On behalf of the UK Delegation

Scottish Government
Riaghaltas na h-Alba

CNL(23)103

NASCO Theme-based Special Session (TBSS) on climate change
Informing a Strategic Approach to Address the Impacts of Climate Change on Wild Atlantic Salmon.

Development of evidence-based management strategies to protect salmon populations from the effects of high river temperatures under climate change through targeted riparian tree planting; case studies from Scotland and England.

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Presentation Structure

- Background
- Scotland Case Study – Scotland River Temperature Monitoring Network (SRTMN) *Faye Jackson (Scottish Government)*
- England Case Study – Keeping Rivers Cool (KRC) *Lawrence Talks (Environment Agency)*
- Conclusions and future look

Background

- River temperature is a key control on freshwater ecosystems, influencing species survival, distribution, abundance and growth.

- Increasing river temperatures are a threat to cold water adapted species such as Atlantic salmon.

- Management strategies that seek to improve climate resilience of rivers are a key component of efforts to protect and recover salmon populations across the UK.

- *Scottish Wild Salmon Strategy, England's Salmon 5 Point Approach, Welsh Salmon and Sea Trout Plan of Action.*

Mitigation: Riparian tree cover

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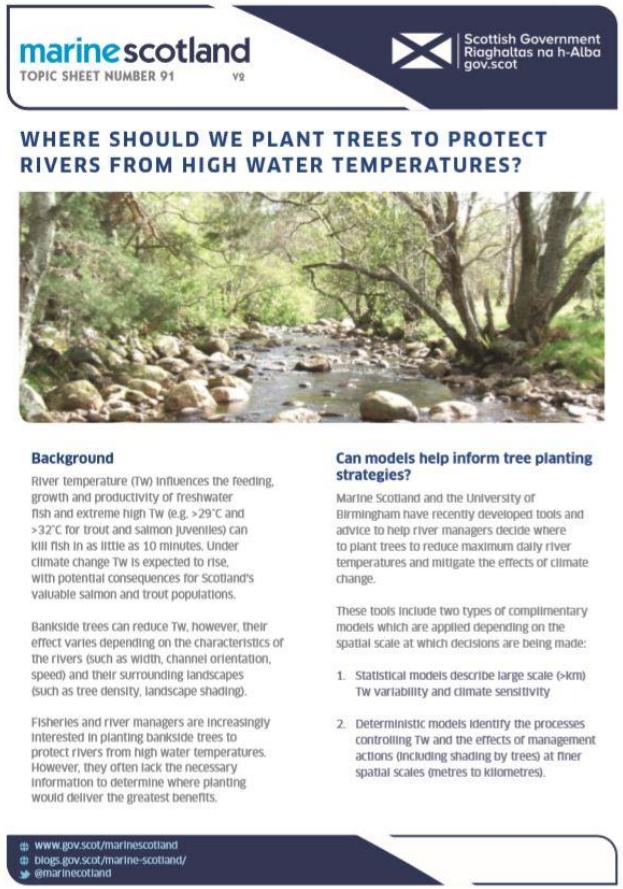
- Shading rivers with riparian trees is one of few options available to reduce river temperature.
- Given constrained resources, it is important to target locations where trees can deliver the greatest benefits.
- Advances in large-scale monitoring and modelling, in addition to the availability of large-scale shading models make development of decision support tools possible.



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TOPIC SHEET NUMBER 91 V2

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WHERE SHOULD WE PLANT TREES TO PROTECT RIVERS FROM HIGH WATER TEMPERATURES?

Background

River temperature (Tw) influences the feeding, growth and productivity of freshwater fish and extreme high Tw (e.g. >29°C and >32°C for trout and salmon juveniles) can kill fish in as little as 10 minutes. Under climate change Tw is expected to rise, with potential consequences for Scotland's valuable salmon and trout populations.

Bankside trees can reduce Tw, however, their effect varies depending on the characteristics of the rivers (such as width, channel orientation, speed) and their surrounding landscapes (such as tree density, landscape shading).

Fisheries and river managers are increasingly interested in planting bankside trees to protect rivers from high water temperatures. However, they often lack the necessary information to determine where planting would deliver the greatest benefits.

Can models help inform tree planting strategies?

Marine Scotland and the University of Birmingham have recently developed tools and advice to help river managers decide where to plant trees to reduce maximum daily river temperatures and mitigate the effects of climate change.

These tools include two types of complimentary models which are applied depending on the spatial scale at which decisions are being made:

1. Statistical models describe large scale (>km) Tw variability and climate sensitivity
2. Deterministic models identify the processes controlling Tw and the effects of management actions (including shading by trees) at finer spatial scales (metres to kilometres).

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Scotland Case Study:
Scotland River Temperature Monitoring Network

