Where to plant trees to protect rivers under climate change?

F.L. Jackson, R.J. Fryer, D.M. Hannah, C.P. Millar, V.O. Ouellet, I.A. Malcolm

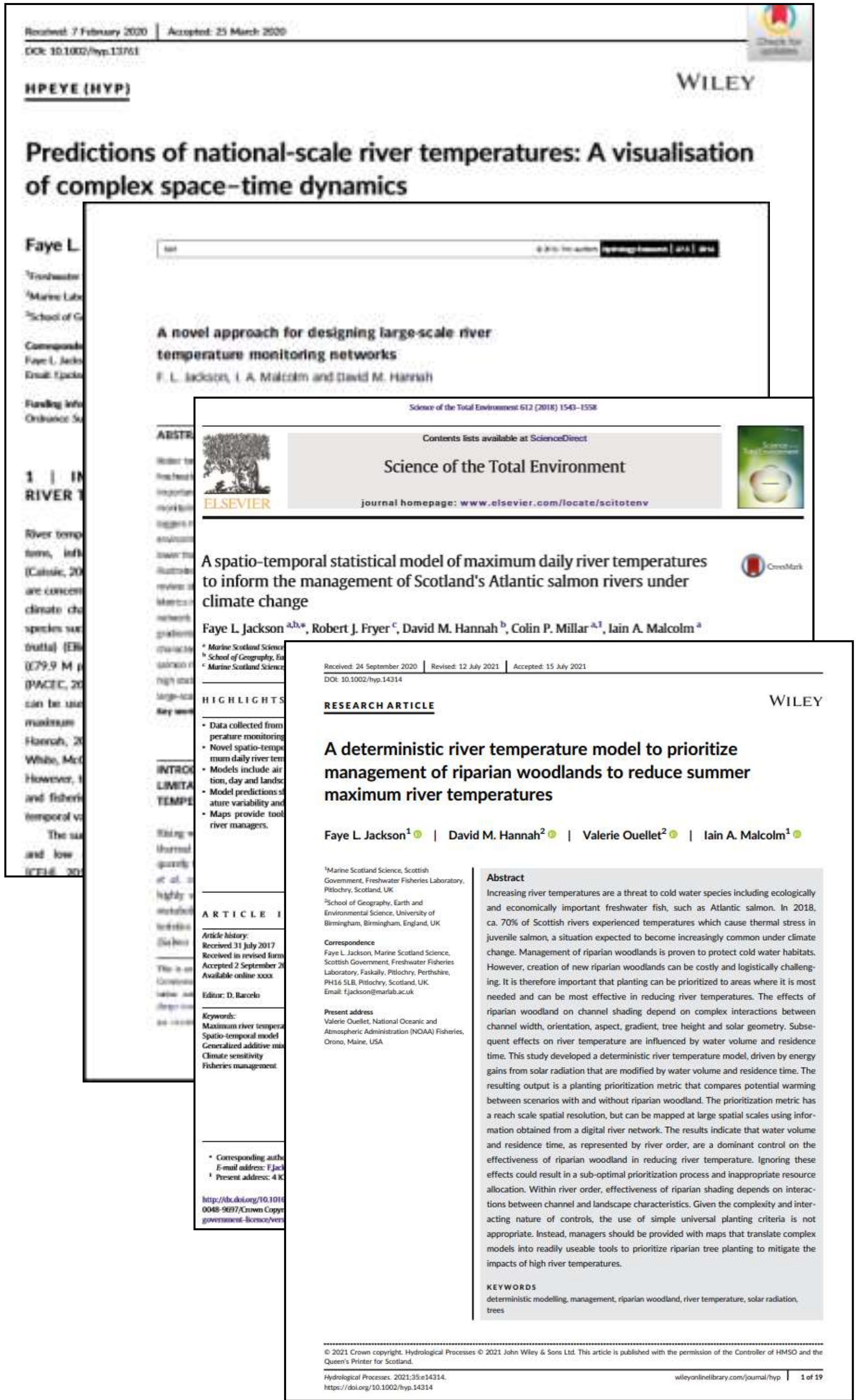
Scottish Freshwater Group Spring 2022 Meeting

Twitter: #SFGSpring2022 #SRTMN
@marinescotland @Faye_L_Jackson @freshwaterflows @DrVal_O @IainAMalcolm

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

Outline

- Background and context
- SRTMN: Using statistical models to understand and predict where river temperatures are hottest and most sensitive to climate change
- PP: Using process-based models to understand where riparian shading most effective in reducing Tw?
- Combining outputs from statistical and process models to prioritise tree planting



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Background

- River temperature is important control on the health of freshwater ecosystems

- Expect rising river temperatures under climate change
- Potentially consequences for cold water adapted species like salmonids

