



Although conditions at sea are impacted by global activities, managing the freshwater environment is much more tangible and optimising the output of smolts from freshwater will help to offset a lower marine survival and hopefully then boost the population.

Each PIT tag contains a unique code that not only provide us with population level data but also life history data of individuals. Utilising PIT tags we are therefore able to quantify and compare parameters such as growth and survival in different parts of the catchment as well as changes to these parameters between years. Hence we are able to identify environmental drivers of changes within the population. It is exactly such knowledge that can inform us how best to manage the river catchment to optimise the output of smolts.

Adult salmon estimate

We estimate the number of returning adults using a resistivity counter that detects the change in electrical resistance of the water caused by a salmon swimming over the counter. As well as providing population data, the adult counter provides data 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 temporal changes in marine growth. In addition, an estimate of the adult return can be made from the PIT tag data obtained from adult fish as they migrate back into the river. The relationship between the freshwater production of smolts and returning adults enables us to quantify the marine 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.

The run of adult salmon is presented for the period 1 February to 31 January inclusive. Past data and personal observations indicate that the majority of the upstream movement in January is caused by the continued migration of fish from the previous calendar year migrating to spawn, not fish migrating to spawn in 11 months' 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, video frame-grab and video analysis. Once again in 2015, debris coming down river resulted in broken wires and as a consequence the counter wasn't fully operational for some periods. In these periods only two of the three electrodes were running, which enables us to detect passing fish but not

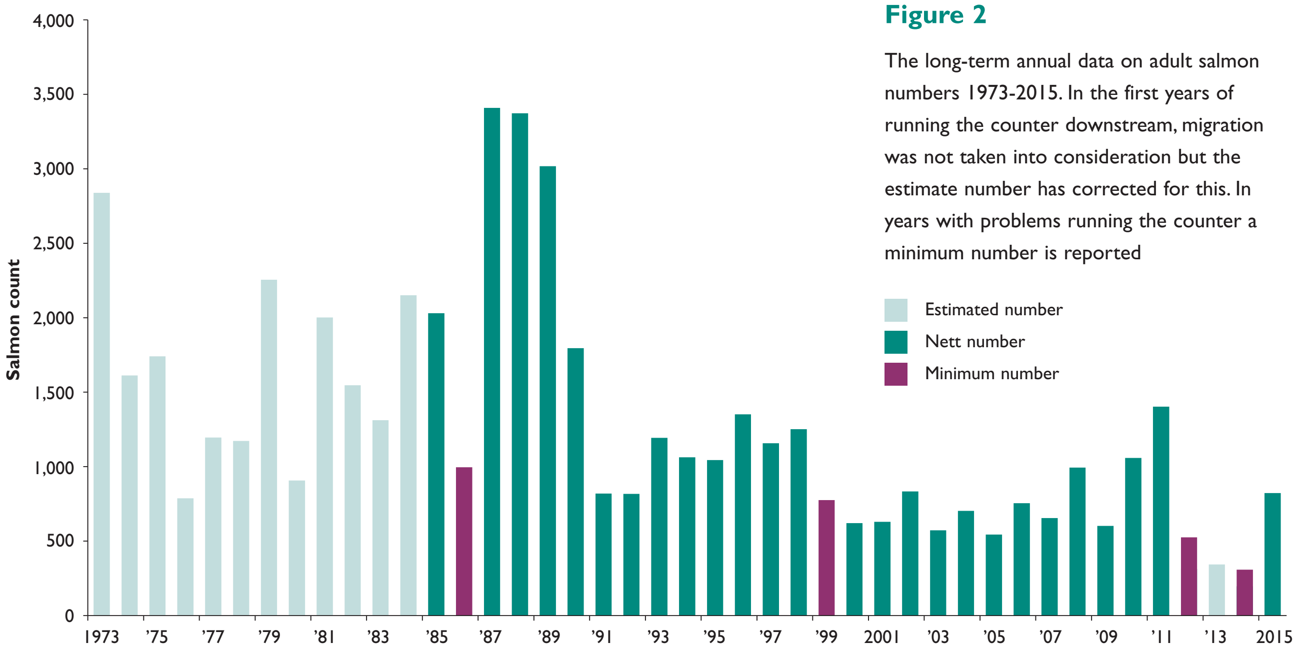


Figure 2

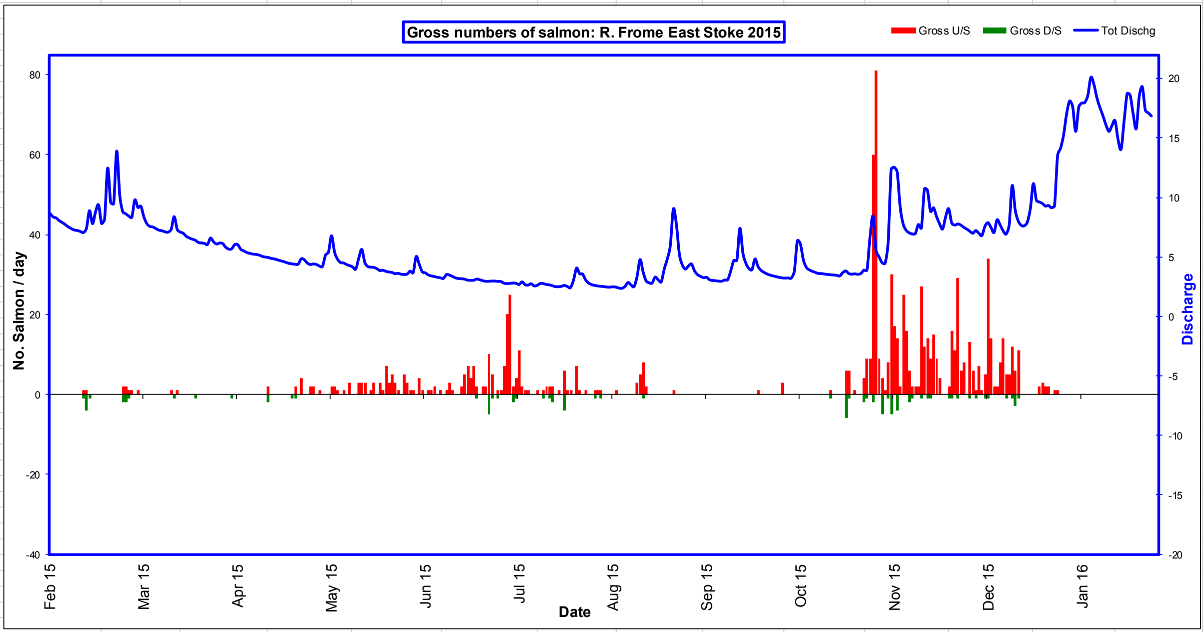
The long-term annual data on adult salmon numbers 1973-2015. In the first years of running the counter downstream, migration was not taken into consideration but the estimate number has corrected for this. In years with problems running the counter a minimum number is reported direction of passage. Fortunately, the summer of 2015 was relatively dry so using video data we were able to verify and assign direction to the vast majority of these fish.