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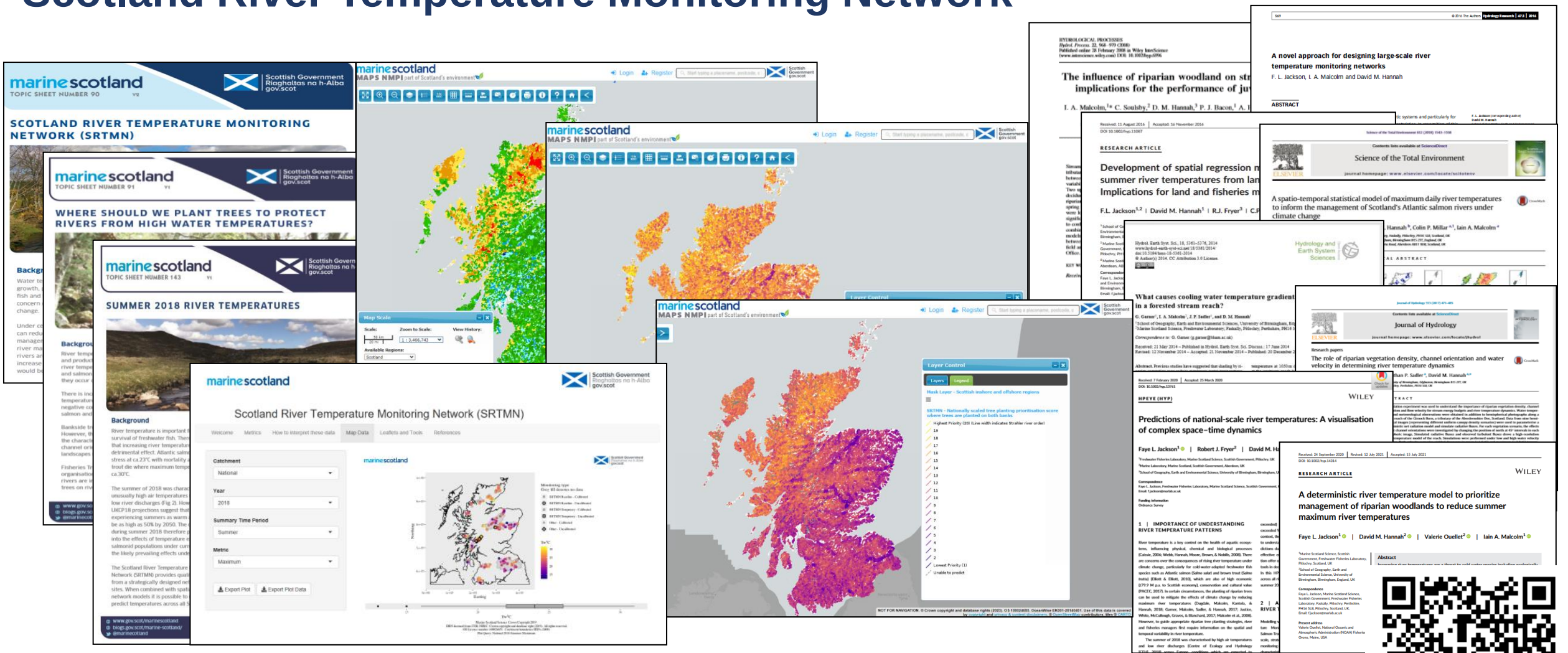

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https://www.gov.scot/publications/scotland-river-temperature-monitoring-network-srtmn/

Scotland Case Study :SRTMN

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Established in 2013 via collaboration of Marine Scotland, fisheries managers and University of Birmingham. Includes:

(1) strategically designed monitoring network supported by QC and database storage,
(2) spatio-temporal statistical models to identify which rivers are hottest and most sensitive to climate change,
(3) simplified process-based shading models to identify where rivers can be most effectively cooled by riparian woodland,
(4) national scale mapping tools to prioritise management to areas where riparian tree planting will have the greatest overall benefit in terms of protecting Scotland's rivers from the adverse effects of high summer river temperatures under climate change

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Scotland Case Study: SRTMN

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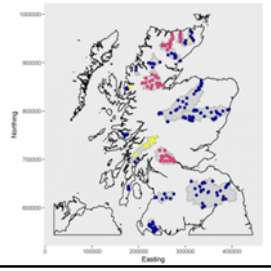
Stage 1: Data and monitoring design

Data

Data calibration, quality control & database infrastructure

Standard Operating Procedures



Strategic monitoring network design

Multi-organisation collaboration

Strategic river temperature monitoring: high quality, robust and reliable evidence

- Sites chosen to cover a range of environmental characteristics that control river temperature - core network of 223 sites.
- Design allows predictive statistical models to be built from SRTMN data and GIS covariates of river characteristics.
- Robust QC and data storage allows long-term temporal trends to be assessed as the dataset builds over time.

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A novel approach for designing large-scale river temperature monitoring networks

F. L. Jackson, I. A. Malcolm and David M. Hannah

ABSTRACT

Water temperature is an important control on processes in aquatic systems and particularly for freshwater fish, affecting growth, survival and demographic characteristics. In recognition of this importance, the Scottish Government has prioritised developing a robust national river temperature monitoring network. Advances in geographical information systems, spatial statistics and field data loggers make large-scale river temperature monitoring increasingly possible. However, duplication of environmental and thermal characteristics among monitoring sites means many networks have lower than expected statistical power. This paper describes a novel methodology for network design, illustrated by the development of the Scotland River Temperature Monitoring Network. A literature review identified processes controlling stream temperature and associated landscape controls. Metrics indicative of these landscape controls were calculated for points every 500 m along the river network. From these points, sites were chosen to cover the full range of observed environmental gradients and combinations of controlling variables. The resulting network contains sites with unique characteristics covering the range of relevant environmental characteristics observed in Scottish salmon rivers. The network will thus have minimal redundancy, often not seen in large networks, and high statistical power to separate the relative importance of predictor variables thereby allowing large-scale water temperature predictions.