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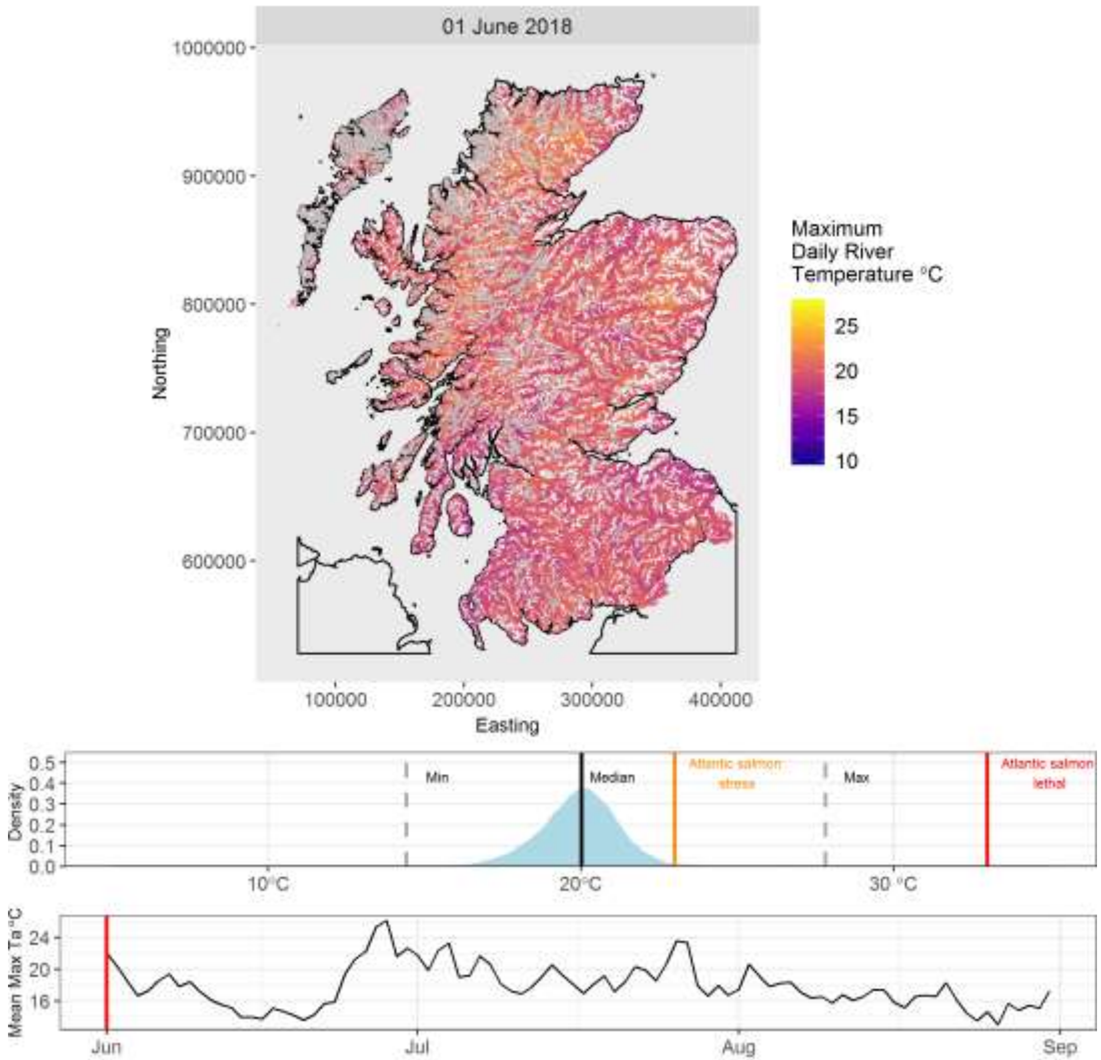
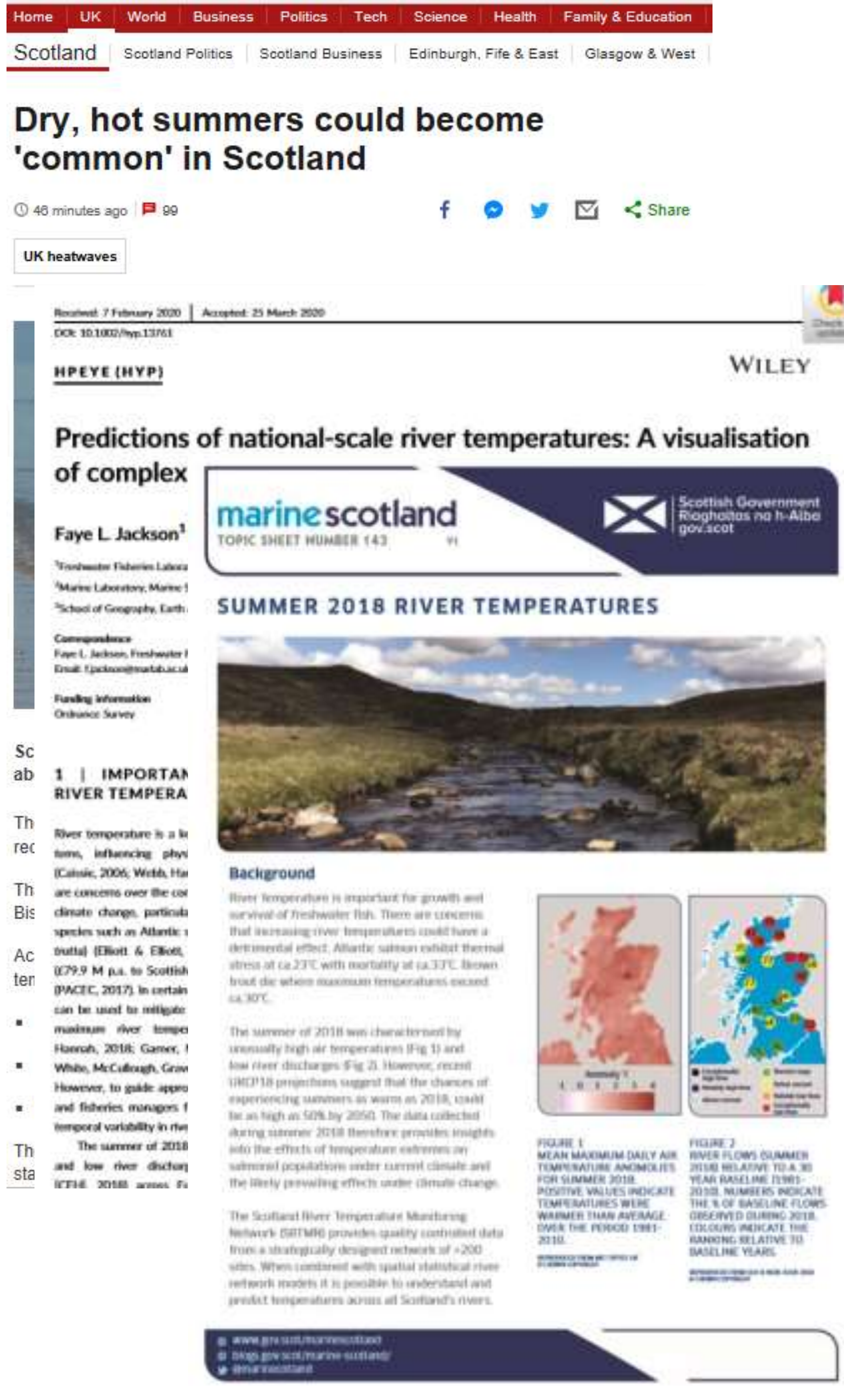
Summer 2018; an indication of things to come?