After two consecutive years with adult estimates well below the conservation limit, 2015 proved to be a much better year with an estimated 822 returning adults, which meets the conservation limit for the Frome in 2015 (see Figure 2). The increase in returning adults was largely as a result of a big run of fish of mixed age in late autumn (see Figure 3). For a more detailed account of the 2015 salmon run contact us for a copy of the *2015 GWCT Salmon Research Report*.

Figure 3

The monthly run data for 2015 and a graph showing daily gross upstream numbers and river flow

	MONTH												
Month	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Total
Gross U/S	8	3	13	55	70	94	21	4	177	300	157	0	902
Gross D/S	11	2	5	0	8	12	2	0	13	24	10	0	87
Nett U/S	2	3	8	55	62	82	19	4	164	276	147	0	822



Juvenile estimates

In September for the past 11 years, we electro-fished and tagged 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 wide – see below) are inserted into parr and enable us to individually identify the fish when they swim past our detector antennae. 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. In 2015 we tagged 8,424 salmon parr, slightly below the target 10,000 partly due to a very wet start to the tagging campaign. The PIT tag stays with the fish for life and passage of tagged fish out to sea and any

Salmon parr and PIT tag (circled). Individual ID of the tag is shown on the label.

We caught 1,810 salmon smolts in the Rotary Screw trap and of these 226 (12.5%) were tagged.

fish returning from the sea are recorded by the tag detecting equipment installed throughout the catchment.

Smolt estimate

We have estimated the number of smolts emigrating from the river since 1995 but the installation of our first PIT antennae in 2002 marked a milestone in the accuracy of these estimates. This methodology has allowed us to provide a very accurate estimate and to calculate potential variation around this estimate (95% confidence intervals).

During the smolt run we use a device called a Bio-Acoustic Fish Fence (BAFF) to divert the fish into the Mill Stream at East Stoke. The BAFF is a curtain of bubbles that has sound entrained within the bubbles, thereby creating an audio-visual impression of a barrier diverting the fish. The diversion efficiency of the BAFF has been shown to be very good, deflecting approximately 80% of the smolts down the Mill Stream where a proportion of the fish are trapped using a rotary screw trap (see picture above).

In 2015 we caught 1,810 salmon smolts in the trap and of these 226 (12.5%) were tagged. Using the number of tags detected, the ratio of tagged to non-tagged smolts and the efficiency of the PIT tag antennae we can calculate that the smolt output in 2015 was 7,794 (see Figure 4). The smolt output in 2015 was considerably below the average for the past nine years (10,710) which is probably linked to a low adult run in 2013 (see Figure 2).

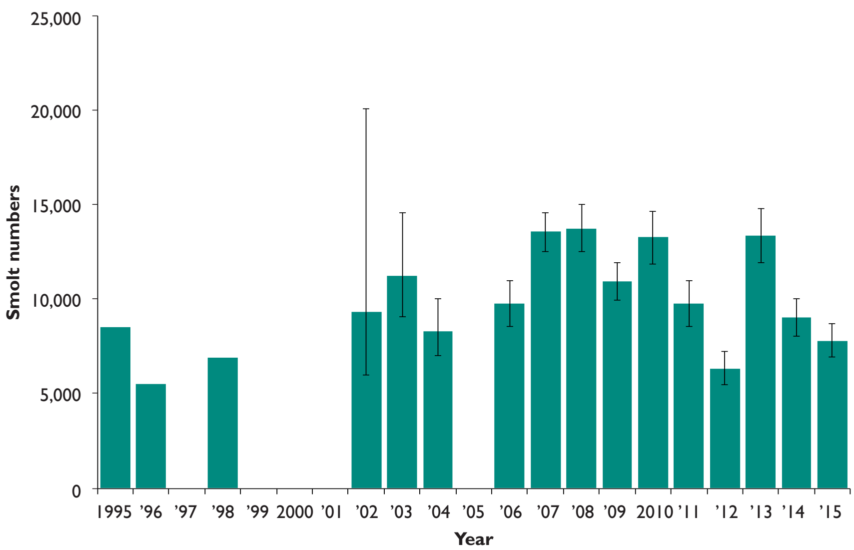


Figure 4

Annual estimate of emigrating smolts from the Frome catchment and (where available) 95% confidence limits

2. Migratory trout

The River Frome has a significant population of migratory trout and we have now started a long-term study of these.

The River Frome has a significant population of migratory trout and with the PIT antennae in place this trout population has long been the elephant in the room; why not tag trout too? Tagging 10,000 salmon parr throughout the catchment is a mammoth task and there hasn't been resources available to also tag trout parr on a scale that would facilitate robust analysis. But with the help of the Cefas salmon and freshwater team from Lowestoft, 2015 marked the first year where a significant number of trout parr were tagged in the Frome catchment. We tagged nearly 3,000 young of the year trout parr during the tagging campaign and it is with great excitement that we await detections of these trout when they go to and return from sea. The plan is to continue tagging trout parr in the coming years and the data from these fish will provide us with estimates of the trout smolt output as well as the number of returning adults. Furthermore, as trout were tagged throughout the catchment we will also be able to determine if any particular parts of the catchment contributes disproportionately to the migratory population.

Cefas

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For the first time in 2015 we tagged trout as well as salmon to quantify sea trout population size and find out more about their migration. A salmon (upper) and a trout (lower) parr.

Finding out more about sea trout

It is suggested that nocturnal migration is an adaptive behaviour to avoid visual predators.

Migration between freshwater nursery grounds and saltwater feeding areas is a critical event in a sea trout's life history. During their seaward migration, smolts encounter both natural and man-made obstructions as well as increased exposure to predators. This is particularly true in the transition zone between freshwater and saltwater where smolts enter a new environment, change their behaviour and encounter new predators. Over two years (2013-14), 81 trout smolts were trapped and acoustically tagged 17 kilometres (km) upstream of the tidal limit in the River Frome. Smolt migrations were then tracked by acoustic receivers deployed throughout the lower river and its estuary (see Figure 5) and the detected movements were used to estimate loss rate and migration behaviour.

More than 90% of the in-river detections occurred at night whereas detections at the saline limit and throughout the estuary were spread evenly between day and night. Median migration speed in the river was 65-70km per day in both years, whereas the migration speed was slower through the estuary with median speeds of less than 10km per day. The high migration speed in freshwater indicates an active migration; however, as the vast majority of the observations in this zone were made at night, the smolts must have held station during the day, indicating an in-river 'start-and-stop' pattern of migration behaviour. Similar nocturnal freshwater migration patterns have been observed elsewhere and it has been suggested that nocturnal migration is an adaptive behaviour to avoid visual predators.