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Key words | large-scale monitoring, network design, river temperature, Scotland

INTRODUCTION: CURRENT STATUS AND LIMITATIONS OF LARGE-SCALE RIVER TEMPERATURE NETWORKS

Rising water temperatures (*T*w) have the potential to alter the thermal suitability of rivers for freshwater fish, which are frequently the focus of management (Mohseni *et al.* 2003; Isaak *et al.* 2010, 2012). Cold water fish such as salmonids are highly sensitive to river temperature which affects growth, metabolism, performance, survival and demographic characteristics (Elliott 1994; Gurney *et al.* 2008). Atlantic salmon (*Salmo salar*) and, to a lesser extent, brown trout (*Salmo trutta*) have a high economic (Radford *et al.* 2004), recreational and conservation value (Anon 2009). Consequently, there are strong socio-economic drivers for understanding the spatio-temporal dynamics of thermal regimes, their sensitivity to drivers of change and opportunities for management or mitigation of thermal extremes (Malcolm *et al.* 2008; Hrachowitz *et al.* 2010). In recognition of the importance of these issues, CAMERAS (Coordinated Agenda for Marine, Environment and Rural Affairs Science), an umbrella group of Scottish Government departments and agencies, prioritised the development of a strategic national water temperature network in their recent freshwater monitoring action plan.

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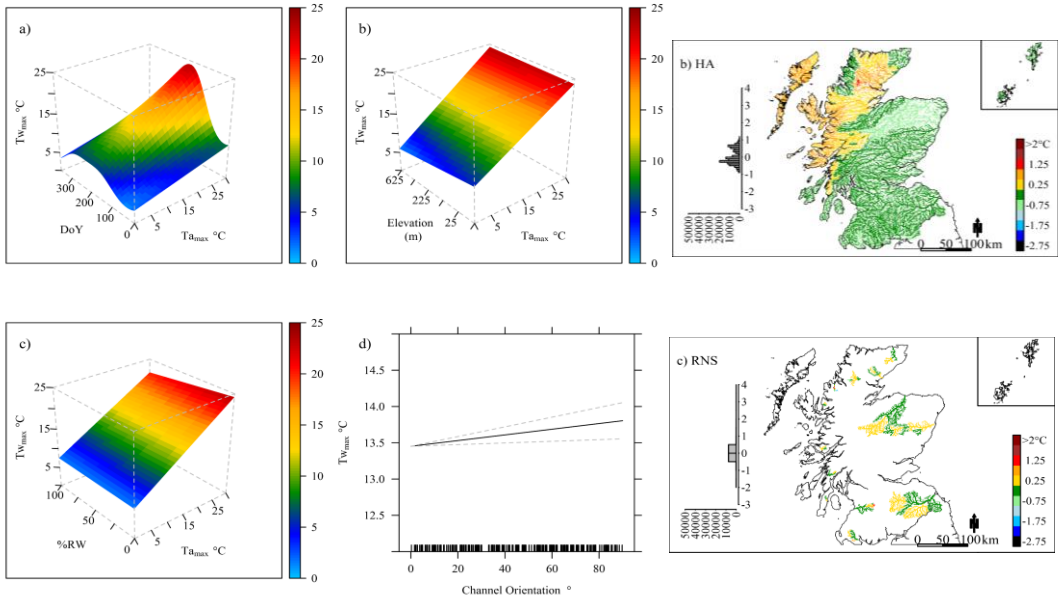
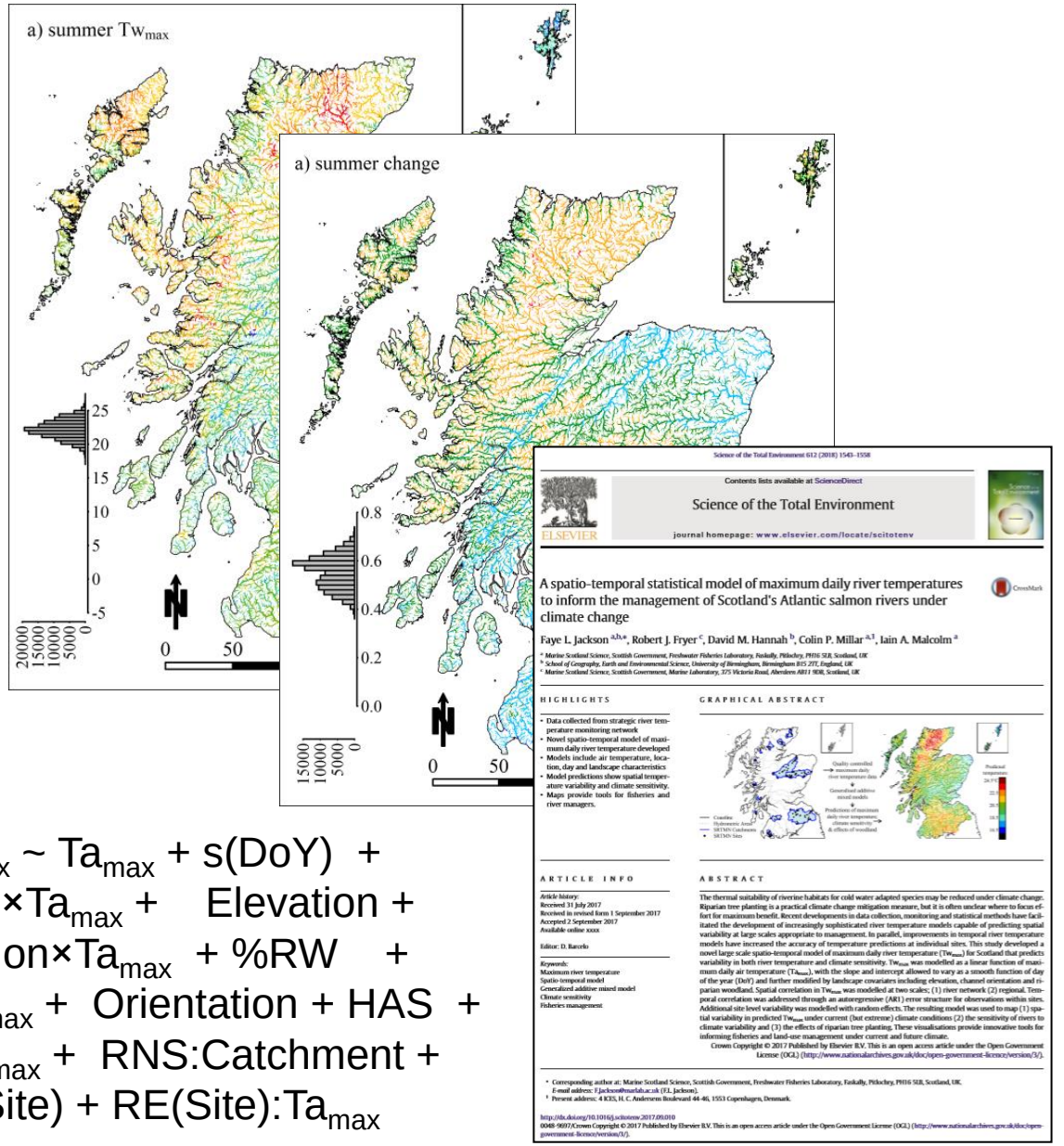
Statistical models

