BU MATCH FUNDED STUDENTSHIPS 2024 PROJECT DESCRIPTION

PROJECT TITLE

Predicting the roles of anadromy and freshwater carry-over effects in the sustainability of threatened brown trout *Salmo trutta* populations

PROJECT SUMMARY

Rationale

Our ability to live sustainably with the natural world is dependent on how we derive societal benefits from freshwater ecosystems, including the provision of fresh water, food and energy. Currently, our derivation of these benefits is increasingly recognised as unsustainable; provision of freshwater for drinking and industry results in drying rivers; food supplies either over-exploit wild fish stocks leading to collapse or rely on aquaculture activities that pollute surrounding waters; and energy production transforms aquatic environments through loss of river connectivity. These activities are driving major and unsustainable declines in freshwater biodiversity, with population reductions of over 80% since the 1970s.

These freshwater biodiversity declines are most apparent in species with complex lifecycles, especially diadromous fishes (lifecycles involving movements between freshwater and marine environments), with all 16 European mid- and long-distance migratory fishes suffering substantial population declines in recent decades (by up to 93%). Returning populations of these species back to sustainable levels is thus a high conservation priority globally. Achieving this priority action is, however, highly challenging, as our current understandings of these population declines have major knowledge gaps that arise from the difficulty and complexity of collecting and analysing long-term data across spatially discrete habitats and multiple life-stages. However, developments in fish telemetry technologies now enable the tracking of migrations of individual fishes across key lifetime events.

An example of an anadromous fish species experiencing recent and rapid population declines is the brown/sea trout *Salmo trutta*. A major impediment to understandings of their declines is that their populations consist of both freshwater resident (non-migratory) and migratory (anadromous ‘sea trout’) forms, with the drivers of this divergent life history strategy remaining unclear. Whilst it is considered that anadromous females provide a greater reproductive contribution to the next generation than freshwater residents, but with trade-offs involving considerably higher energetic costs and mortality risks, why some individuals migrate when others remain river-resident remains a major knowledge gap.

Although brown/sea trout population declines are considered as driven strongly by reduced survival during the marine phase of their life cycle, it is also considered that carry-over effects from freshwater life stages have a strong influence on this survival, as has been already identified in the anadromous Atlantic salmon *Salmo salar*, where collaborative work between BU and the match funder recently revealed the positive influence on marine survival and river return rates of larger emigrating juveniles (‘smolts’).

Aim & objectives

The aim is to assess how key factors in the juvenile stages of brown trout in the river influence their subsequent life history strategy (e.g. non-migratory or anadromous), and the implications at individual levels for growth, behaviour, migrations (as timings (‘phenology’) and distances), and survival probability to spawning. The primary dataset used for meeting this aim is a long-term brown trout dataset on the River Frome, Dorset, where in the last decade, juvenile trout at multiple sites across the catchment have been

implanted with passive integrated transponder (PIT) tags and their movements tracked over their lifecycle using recapture events (non-migratory fish) and PIT tag detection systems in the lower river (migratory forms, detecting smolt emigration and adult immigration). Complementary data will also be available from other rivers in England (e.g. River Tamar, Devon) and mainland Europe. Objectives (O) are to:

O1. Quantify the age and length structure of the river-resident and anadromous components of the brown trout populations and assess the extent of their migratory behaviours (as phenology of emigration and return, duration of marine sojourn, and marine return rates).

O2. Develop predictive models for simulating juvenile trout production, growth and survival according to abiotic and biotic factors (and interactions), including the probability of individuals remaining river resident versus developing anadromy.

O3. Develop more general predictive models for predicting trout population dynamics in rivers across their range, developing novel population simulations.

Methods

In the last decade, over 30,000 juvenile brown trout have been captured, measured, weighed, and PIT tagged across the River Frome catchment, with these fish subsequently recaptured in sampling events and/or detected on the PIT tag detectors as they migrate to sea as smolts in spring. Those fish that do emigrate as smolts spend between 30 days to several years in the marine environment before returning to the river where they are once more detected on the detectors. Similar data are available for the River Tamar, but with fewer fish tagged. As PIT tagging enables individual identification, all data are at the individual fish level and the data previously collected (that will also be added to within the studentship) allows each objective to develop a series of relevant hypotheses that are tested through the development of powerful, multivariate models.