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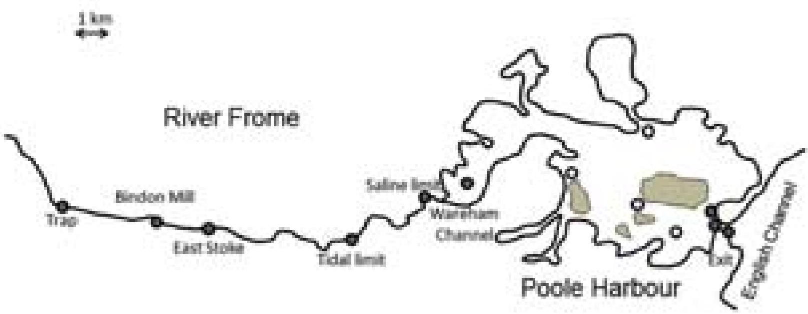
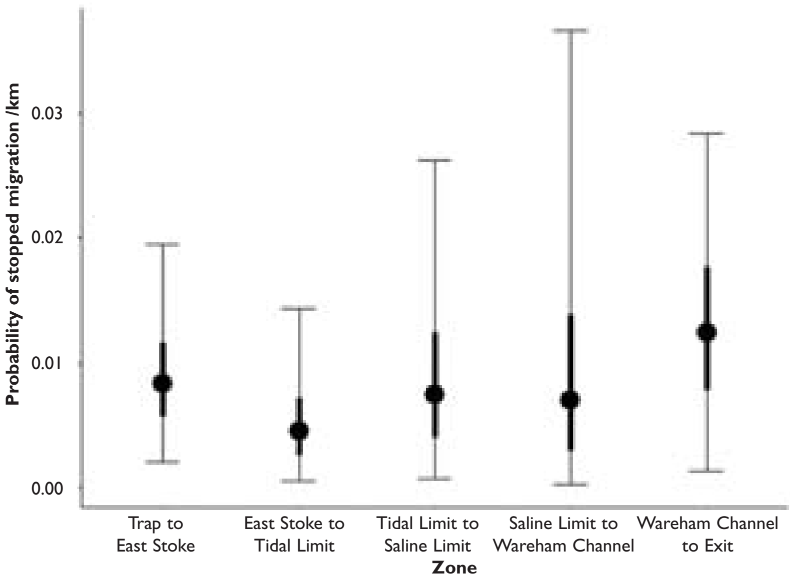


Figure 5

Map of the lower River Frome and its estuary at Poole Harbour. Grey circles indicate location of trap and acoustic receivers deployed in both 2013 and 2014. Open circles indicate estuary receivers deployed in 2014 only

Figure 6

Probability of stopped migration within individual zones divided by the length of the zone (km) years combined with 95% credible intervals



A number of studies have reported very high loss rates in the transition zone between freshwater and saltwater for sea trout and salmon smolts. However, in this study no zone displayed particularly high loss rates (range 0.5-1.1% per km), hence there was no pronounced increase in mortality in the transition zone (see Figure 6). High loss rates in the transition zone are therefore not inherent and it appears that the wild smolts tagged in this study were fully adapted for the physiological and behavioural changes experienced in the transition zone. Studies reporting high loss rates in the transition zone were linked to very high predation rates from fish and birds, but this will be highly variable depending on the predator populations in different estuaries.

The cumulative loss of trout smolts through the 33km section that the smolts were tracked was 24%, demonstrating a significant cost associated with smolt migration. However, it is important to bear in mind that these losses effectively represent stopped migration. Stopped migration could be caused by fish mortality, but there are other possible explanations, such as tag failure or the fish taking up residence between receivers (slob trout).

The battery life of the acoustic tags was extended and extra receivers were placed in the estuary during the second study year (2014), but no fish were detected foraging in the estuary during the second summer. Furthermore, of the 11 adults observed returning to the river, all but one was recorded by the acoustic receivers at the exit where the harbour meets the sea. It appears that the anadromous individuals of the River Frome all leave the estuary and seek inshore or offshore feeding areas in the English Channel.

In this study we established a significant cost-penalty in terms of the cumulative loss associated with the outward migration of smolts through the lower river and the transition zone. Although this study does not indicate if this mortality rate is outweighed by benefits in growth and fecundity, it contributes to our understanding of near-shore mortality in relation to the cost-benefit analysis that must underpin the life-history strategy choices of trout.

Eleven of the 81 acoustically tagged smolts were observed returning to the river as adults from the English Channel.

3. Hydropower effects on migratory fish

The recent drive towards renewable energies has caused a marked increase in applications for small-scale hydropower schemes. These schemes often involve the installation of generating hardware such as an Archimedes screw. However, very little is known regarding the impact of such installations on fisheries and the freshwater ecosystem. These schemes have therefore caused concern within environmental organisations because of the potential damage to fish which may pass through the rotating turbine.

In 2010, an Archimedes screw turbine was installed at Bindon Mill. This presented an opportunity for evaluating the effect of the Archimedes screw turbine on migratory fish, in a catchment already equipped with PIT tag antennae at East Stoke 3.5km downstream of Bindon Mill. A partnership with the Environment Agency was formed where they contributed significantly to the installation of PIT tag antennae covering all routes at Bindon Mill. The installation proved a challenge but efficient PIT tag antennae covering all three channels at Bindon Mill were installed in 2014 ready for the 2015 smolt run.

In this study we set out to quantify whether there was an increased mortality of smolts passing through the turbine compared with those using other routes passing through Bindon Mill. We studied this over the next 3.5km of their seaward migration to East Stoke. We also studied whether migrating through the turbine impacted the migration behaviour of the smolts.

Of 583 emigrating salmon smolts detected at Bindon Mill in 2015, 31% passed through the turbine route (possible range of smolts using turbine route: minimum 22% – maximum 51%). The re-detection rate at East Stoke was 91% and 92% for fish migrating through the turbine and using routes other than the turbine respectively. Hence there was no difference in the probability of being re-detected at East Stoke between individuals passing through the turbine route and other routes at Bindon Mill. It is important to point out that whereas this is a test of difference in survival between individuals using either turbine or other routes at Bindon Mill, the reported 91% and 92% re-detection rates are not equivalent to survival rate as the PIT tag system at East Stoke wasn't 100% efficient.

The mean transition times were 0.70 days and 0.66 days for fish migrating through the turbine and other routes respectively (see Figure 7). Hence there was also no effect of smolt route choice on the transition time between Bindon Mill and East Stoke.

The majority of smolts were detected at night and smolts migrating during daylight appeared to avoid the turbine channel at Bindon Mill. Restricting the use of the turbine at night during the smolt run would therefore be an effective way of reducing the number of smolts using this route should this be desired.

It is important to emphasise that the results reported in the present study is for the particular hydropower scheme installed at Bindon Mill and it would be

Smolts migrating during daylight appeared to avoid the turbine channel at Bindon Mill.