Large-scale spatio-temporal statistical river temperature models driven by air temperature & landscape characteristics

National predictions of risk: maximum river temperature & climate sensitivity

Stage 2 Statistical models





$$Tw_{max} \sim Ta_{max} + s(DoY) + s(DoY)\times Ta_{max} + Elevation + Elevation\times Ta_{max} + \%RW + \%RW\times Ta_{max} + Orientation + HAS + HAS{:}Ta_{max} + RNS{:}Catchment + RE(Site) + RE(Site){:}Ta_{max}$$

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Simplified process-based models

Modelled differences in solar radiation receipt between trees & no tree scenarios in rivers with varying characteristics

National predictions of potential benefits: effectiveness of riparian woodland in reducing river temperatures

Stage 3 Simplified process-based models

- Prioritisation layers - both, only northerly or southerly banks can be planted.
- Scaled from 0-10, with 0 being low priority (no temperature reduction) and 10 high priority (large temperature reduction).

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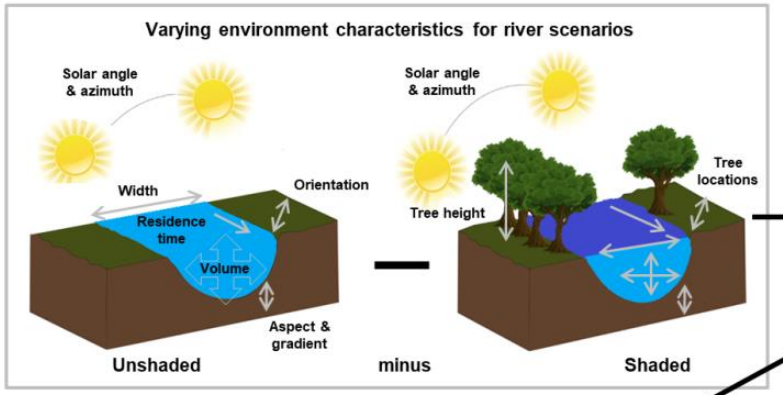
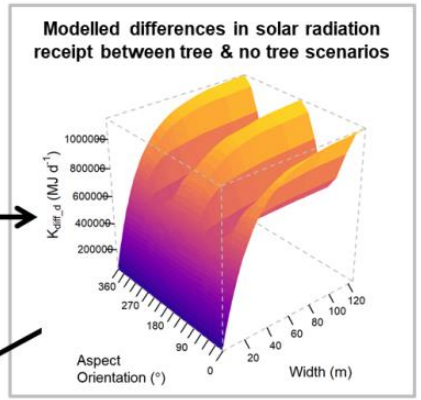
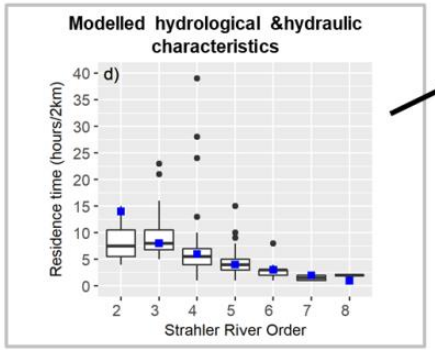
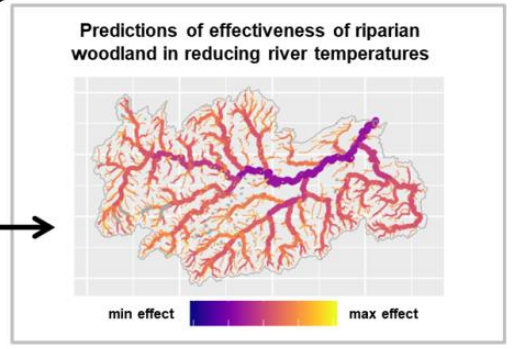






Temperature Differences

Management tools to target tree planting



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RESEARCH ARTICLE

WILEY

A deterministic river temperature model to prioritize management of riparian woodlands to reduce summer maximum river temperatures