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Dry, hot summers could become 'common' in Scotland

46 minutes ago | 99 | Share

UK heatwaves

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HPEYE (HYP) WILEY

Predictions of national-scale river temperatures: A visualisation of complex

Faye L. Jackson[1]

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TOPIC SHEET NUMBER 143

Scottish Government
Riaghaltas na h-Alba
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SUMMER 2018 RIVER TEMPERATURES

Background

1 | IMPORTANT RIVER TEMPERA

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Mitigation: riparian tree cover

- **Riparian woodland can reduce high temperature extremes**
- **One of few management options**
- **Preliminary GIS analysis indicates only ca. 35% of rivers are protected by any substantial tree cover**
- **New woodland creation can be costly and logistically challenging**
- **Strategically target effort:**
  - Where are rivers hottest
  - Where are rivers most sensitive to effects of climate change
  - Where does riparian tree planting have the greatest effect on river temperature

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TOPIC SHEET NUMBER 91 V2

Scottish Government
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Where should we plant trees to protect rivers under climate change?

Background

River temperature (Tw) influences the feeding, growth, productivity and survival of freshwater fish. For juvenile Atlantic salmon, 16˚C is optimal for growth, while temperatures greater than 23 ˚C cause thermal stress and greater than 32˚C can kill fish in a few minutes. In 2018 around 69% of Scottish rivers experienced temperatures that would cause thermal stress, conditions likely to occur every other year by 2050.

Bankside trees can reduce Tw. However, the size of their effect varies depending on river characteristics (e.g. width, orientation, aspect, speed, depth) and the topography of the surrounding landscape, which can also shade the river.

Fisheries and river managers are planting bankside trees to protect rivers from high water temperatures. However, the information necessary to prioritise where planting would deliver the greatest benefits has not been available until recently.

How can models help inform tree planting strategies?

Marine Scotland and the University of Birmingham have developed GIS maps and advice for river managers to identify where tree planting can have the greatest benefits for Tw and temperature sensitive salmonid species.

The maps have been developed from two types of complimentary river temperature models developed under the Scotland River Temperature Monitoring Network (SRTMN):

1. Statistical models which describe spatial variability in maximum Tw and sensitivity to climate change
2. Simplified 'process-based' models which describe where riparian woodland can be most effective in reducing maximum summer river temperatures (*see* figure 1)

Large-scale statistical models

Statistical models used Tw data from SRTMN together with spatial information on landscape characteristics and air temperature.

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blogs.gov.scot/marine-scotland/
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science

SRTMN:

Where river temperatures are hottest?

Where are rivers most sensitive to climate change?