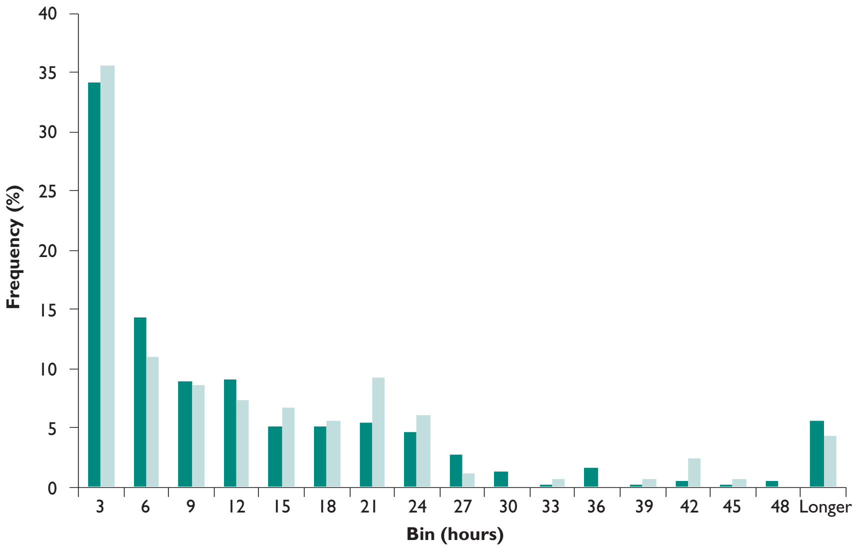


Figure 7

Histogram of transition time for individuals detected both at Bindon Mill and East Stoke grouped by detection at the turbine or other routes at Bindon Mill

Other route
Turbine route

misleading to use the results reported as generic assessment of all Archimedes hydropower schemes as local conditions and the design of Archimedes screws vary. However, from this first year of data collection it appears that the turbine design used at Bindon Mill has no or limited short-term impact on emigrating smolts.

The limited studies conducted on the effect of Archimedes screw turbines on migratory fish have focused on damage caused by the screw assessed immediately downstream of the screw. In this study we extended the assessment zone to 3.5km downstream of the Archimedes screw. However, this 3.5km assessment zone represented less than 24 hours post-turbine passage for >85% of the studied individuals (see Figure 7). Minor injuries incurred during passage through the turbine, such as scale loss, might only manifest when the smolts enter saltwater.

As the PIT tags will stay with the salmon for life, comparison of marine survival of smolts using either the turbine route or other routes at Bindon Mill will be possible from detections of returning adults. However, as marine survival is low (3-8%) it will take a number of years to build up enough adult detections to test the effect of the smolt route at Bindon Mill on marine survival. The effect of smolt route at Bindon will, however, only be complete with an assessment of effect on marine survival.

The present study only encompasses the effects on emigrating juvenile salmon and no impact assessment was made of the hydropower scheme on larger fish such as salmon and sea trout kelts and emigrating silver European eels.

4. MorFish closing conference

(L-R) Marie Nevoux and Jean-Marc Roussel (INRA), Luke Scott, Dylan Roberts, Paul Knight (S&TC) and Rasmus Lauridsen from the GWCT at the MorFish Conference. © INRA

Last year on the 3-4th of March, the MorFish project held its closing conference close to the banks of the River Frome in Wareham, Dorset. The event was very well attended by over 90 delegates including 27 from France, representatives from NGOs and public organisations who are involved in salmon population monitoring, assessment and management. The list of delegates included some key players in the salmon world and a huge thank you from the MorFish Project team to everyone who attended.

Day one of the event was dedicated to discussing the salmon monitoring undertaken in England, Wales and France and the techniques used. For example there were talks by Ian Davidson who leads the salmon monitoring for Natural Resources Wales and Jean-Luc Bagliniere who gave an overview of current and historical salmon data collection and management in France.

Day two focused on how the collected data are being used or could be interrogated using contemporary data modelling techniques to further our understanding of what drivers cause changes in salmon abundance. Stephen Gregory, the MorFish project scientist presented his work on modelling changes in salmon parr lengths over the last 25 years and how to fill gaps in data in salmon population estimates using contemporary modelling techniques. There was particular reference to monitoring on salmon Index rivers presented by Etienne Prevost from INRA and how modelling of data could be used to increase the precision on setting conservation limits on rivers.

For the talks presented at the event please visit **www.MorFish.org.uk**

5. Are salmon parr lengths changing?

Changes in juvenile salmon condition, notably length, could be responsible for recent decreases in Atlantic salmon abundance, either by reducing the number or timing of salmon smolts migrating to sea or by reducing their condition and consequently their survival at sea. Yet, few studies have shown that between year changes in juvenile salmon lengths are correlated with environmental factors. Still fewer studies have considered whether these environmental factors are acting at the local scale, ie. they affect parr differently on different rivers, or the regional scale, ie. they affect parr in geographically close rivers similarly.

Using the salmon parr monitoring data collected on the rivers Frome, Oir (Normandy) and Scorff (Brittany) for 10-25 years, amounting to approximately 100,000 measured parr, we have been able to describe observed parr length changes and how they have been affected by river temperature, flow, or numbers of competitors for food or habitat. Moreover, we have been able to determine which of those environmental factors are acting at the local or the regional scale.

Focusing on the Frome as an example, we have shown that lengths of salmon parr in the Frome have been decreasing by approximately four millimetres (mm) per year (see Figure 8) and this decline appears to be associated with parr density in September, over-winter water temperature and minimum summer water flow. It seems that Frome salmon parr are shortest in years when there are many other salmon parr in the river and thus high competition for food, cold over-winter temperatures causing slower and later egg development, and a summer drought that concentrates food and shelter and intensifies competition for these resources.

As we expected, environmental factors associated with large-scale climate phenomena affected salmon parr lengths similarly on all three rivers. For example, the effect of temperature-related variables was similar in strength and direction on all three rivers. Whereas, environmental factors more likely to be influenced by local river and weather conditions affected salmon parr differently on each river. For example, the effect of flow on salmon parr lengths differed on the Frome compared with the Oir and Scorff, which perhaps reflects different water abstraction practices in England and France.

The findings of this project have highlighted the need to manage salmon parr habitat on specific rivers but have also highlighted the need for international co-operation to safeguard salmon populations from the threats of rising river water temperature and diminishing summer river flows under future climate change.