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Abstract

Increasing river temperatures are a threat to cold water species including ecologically and economically important freshwater fish, such as Atlantic salmon. In 2018, ca. 70% of Scottish rivers experienced temperatures which cause thermal stress in juvenile salmon, a situation expected to become increasingly common under climate change. Management of riparian woodlands is proven to protect cold water habitats. However, creation of new riparian woodlands can be costly and logistically challeng-
nt that planting can be prioritized to areas where it is most
effective in reducing river temperatures. The effects of
annel shading depend on complex interactions between
n, aspect, gradient, tree height and solar geometry. Subse-
mperature are influenced by water volume and residence
d a deterministic river temperature model, driven by energy
that are modified by water volume and residence time. The
ting prioritization metric that compares potential warming
nd without riparian woodland. The prioritization metric has
ution, but can be mapped at large spatial scales using infor-
igital river network. The results indicate that water volume
epresented by river order, are a dominant control on the
woodland in reducing river temperature. Ignoring these
b-optimal prioritization process and inappropriate resource
rder, effectiveness of riparian shading depends on interac-
d landscape characteristics. Given the complexity and inter-
ls, the use of simple universal planting criteria is not
agers should be provided with maps that translate complex
le tools to prioritize riparian tree planting to mitigate the
eratures.

agement, riparian woodland, river temperature, solar radiation,

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- Feedback was people wanted a single layer

Stage 4 Policy and management tools

Policy and management tools

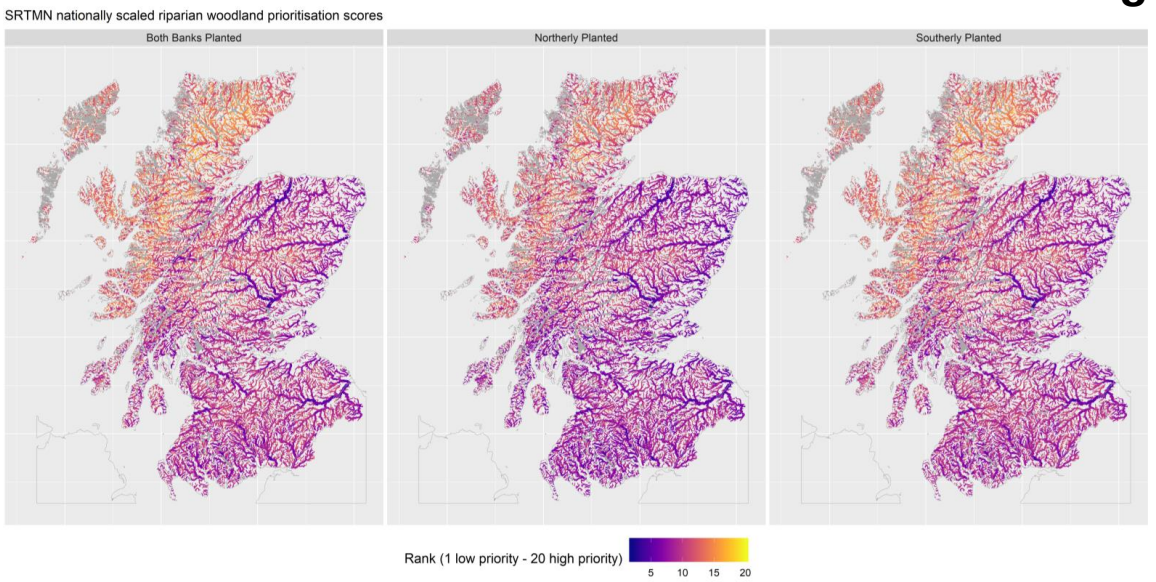
Riparian Woodland Prioritisation Scores for Scotland – national & regional scales

Equal weighting combination of predictions
- 1 is low priority - low temperature, weak climate sensitivity & only a small temperature ↓ gained trees

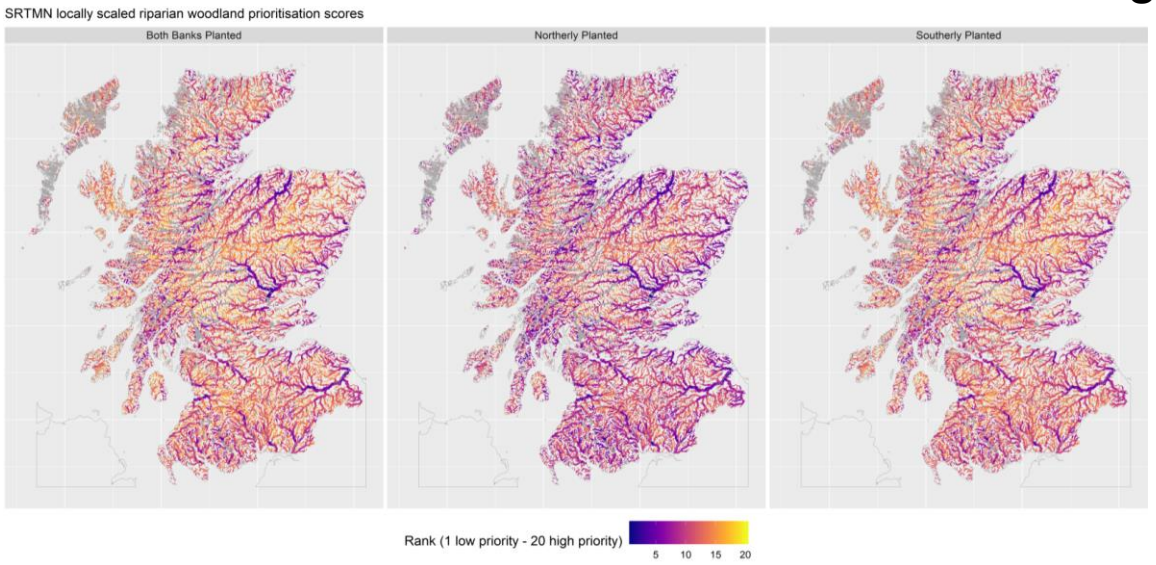
- Scaled from 1- 20, where 1 is low priority (low Tw, weak climate sensitivity & only a small reduction in Tw from planting trees) and 20 is high priority (high Tw, strong climate sensitivity and a large expected reduction in Tw where trees are planted).