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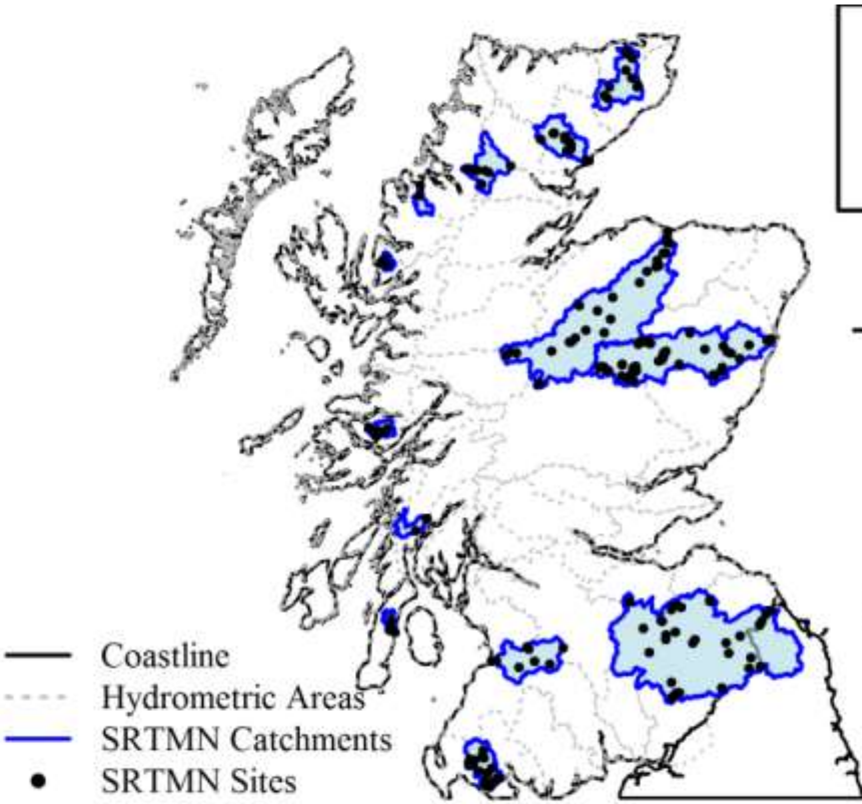
Developing a model to predict current and future river temperatures



Air temperature & river characteristics (elevation, orientation, riparian woodland)

→ Quality controlled maximum daily river temperature data

↓

Generalised additive mixed models

↓

Predictions of maximum daily river temperature, climate sensitivity & effects of woodland

↓

Management tools

 © 2016 The Authors Hydrology Research | 47.3 | 2016

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.

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

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

Rising water temperatures (*Tw*) 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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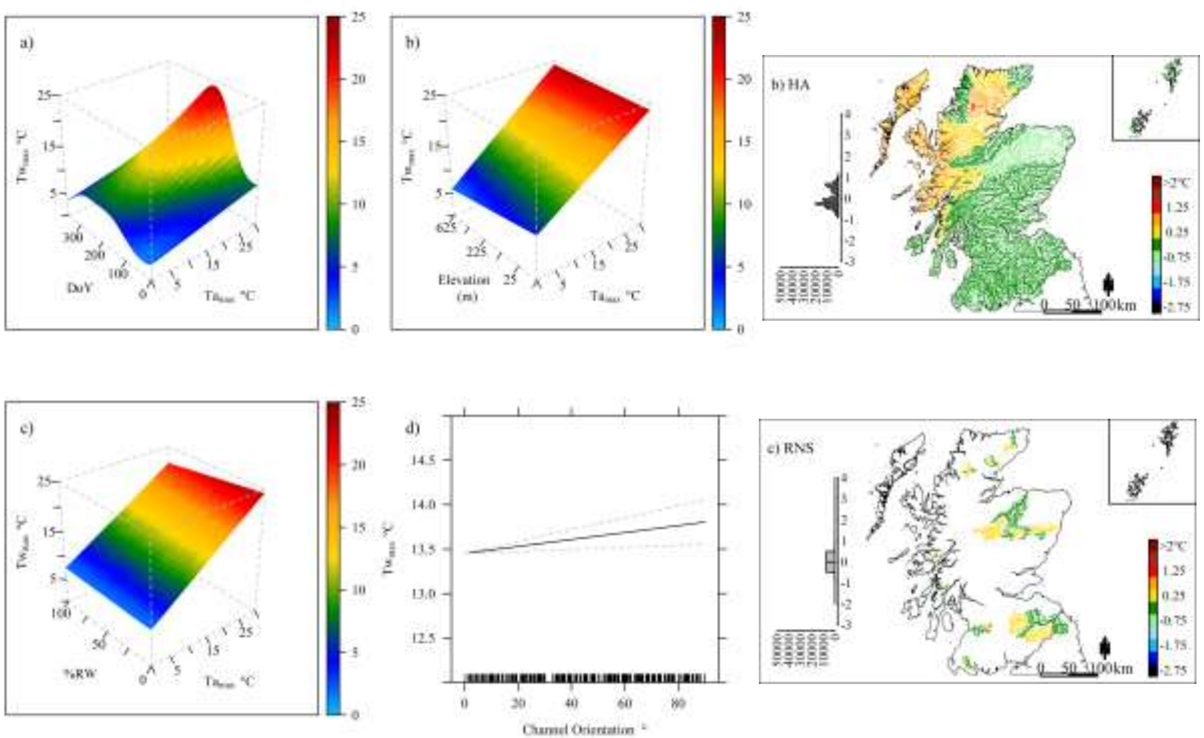
Use models to predict river temperature in unmonitored locations

Large-scale spatio-temporal 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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journal homepage: www.elsevier.com/locate/scitotenv

A spatio-temporal statistical model of maximum daily river temperatures to inform the management of Scotland's Atlantic salmon rivers under climate change