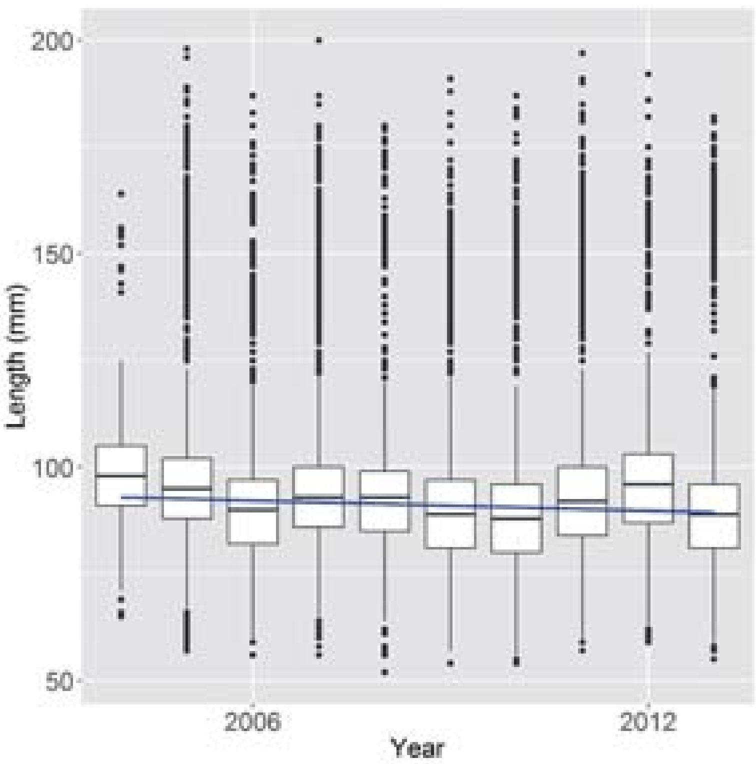


Figure 8

A boxplot of River Frome salmon parr lengths (mm) measured in September 2004-2013. The boxes and whiskers capture the majority of length measures and closed circles represent extreme values. The blue trend line is a linear regression of length by year, suggesting that Frome salmon parr lengths are decreasing over time

6. Wylye Grayling Study: floods and recruitment

European grayling *(Thymallus thymallus)* are closely related to salmon and trout species and share many of the same habitats. For example, they construct nests in the gravel streambeds in which they deposit their eggs. Compared with salmon and trout, however, grayling are known to be more sensitive to pollution and extreme temperatures because they have lower tolerances than their larger cousins. It is also thought that their recruitment – the survival of their progeny from eggs to the breeding population – is more sensitive to extreme river flows than salmon and trout because their nests, also known as redds, are usually shallower and more prone to damage from floods, known as egg washout.

The Wylye Grayling Study celebrated its 20th year in 2015, not including the opportunistic surveys done between 1984 and 1996 by then river warden Hal Thirlaway. During those 20 years, and with the help of partners Natural Resources Wales and the Piscatorial Society, the GWCT fisheries team have marked approximately 9,000 individual grayling resulting in a total of over 11,000 records, including individual lengths, weights and even scales.

During those 20 years, Britain has experienced some very wet weather, which is becoming a regular feature of our climate: according to the Met Office, four out of the five wettest years on record have been since 2000, including the great floods of 2000 and the more recent 2012 floods, the first and second wettest years on record. And the situation doesn't look to be improving: January 2014 was the wettest winter month in over 250 years and the 2015/2016 winter was the second wettest UK winter on record.

It is only with extensive datasets, such as the Wylye Grayling Study, that scientists can answer questions about the effects of rare extreme events, such as floods, on

The survival of grayling's progeny from eggs to the breeding population, is more sensitive than salmon and trout to extreme river flows.

wildlife populations. This is because these datasets have a higher chance of including multiple rare events, by merit of their length, which therefore provide better evidence of a general effect.

For example, we can plot the mean daily Wylye flow by year on a graph (see Figure 9A). From this, we note that we observed three major flood events during the 18 years from 1996 to 2013; years 2000, 2007 and 2012. We can do the same for the numbers of young-of-year grayling caught in the annual survey; combining numbers across all sites (see Figure 9B); a measure of successful recruitment. Visually comparing the grayling captures with the mean daily flow for each year shows that the young of year grayling catches were depressed in each of the flood years by as much as 80-90% relative to the preceding year.

Although these circumstantial findings are suggestive of an effect of flooding on grayling recruitment, we must remain aware of alternative explanations.

We will carry out a full and careful analysis of the Wylye Grayling Study data to evaluate the evidence for an effect of flooding compared with competing hypotheses. Furthermore, we will seek evidence of egg washout via its effect on population age-structure and abundance in the Wylye Grayling Study dataset. Any evidence of egg washout would demonstrate that floods are detrimental to grayling – and by extension, salmon and trout – populations and that it is imperative to reconcile the risks of floods to humans and the environment in the development of flood mitigation plans.

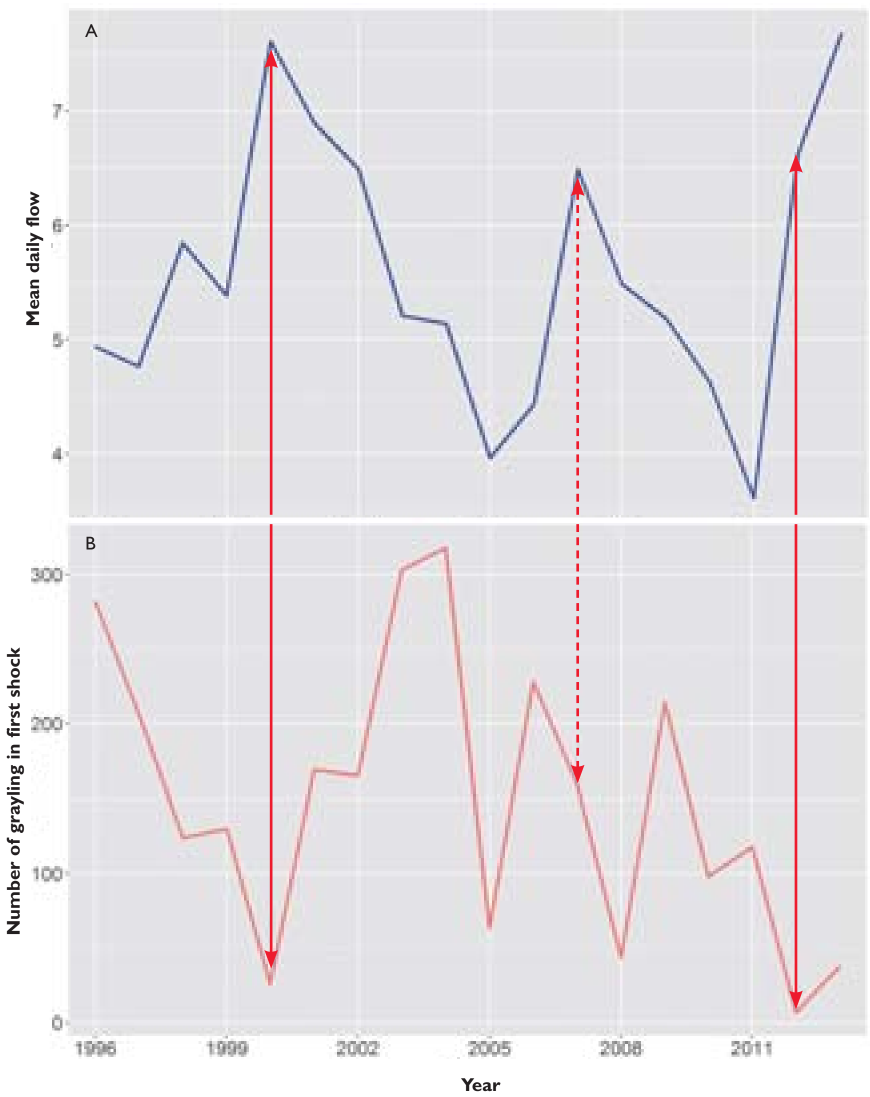


Figure 9

Line plots showing (top graph) the mean daily flow (cubic metres per second), and (bottom graph) the numbers of young-of-year (YOY) grayling captured in the first electrofishing shock for years 1996 to 2013. Solid red arrows highlight the high flows of 2000 and 2012 and the corresponding pattern in the YOY grayling captures; the dashed red arrows highlight the high flows of 2007 and the weak patterns in the YOY grayling captures

7. Ranunculus in chalkstreams

By Jessica Marsh, PhD student

Flowering Ranunculus on the Mill Stream.