Currently recommended tool for prioritising riparian tree planting

National scaling



Local scaling



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Where to get more info:

https://www.gov.scot/publications/scotland-river-temperature-monitoring-network-srtmn/

Habitat: Providing a good home to return to - Our Wild Salmon Series | Fisheries Management Scotland: https://www.youtube.com/watch?v=BM_SxpDtNjA&t=1s

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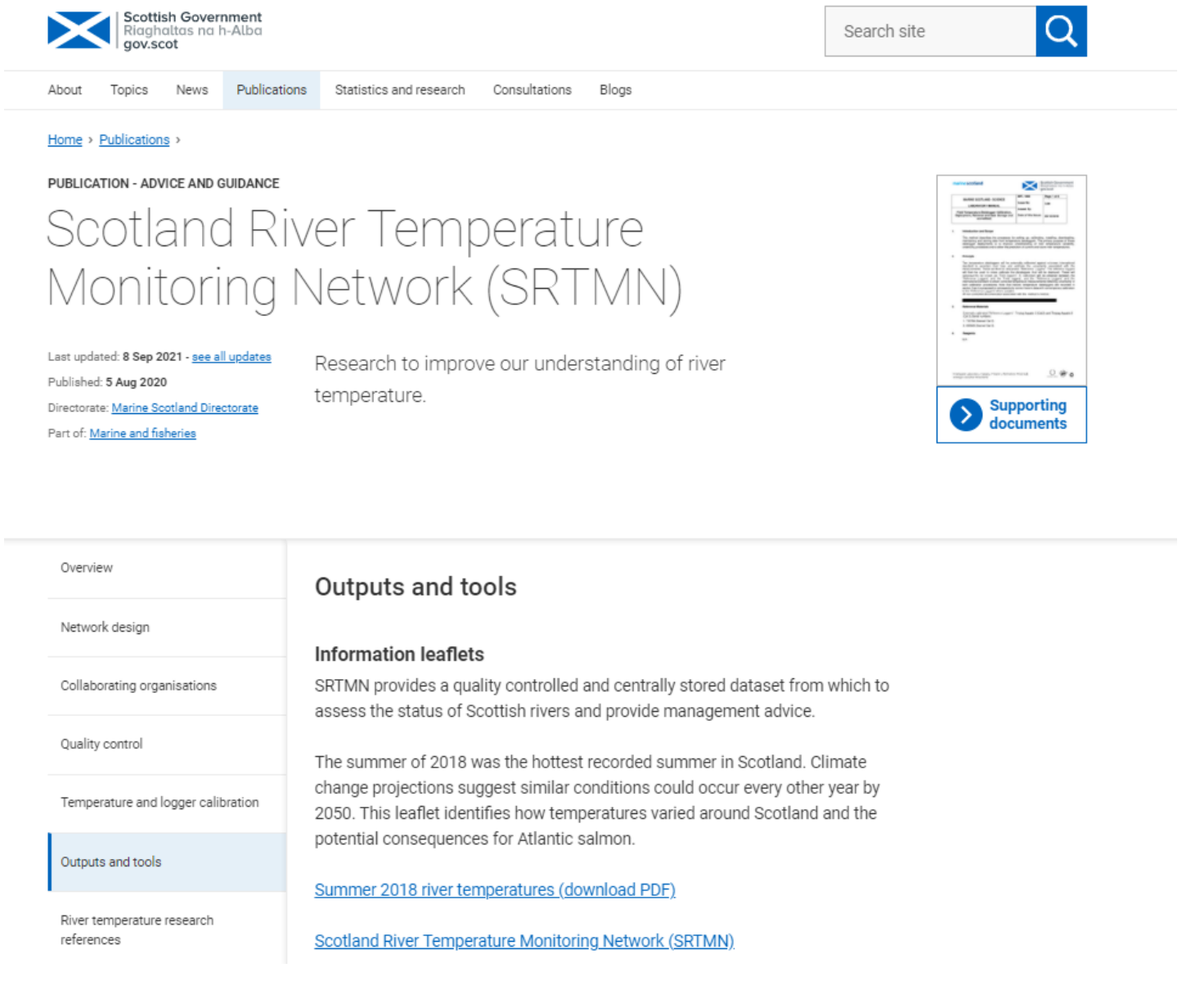