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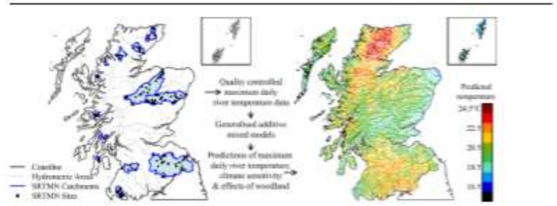
[c] Marine Scotland Science, Scottish Government, Marine Laboratory, 375 Victoria Road, Aberdeen AB11 9DB, Scotland, UK

HIGHLIGHTS

- Data collected from strategic river temperature monitoring network
- Novel spatio-temporal model of maximum daily river temperature developed
- Models include air temperature, location, day and landscape characteristics
- Model predictions show spatial temperature variability and climate sensitivity.
- Maps provide tools for fisheries and river managers.

GRAPHICAL ABSTRACT



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Maximum river temperature
Spatio-temporal model
Generalized additive mixed model
Climate sensitivity
Fisheries management

ABSTRACT

The thermal suitability of riverine habitats for cold water adapted species may be reduced under climate change. Riparian tree planting is a practical climate change mitigation measure, but it is often unclear where to focus effort for maximum benefit. Recent developments in data collection, monitoring and statistical methods have facilitated the development of increasingly sophisticated river temperature models capable of predicting spatial variability at large scales appropriate to management. In parallel, improvements in temporal river temperature models have increased the accuracy of temperature predictions at individual sites. This study developed a novel large scale spatio-temporal model of maximum daily river temperature (Tw_{max}) for Scotland that predicts variability in both river temperature and climate sensitivity. Tw_{max} was modelled as a linear function of maximum daily air temperature (Ta_{max}), with the slope and intercept allowed to vary as a smooth function of day of the year (DoY) and further modified by landscape covariates including elevation, channel orientation and riparian woodland. Spatial correlation in Tw_{max} was modelled at two scales; (1) river network (2) regional. Temporal correlation was addressed through an autoregressive (AR1) error structure for observations within sites. Additional site level variability was modelled with random effects. The resulting model was used to map (1) spatial variability in predicted Tw_{max} under current (but extreme) climate conditions (2) the sensitivity of rivers to climate variability and (3) the effects of riparian tree planting. These visualisations provide innovative tools for informing fisheries and land-use management under current and future climate.

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http://dx.doi.org/10.1016/j.scitotenv.2017.09.010

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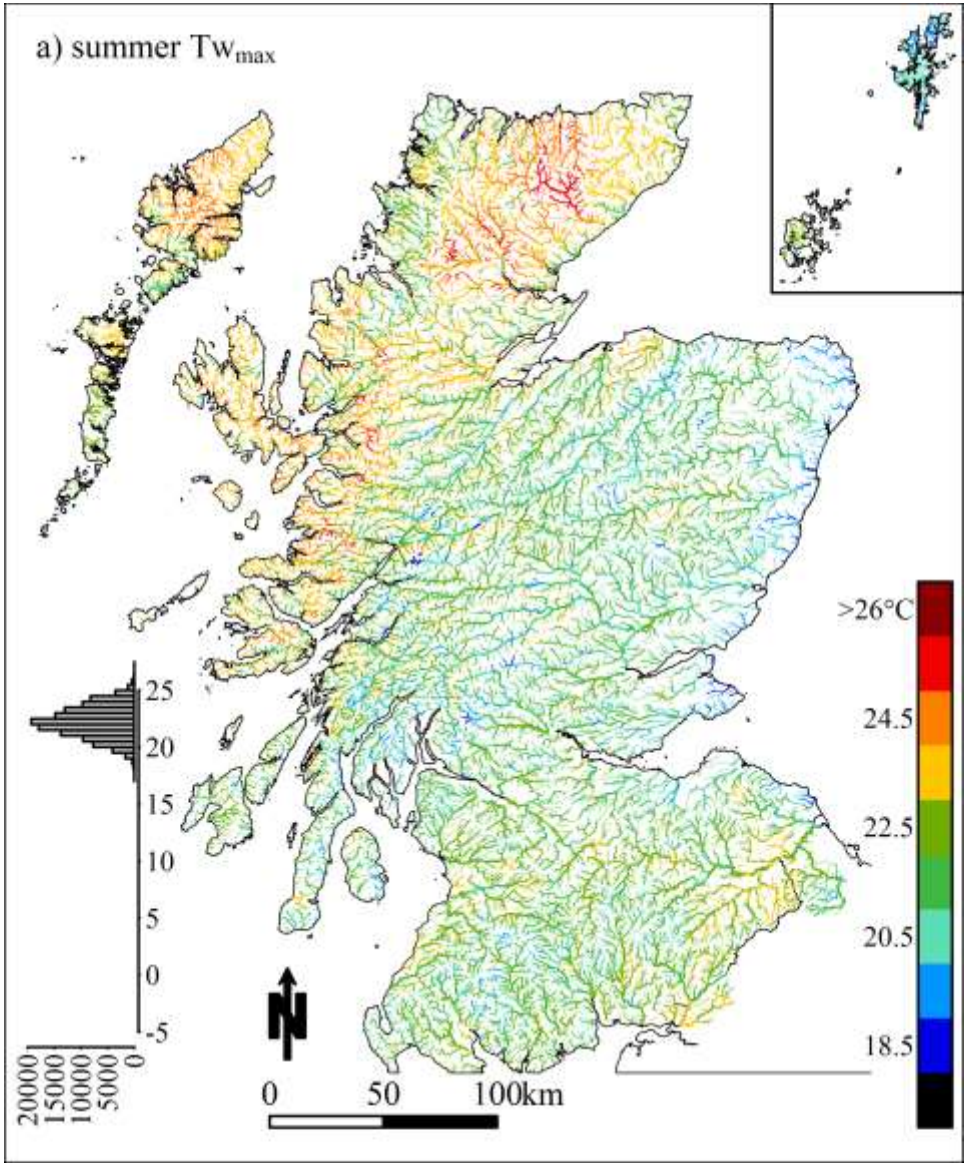
Predictions of daily maximum river temperatures under 'extreme' conditions (highest Ta observed in 2003)