This PhD project will focus on studying the relationships between water crowfoot *(Ranunculus Spp.)* and the other plants, invertebrate and salmonid communities in chalkstreams. Data will be collected from in-river experiments in the River Frome to understand how the presence of water crowfoot drives variability of flora and fauna throughout the river catchment.

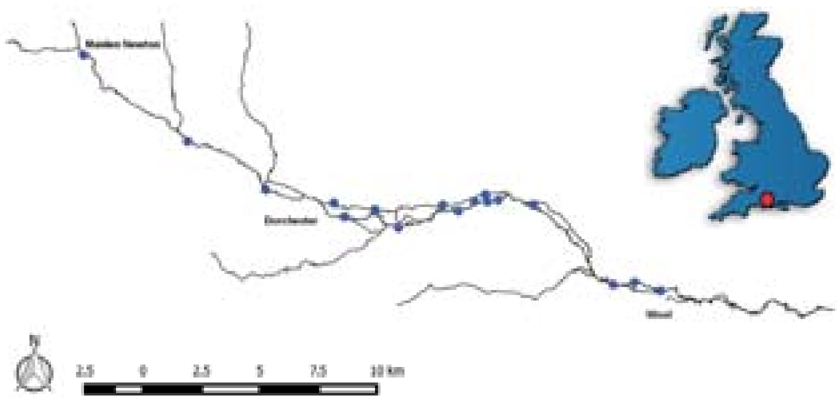
Unique in their stability to temperature, chemical and physical conditions, lowland chalkstream habitats are of both national and international importance. Chalkstreams sustain a high diversity of flora and fauna including species of conservation concern such as water vole, European eel and white-clawed crayfish. They also support the important salmonid game fish species, Atlantic salmon and brown trout.

The high biodiversity supported by chalkstreams is thought to be due to the presence of the water crowfoot family. These higher plants (macrophytes) are the dominant in-river plant species throughout chalkstream catchments and are described as pioneer species for their ability to colonise a variety of habitats.

The presence of water crowfoot subsequently creates habitats for other flora and fauna. The plant greatly reduces water velocity within and immediately downstream of the plant stands, while increasing velocity elsewhere by directing water around its cover, altering flow dynamics within the river. The reduction in flow results in an increase of fine sediments being deposited downstream of the plant structure. This encourages growth of other macrophyte species, such as watercress and

Figure 10

Study sites (blue circles) on the River Frome, Dorset. Insert map shows the position (red circle) of the River Frome on the south coast



Electro-fishing and tagging of juvenile salmonids in autumn 2015. © Amy Brocklehurst

starworts, that may otherwise be unable to establish themselves due to a lack of organic material or high flow rates.

This results in the creation of more complex habitats within the river which, in turn, is linked to the abundant and diverse invertebrate communities that are present in chalkstreams by providing a food source and refugia. For example, the submersed parts of macrophytes provide a large surface area for suspension-feeding invertebrates, such as black fly larvae and certain caddis fly larvae, to attach to and feed on organic particles. The mosaic of macrophyte species provides suitable habitat for many different insects during their larval stage, such as damselflies and dragonflies.

This high invertebrate production in turn generates large numbers of potential prey for juvenile salmonids, including mayfly and blackfly larvae. The absence of any naturally occurring large substrate in lowland streams for physical shelter also makes submerged macrophytes a fundamental requirement for juvenile salmonids to reduce energy consumption and provide shelter from predators.

Although the importance of water crowfoot in driving diversity in chalkstream ecosystems is acknowledged, existing studies on this family are often limited in duration and physical scale and most previous studies have only encompassed single components such as macrophytes, invertebrates or fish rather than the whole stream ecosystem.

This project aims to establish patterns in the number of salmon and brown trout, and diversity and density of invertebrate species in areas with varying amounts of water crowfoot. The first of three years of data on macrophyte cover, substrate structure, and invertebrate and fish communities was collected from sites spread throughout the Frome catchment in 2015 (see Figure 10). The data were collected

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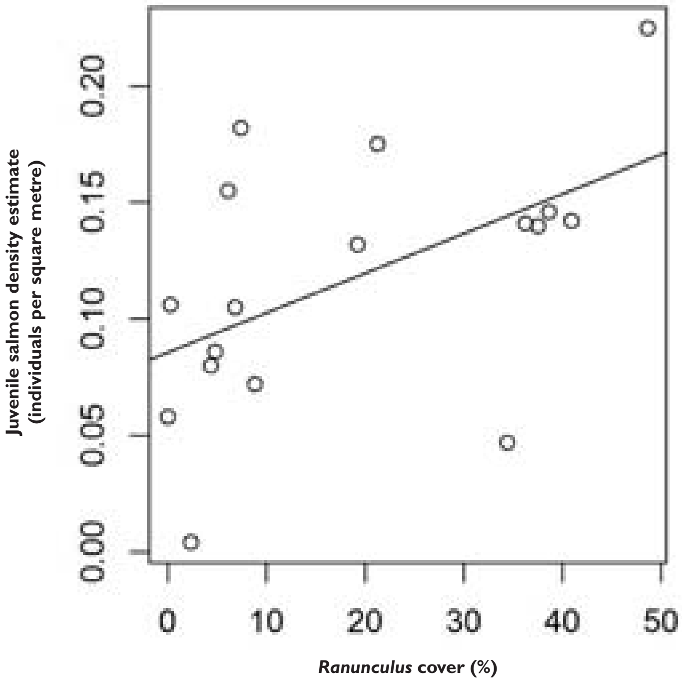
Jessica Marsh conducting habitat mapping of macrophyte cover in autumn 2015.

Figure 11

There was a significant positive relationship between the density of juvenile salmon and the percentage of water crowfoot cover



Flowering Ranunculus beds.