England Case Study - Keeping Rivers Cool

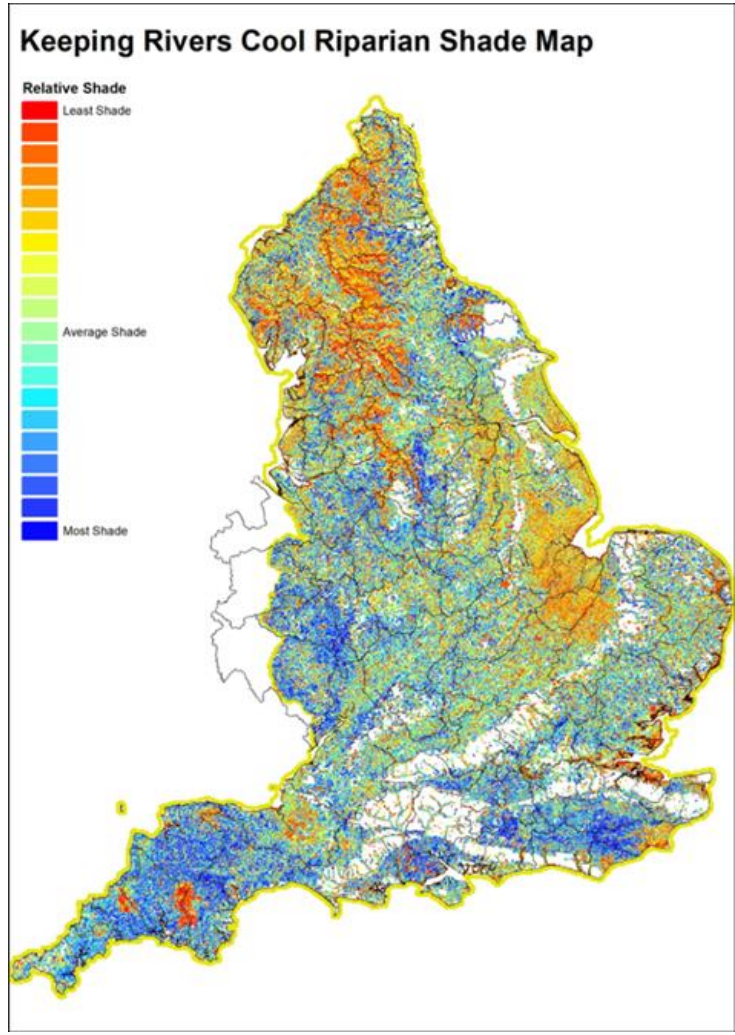
Aim: To increase the resilience of sensitive ecosystems and freshwater wildlife, particularly salmon and trout, to the impacts of climate change-induced temperature increases by using riparian shading to cool rivers.

To encourage targeted riparian tree planting three areas have been developed:

1) **Riparian shade map**, which grades the river on a spectrum from red (low shading) to blue (high shading) to indicate the degree of relative shading.

2) **Best practice guidance**, which is now administrated by The Woodland Trust.

3) **Direct links to funding**, including via the England Woodland Creation Offer, which is focussed on rivers less than seven metres wide.



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England Case Study - Keeping Rivers Cool

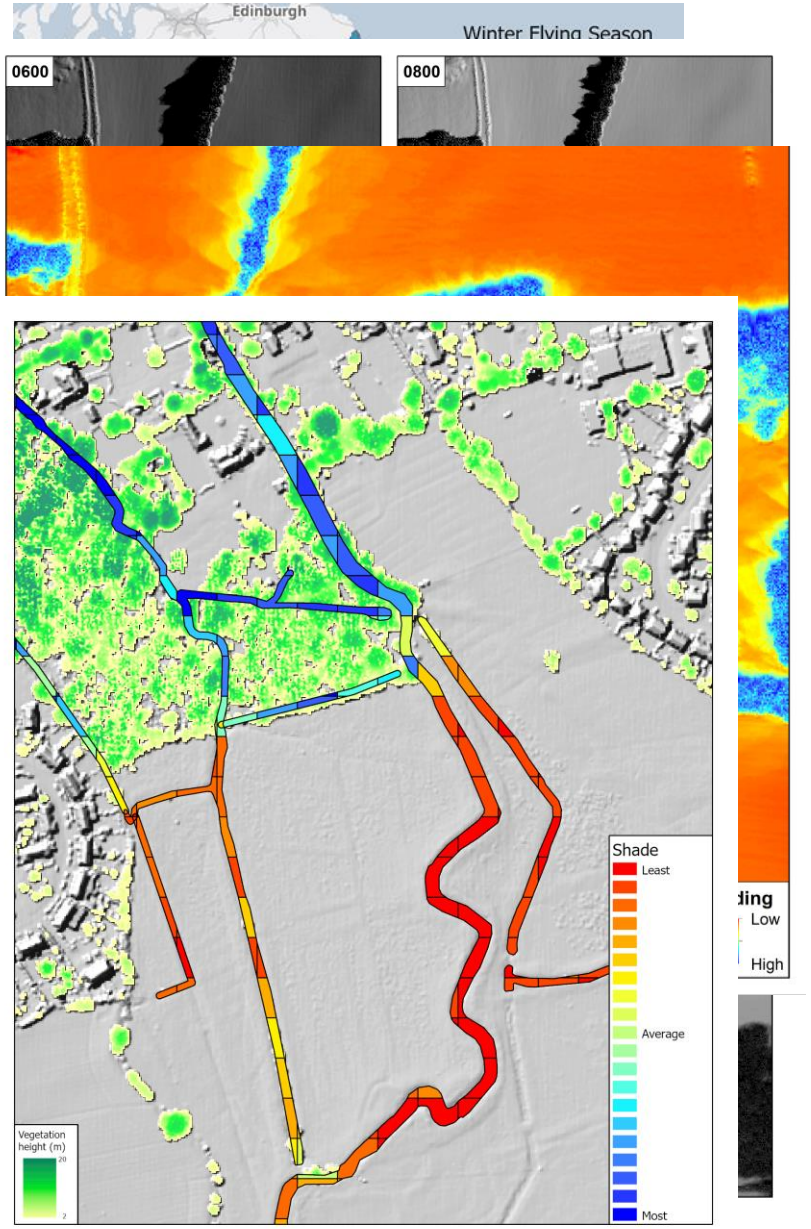
To assist with targeting tree planting, a 2nd generation KRC England-wide shade map has been produced, using:

a) New England-wide 1m resolution lidar survey, which gathered data between 2017-2022 to map vegetation.

b) Employed a first-return Digital Surface Model to gauge vegetation height.

c) Applied multi-directional sun-shading to a combination of a Digital Terrain Model and the first-return Digital Surface Model to determine shading.