Results:

Spatial patterns reflect Ta, landscape covariates, HA and RNS

Warmest temperatures are in low altitude (high Ta) unshaded rivers, particularly in North.



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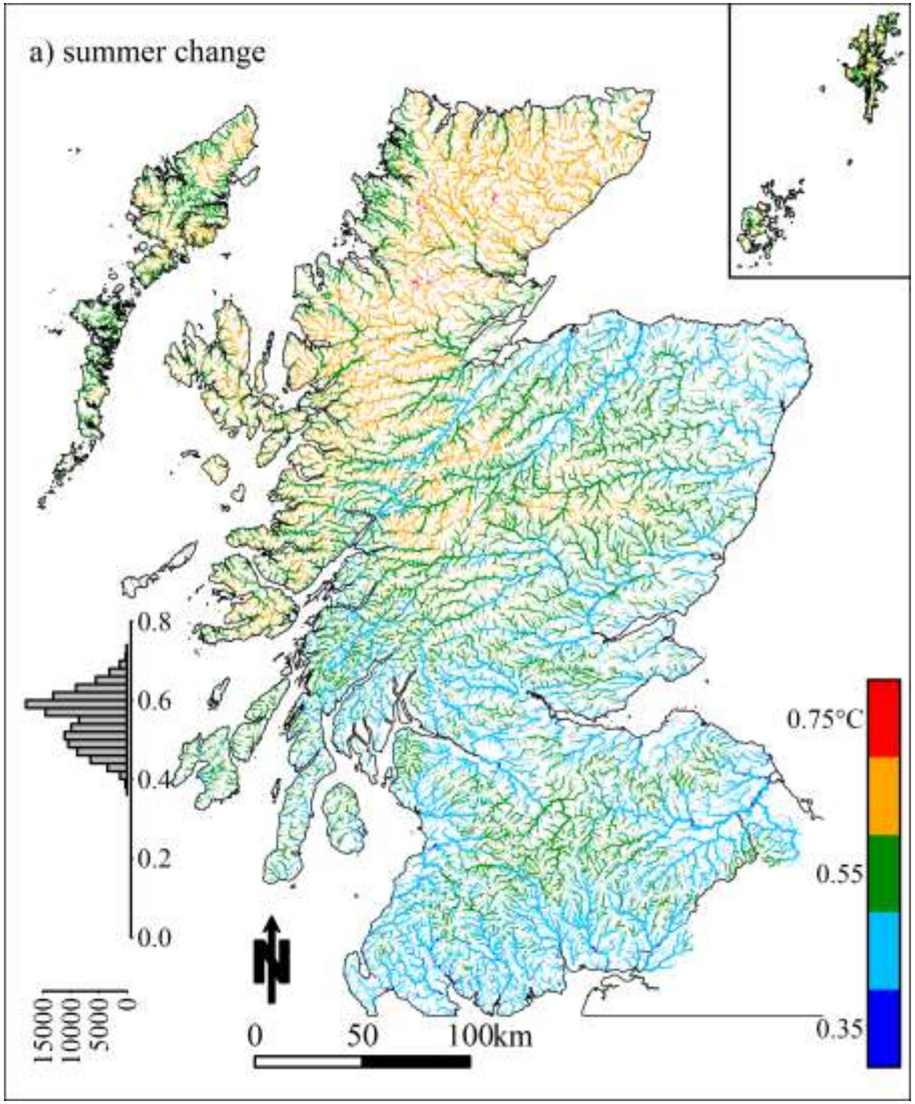
Predictions of climate sensitivity

How much Tw_{max} will change for a 1 degree C change in Ta_{max}

Results:

Biggest changes are seen in northern rivers and in the Cairngorms



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Planting Potential

Where does riparian tree planting have the greatest effect on river temperature?