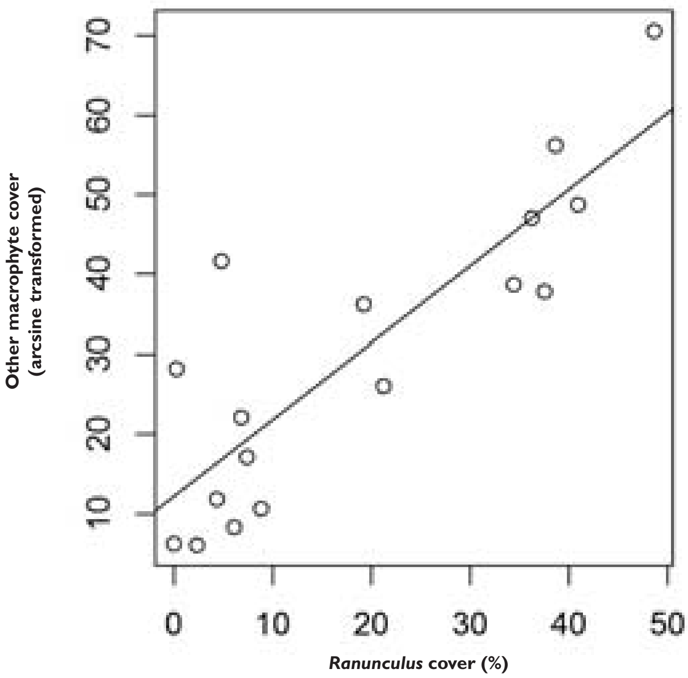
during the GWCT fisheries team's annual parr-tagging event, where 10,000 salmon parr are caught, tagged and released, providing critical population data.

Preliminary results of this initial data collection show a significant positive association between increasing cover of water crowfoot and the density of juvenile salmon (see Figure 11); as well as an increase in cover of other aquatic plant species (see Figure 12). These findings suggest that an increase in water crowfoot cover, to a certain extent, is beneficial to other chalkstream ecosystem components. The next stage of the research is to explore these correlative relationships through manipulation experiments which started in spring 2016. These in-stream studies aim to elucidate the mechanisms behind the patterns discovered by altering existing water crowfoot assemblages and monitoring the effects on salmon and brown trout densities, invertebrate communities, other macrophyte species and the interaction between all of these groups.

Gaining an understanding of these relationships is essential to develop effective river management strategies to direct successful conservation of chalkstream ecosystems.

Figure 12

There was a significant positive relationship between the percentage of other macrophyte species cover and the percentage of water crowfoot cover



8. Effect of flow on salmon redd distribution

Spawning salmon are less likely to access spawning grounds higher in the Frome catchment when there is insufficient water in the river between October and January. © Laurie Campbell

Elinor Parry did her MSc research project with the GWCT fisheries team in 2015 on the effect of flow on the distribution of salmon redds in the Frome.

Elinor found that flow affects salmon redd distribution in ways that she predicted: redds were more aggregated in the mid-river in years of low flow compared with years of high flow (see Figure 13). This suggests that spawning salmon have difficultly accessing spawning grounds higher in the Frome catchment when there is insufficient water in the river between October and January.

There are important management implications from Elinor's study, particularly in light of the forecast increase in frequency and intensity of extreme floods and droughts under climate change, together with forecast increases in the human population size in Dorset. Her findings suggest that we should manage water levels sensitively, particularly between October and January, to ensure that salmon can distribute their redds throughout all of the available spawning habitat, which will give the emerging fry the best chance of survival.

Elinor's study was very challenging. Among the many difficulties she had to overcome, three were particularly prominent:

1) She had the arduous task of collating incomplete and inconsistent datasets into a single manageable database that she could use to test her predictions;
2) She had the near impossible task of deciding how to summarise river discharge data in a way relevant to salmon spawning migrations on the Frome; and
3) She had to devise a statistical analysis to describe salmon redd distributions using only a few simple explanatory variables.

In completing these tasks, Elinor demonstrated great care, attention to detail, innovative thinking and an ability to critically appraise literature and information. She submitted her thesis to the Cardiff University School of Biosciences in September and was awarded a well-earned Distinction – congratulations Elinor.

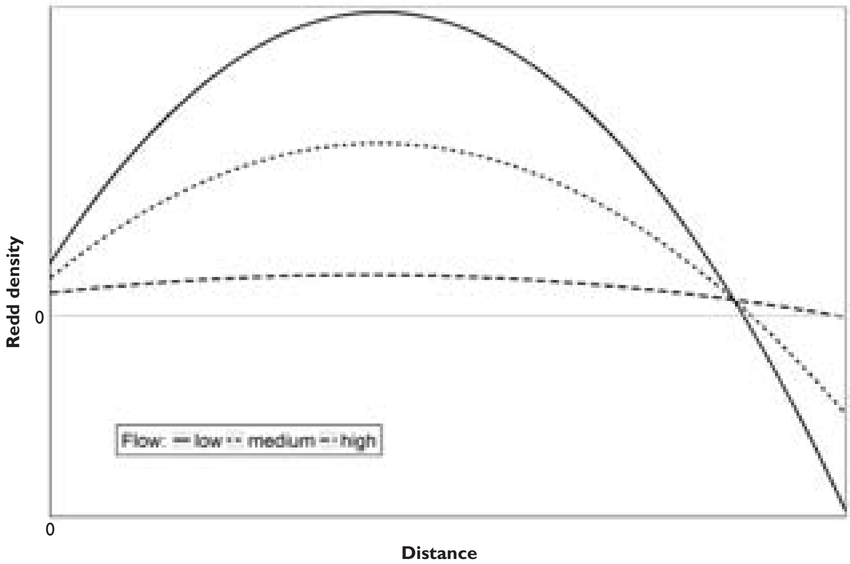


Figure 13

Diagram showing how the density of redds is predicted to change with distance from the tidal limit under low, medium and high flow conditions

9. Flow reduction: what, why and how

By Jessica Picken, PhD student


We are studying three streams on the River Itchen.

Climate change models predict that average temperatures in the UK will increase over the next 50 years, with the greatest warming in the south of England during summer months, and that annual average rainfall will reduce. The reduction in rainfall is expected to be more pronounced during summer than winter and extreme winter weather events are expected to become more frequent. With an overall shift towards drier summers but wetter winters, climate change is considered to be the most critical disturbance likely to be imposed on natural systems such as our rivers.

River flow regimes are widely recognised to be the most important variable controlling key aquatic processes, levels of dissolved oxygen, sediment transport such as deposition, water quality, and habitat quality and distribution. These processes in turn will influence the spatial and temporal distribution and abundance of the flora and fauna of our rivers. This is likely to be of particular importance for the relatively more stable chalkstreams of southern England. Drought and the accompanying low river discharges (often exacerbated by human influences such as abstraction, flow regulation and land use), are thought to be the biggest threat. In the future chalkstreams are likely to suffer from periods of intense summer drought more frequently, with potentially disastrous implications for their fish populations.

We are studying three streams on the River Itchen in Hampshire where complete control of the flow can be achieved by using sluice gates at the top of each stream. During the summer the sluice gates will be either left as they are or lowered to reduce the flow by either 45% or 90%. The following summer the individual streams will be subject to a different flow treatment, so that at the end of the three years, each stream will have experienced all of the three different flow treatments.

Samples of invertebrates (fish prey) will be collected from each stream throughout the year to enable any response to be identified. The stomachs of

Jessica Picken sampling for invertebrates such as Serratella ignita and Gammarus pulex. (Inset pictures © Cyril Bennett)

juvenile salmon and trout will be flushed to determine their diet, and to enable us to construct food webs within the streams under the different flow regimes. Reduced flow may result in the loss of certain habitat types that are required by some invertebrates (eg. decreases in stoneflies may occur where fast flowing habitats are lost) which, in turn, could affect salmonid diet.