ACADEMIC IMPACT

This research will substantially strengthen the empirical evidence base for enhancing the freshwater life-stages of brown trout populations (and similar salmonid species) as it develops novel understandings of how within-catchment juvenile and smolt production (in both quantity and quality) can influence the number of returning spawning adults surviving at sea and returning to natal rivers to spawn. These understandings are thus fundamentally important for population sustainability and conservation. This research is thus of global academic interest, given the importance of salmonid fishes in many regions, including Northwest Europe and North America.

The PhD student will further this academic impact by presenting results at international conferences (e.g., the NoWPaS Salmonid Research Network; https://nowpas.eu) and will integrate into the research and scientific community at BU and the collaborating partners, including contributing to the evidence base of the International Council of the Exploration of the Sea (https://www.ices.dk) via the match funder and also to UK Government via the project partner the Centre of Environment, Fisheries and Aquaculture Science (CEFAS).

SOCIETAL IMPACT

Anadromous salmonid fish populations have declined by over 90% in Europe since the 1970s. This is despite these fishes being strong ecological status indicators in the EU Water and Marine Directives and having strong legislative protections. Recent crashes in the numbers of returning salmonids across their

range, including England, are alarming and show no signs of abating. The ultimate aim of this research is, in conjunction with the match funder, other project partners (Cefas, ICES) and researchers, to create and disseminate new knowledge that will return salmonid populations back to being sustainable. The focus in this PhD is generating new knowledge of how river management can contribute to population sustainability via increasing population resilience through developing stronger, more beneficial carry-over from freshwater into marine life-stages, and so, ultimately, the number of adult spawners.

By working with our collaborating partners in this project, this research will thus help sustain European salmonid populations via more effective management and, in doing so, it will deliver considerable societal and economic benefits, including via increased economic values of fisheries, increased angler participation leading to enhanced human well-being, and increased existence values. These impacts will be achieved through effective outreach, including engagement with policy-makers at national and international levels, as well as with local and national conservation and angling stakeholders.

PGR DEVELOPMENT OPPORTUNITIES

The development opportunities include:

- **Tracking fish movements and migrations:** A novel aspect of the research is its use of animal telemetry-based methods based on passive integrated transponder (PIT) technology. This will require the successful candidate to receive considerable training in PIT tag technologies that has high relevance to tracking animal migrations at global levels.

- Predictive modelling: The successful candidate will work on datasets of >30,000 trout collected across multiple locations around the Frome catchment and over a number of years. Consequently, the development of the models to complete the objectives are complex, requiring model development and parameterisation, and fitting. The successful candidate will receive strong support and training in model development, fitting and interpretation from all project partners, using software such as R (the global standard for these analyses).

- Standardised sampling methods: The sampling of juvenile salmonids requires the safe application of electric fishing, including fish handling and processing. Sampling the physical habitats of rivers requires training in measuring substrate composition using standardised methods. Correspondingly, the successful candidate will receive training in all relevant sampling and fish handling methods.

- **Research ethics**: The project works with live fish, including the internal tag implantation using regulated procedures under current legislation. Thus, the successful candidate will receive training in research ethics and animal welfare in order to complete their research, and be trained in all techniques. This includes supporting their training and competency development so they can obtain their Home Office personal licence for working on live fish under the supervisor's project licence.

- **Research and professional skills**: training will be provided via formal and informal training on research and professional skills, including literature review, academic writing, oral and poster presentation skills, and network development. This also includes working with national and international partners, including regulators and policy-makers.