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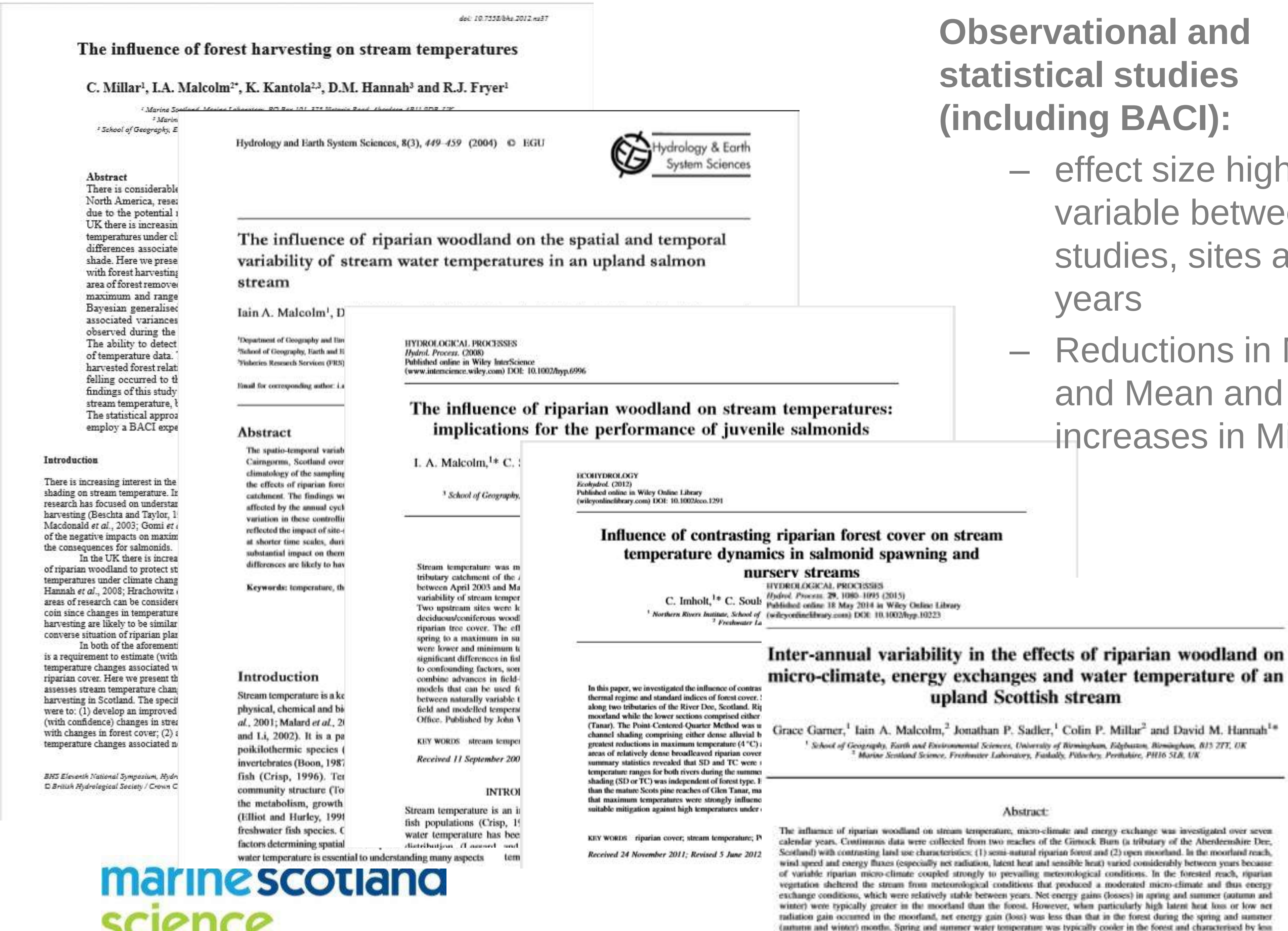
"Woodland effects"



Observational and statistical studies (including BACI):

- effect size highly variable between studies, sites and years
- Reductions in Max and Mean and increases in Min T