The movement and behaviour of salmonids may also change in response to changing food availability, with fish increasing their foraging range to seek out food of a better quality or to seek more suitable instream habitats. However, salmonid movement may be restricted due to the reduced amount of available habitat during the low flow period, which could cause an increase in foraging competition as fish density increases. To monitor behavioural responses, individual fish will be PIT tagged and monitored so that we can observe any changes in habitat choices of salmonids before, during and after flow reduction in all three streams.

Results from this three-year project will increase our understanding of the effect of short-term summer drought events on salmon and trout. This knowledge is vital to safeguard salmonid stocks in chalkstreams and to define future catchment and water resource management strategies for the south of England, so that we can make knowledge-based management decisions if these changes occur.

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The stomachs of juvenile salmon and trout will be flushed to determine changes to their diet due to flow reduction.

10. Do beaver dams impact salmonid migration?

By Robert Needham, PhD student

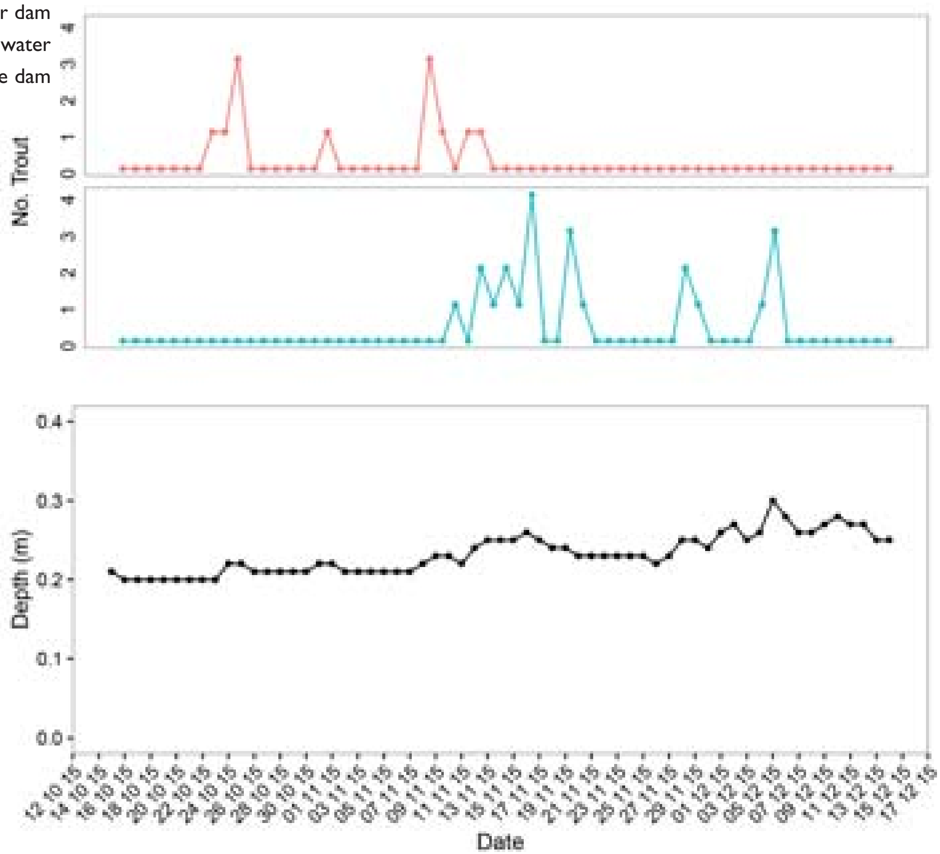
The beaver dam relating to Figure 15 where the passage of brown trout was monitored.

Populations of re-introduced and escaped Eurasian beaver *(Castor fiber)* currently exist in England and Scotland and concerns have been raised that beavers, specifically the dams that they construct, may negatively effect populations of migratory fish, particularly salmon and trout, by impeding their movements and fragmenting important habitats.

PhD researcher Robert Needham, studying at Southampton University, has now spent two autumn spawning seasons and one spring juvenile migration season in the north of Scotland using PIT telemetry to assess the ability of trout to pass a series of beaver dams in both the upstream and downstream directions.

Figure 14

Upstream (——) and downstream (——) passage of brown trout past the beaver dam pictured above in relation to depth of water behind the dam



The field site consists of a Loch with two feeder tributaries. Beavers have been present in this system since 2007. One of the feeder tributaries has been dammed in four places by a family group of beavers while the other tributary has had no beaver activity. Data analysis is still in the early stages, but to date:

- 454 trout have been PIT tagged.
- Upstream and downstream movements past dams has been observed on many occasions.
- Dams are proving to be a barrier, but as expected, flow conditions appear to determine the success of upstream passage (see Figure 14).
- Trout in the beaver modified tributary are significantly larger than in the tributary with no beaver activity (see Figure 15).
- New side channels have been formed due to beaver activities which bypass two beaver dams and fish have already been recorded using these during upstream migration in the autumn.
- Spawning continues to be observed above the fourth (most upstream) dam in the beaver modified tributary.

Much has been said in the media about beaver impacts – negative and positive – and we look forward to following this project as it provides evidence about this new conservation issue.

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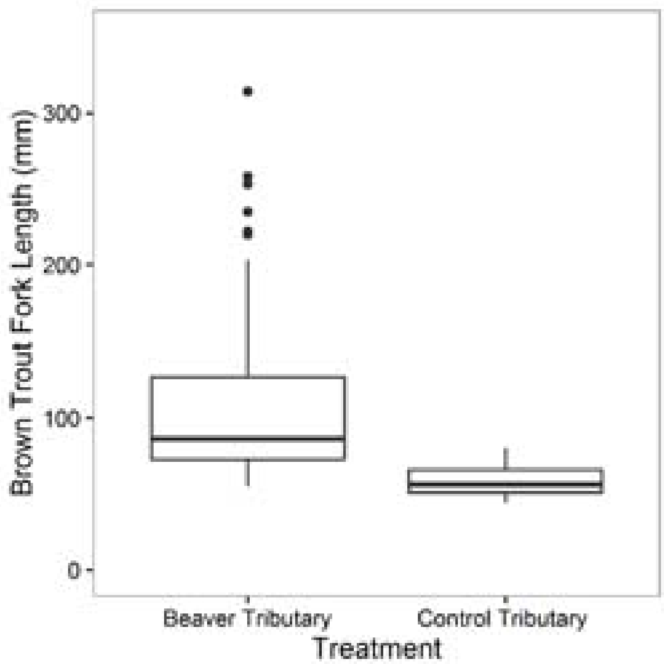

Figure 15
Fork length (mm) of brown trout caught from the control tributary and beaver modified tributary (data combined from autumn 2014 and spring 2015)

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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.

One of the feeder tributaries has been dammed in four places by a family group of beavers.

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