SUPERVISORY TEAM	
First Supervisor	Professor Robert Britton

Additional Supervisors	Dr Tom Major, Dr Matthew Hill (Bournemouth University); Dr Sophie Elliott (Game and Wildlife Conservation Trust; match funder); Dr Jonathan Gillson (Cefas; project partner)
Recent publications by supervisors relevant to this project	Bold font: member of supervisory team. *BU PhD student. Dambrine, C., **Elliott, S.A.M**., et al. 2023. Connecting population functionality with distribution model predictions to support freshwater and marine management of diadromous fish species. *Biological Conservation*, *287*, p.110324. Davies, P*., **Britton, J.R**., et al. 2020. Novel insights into the marine phase and river fidelity of anadromous twaite shad Alosa fallax in the UK and Ireland. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *30*(7), pp.1291-1298. Davies, P*., **Britton, J.R**., et al. 2022. Individual movement variation in upstream-migrating sea lamprey Petromyzon marinus in a highly fragmented river. *Freshwater Biology*, *67*(4), pp.643-656. **Elliott, S.A.M.,** et al. 2023. Modelling the distribution of rare and data-poor diadromous fish at sea for protected area management. *Progress in Oceanography*, *210*, p.102924. **Gillson, J.P, Elliott, S.A.M**. et al. Submitted. Do the biological characteristics and behaviours of spring migrating trout (*Salmo trutta*) smolts influence their maiden marine sojourn duration? Journal of Fish Biology. Gregory, S.D., Armstrong, J.D. and **Britton, J.R.** 2018. Is bigger really better? Towards improved models for testing how Atlantic salmon *Salmo salar* smolt size affects marine survival. *Journal of Fish Biology*, *92*(3), pp.579-592. Gregory, S.D., **Britton, J.R.,** Simmons, O.M.***** et al. 2019. Atlantic salmon return rate increases with smolt length. *ICES Journal of Marine Science*, *76*(6), pp.1702-1712. Marsh, J.E., **Britton, J.R**. et al. 2021. Medium-term environmental changes influence age-specific survival estimates in a salmonid population. *Freshwater Biology*, *66*(8), pp.1530-1545. Marsh, J.E., **Britton, J.R**., et al. 2022. Density-dependence and environmental variability have stage-specific influences on European grayling growth. *Oecologia*, *199*(1), pp.103-117. **Major, T**., et al. 2023. Museum DNA reveals a new, potentially extinct species of rinkhals (Serpentes: Elapidae: Hemachatus) from the Eastern Highlands of Zimbabwe. *Plos One*, *18*(9), p.e0291432. Mathers, K.L., **Hill, M.J.** et al. 2022. Temporal effects of fine sediment deposition on benthic macroinvertebrate community structure, function and biodiversity likely reflects landscape setting. *Science of the Total Environment*, *829*, p.154612. Simmons, O.M.*****, **Britton, J.R.**, et al. 2020. Influence of environmental and biological factors on the overwinter growth rate of Atlantic salmon *Salmo salar* parr in a UK chalk stream. *Ecology of Freshwater Fish*, *29*(4), pp.665-678. Simmons, O.M.*****, **Britton, J.R.** et al. 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* DOI: 0.1111/jfb.14946 Simmons, O.M.*****, **Britton, J.R.** et al. 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 Winter, E.R*., **Britton, J.R**., et al. 2021. Movements of common bream Abramis brama in a highly connected, lowland wetland reveal sub-

	populations with diverse migration strategies. *Freshwater Biology*, *66*(7), pp.1410-1422. Winter, E.R*., **Britton, J.R**., et al. 2021. Detection range and efficiency of acoustic telemetry receivers in a connected wetland system. *Hydrobiologia*, *848*, pp.1825-1836. Yeldham, M.I.*, **Britton, J.R** et al. 2023. Individual repeatability in the timing of river entry indicates the strong influence of photoperiod in the spawning migrations of iteroparous twaite shad Alosa fallax. *Hydrobiologia*, *850*(7), pp.1619-1634.

INFORMAL ENQUIRIES

Please contact the lead supervisor on the following email for informal enquiries: rbritton@bournemouth.ac.uk

ELIGIBILITY CRITERIA

The BU PhD and MRes Studentships are open to UK, EU and International students.

Candidates for a PhD Studentship should demonstrate outstanding qualities and be motivated to complete a PhD in 4 years and must demonstrate:

- outstanding academic potential as measured normally by either a 1st class honours degree (or equivalent Grade Point Average (GPA) or a Master's degree with distinction or equivalent
- an IELTS (Academic) score of 6.5 minimum (with a minimum 6.0 in each component, or equivalent) for candidates for whom English is not their first language and this must be evidenced at point of application.

Candidates for an MRes Studentship should demonstrate outstanding qualities and be motivated to complete a MRes in 18 months and must demonstrate:

- outstanding academic potential as measured normally by an upper second class honours degree (or equivalent Grade Point Average (GPA)
- an IELTS (Academic) score of 6.5 minimum (with a minimum 6.0 in each component, or equivalent) for candidates for whom English is not their first language and this must be evidenced at point of application.

HOW TO APPLY

Please complete the online application form by **the deadline on the project webpage.**

Further information on the application process can be found at: www.bournemouth.ac.uk/studentships