The 2nd generation KRC shade map is available from the Environment Agency and will be via the government's Open Data portal ~ late 2023.



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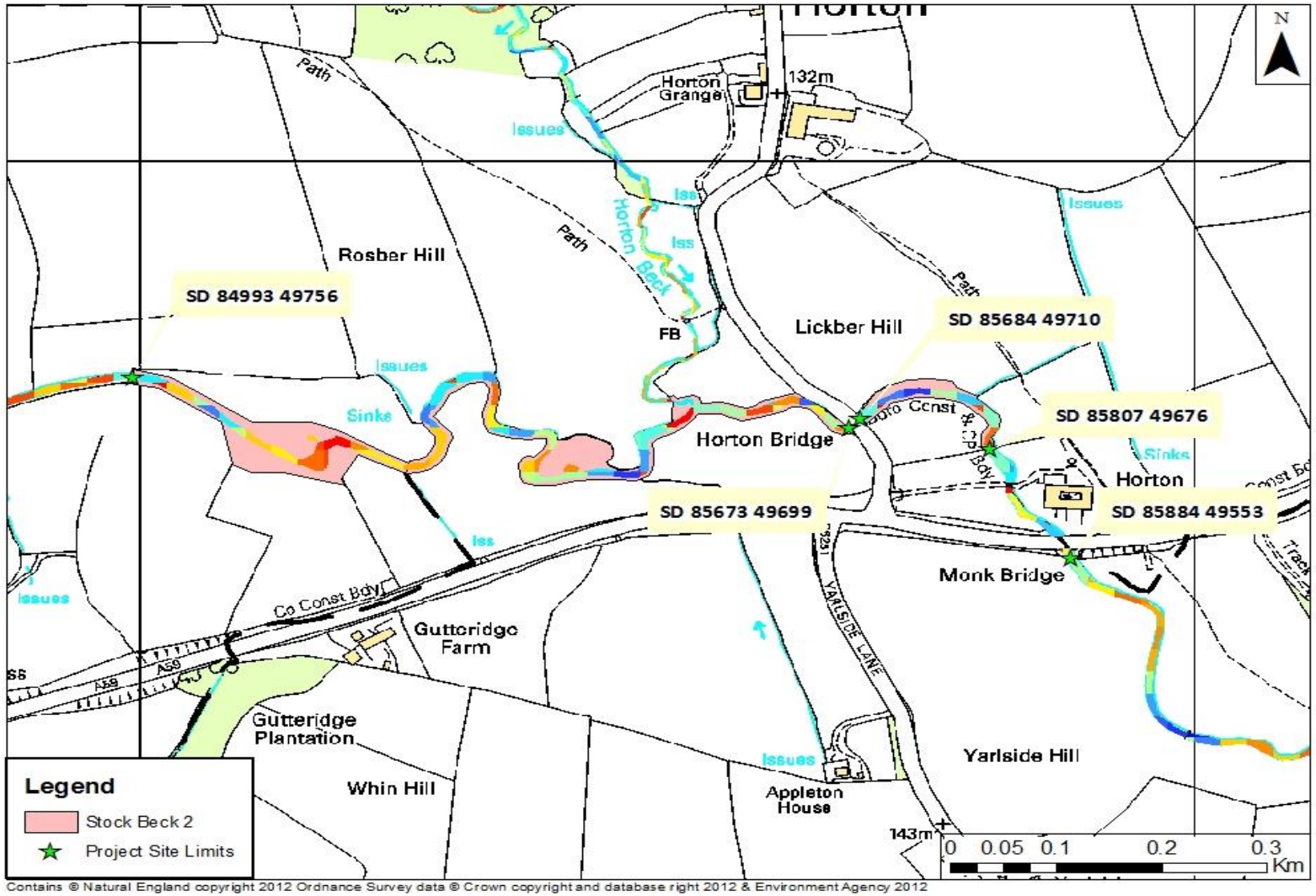
England Case Study: Keeping the Ribble Cool



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Horton Brook

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Partner:
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Project:
Keeping Rivers Cool

Date Produced:
7/6/2013

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Environment Agency

RIBBLE RIVERS TRUST

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Conclusions

- Scotland Case Study: shows that suitable data and models can be used to prioritise tree planting to locations which are hottest, most sensitive to climate change AND where shading can reduce temperatures.

- England Case Study: shows that shade maps, which indicate the level of tree cover, provide a very helpful tool for targeting tree planting.

- Future work could explore river temperatures under different climate change scenarios (e.g. UKCP18 climate projections); and there are opportunities for ‘real-time’ monitoring and management.

- For salmon to realise the benefits of tree planting, however, it needs to be delivered rapidly, at scale and in optimal locations given the time it takes for trees to grow.