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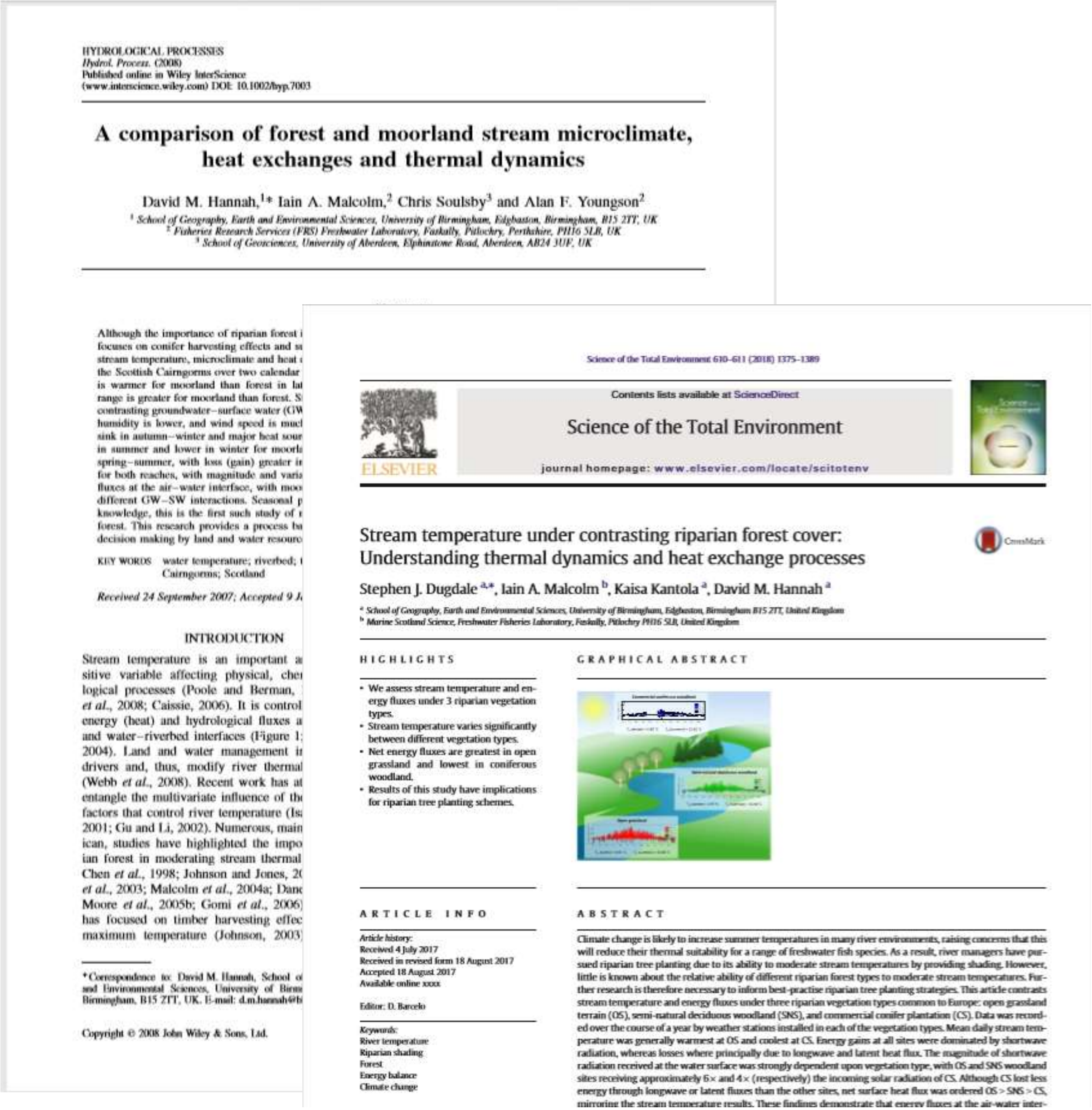
How does riparian woodland influence river temperature?

- **Shading can reduce incoming shortwave radiation**

- **However, also reduces heat loss through evaporation & net longwave radiation**



HYDROLOGICAL PROCESSES
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Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/hyp.7003

A comparison of forest and moorland stream microclimate, heat exchanges and thermal dynamics

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Although the importance of riparian forest i
focuses on conifer harvesting effects and s
stream temperature, microclimate and heat
the Scottish Cairngorms over two calendar
is warmer for moorland than forest in la
range is greater for moorland than forest. S
contrasting groundwater–surface water (GW
humidity is lower, and wind speed is muc
sink in autumn–winter and major heat sour
in summer and lower in winter for moorl
spring–summer, with loss (gain) greater i
for both reaches, with magnitude and vari
fluxes at the air–water interface, with moo
different GW–SW interactions. Seasonal p
knowledge, this is the first such study of
forest. This research provides a process b
decision making by land and water resourc

KEY WORDS water temperature; riverbed;
Cairngorms; Scotland

Received 24 September 2007; Accepted 9 J

INTRODUCTION

Stream temperature is an important a
sitive variable affecting physical, che
logical processes (Poole and Berman,
et al., 2008; Caissie, 2006). It is control
energy (heat) and hydrological fluxes a
and water–riverbed interfaces (Figure 1;
2004). Land and water management i
drivers and, thus, modify river thermal
(Webb *et al.*, 2008). Recent work has a
entangle the multivariate influence of th
factors that control river temperature (Is
2001; Gu and Li, 2002). Numerous, main
ican, studies have highlighted the impo
ian forest in moderating stream thermal
Chen *et al.*, 1998; Johnson and Jones, 2
et al., 2003; Malcolm *et al.*, 2004a; Dan
Moore *et al.*, 2005b; Gomi *et al.*, 2006)
has focused on timber harvesting effec
maximum temperature (Johnson, 2003)

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ELSEVIER

Stream temperature under contrasting riparian forest cover: Understanding thermal dynamics and heat exchange processes

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HIGHLIGHTS

- We assess stream temperature and energy fluxes under 3 riparian vegetation types.
- Stream temperature varies significantly between different vegetation types.
- Net energy fluxes are greatest in open grassland and lowest in coniferous woodland.
- Results of this study have implications for riparian tree planting schemes.

GRAPHICAL ABSTRACT

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Energy balance
Climate change

ABSTRACT

Climate change is likely to increase summer temperatures in many river environments, raising concerns that this will reduce their thermal suitability for a range of freshwater fish species. As a result, river managers have pursued riparian tree planting due to its ability to moderate stream temperatures by providing shading. However, little is known about the relative ability of different riparian forest types to moderate stream temperatures. Further research is therefore necessary to inform best-practise riparian tree planting strategies. This article contrasts stream temperature and energy fluxes under three riparian vegetation types common to Europe: open grassland terrain (OS), semi-natural deciduous woodland (SNS), and commercial conifer plantation (CS). Data was recorded over the course of a year by weather stations installed in each of the vegetation types. Mean daily stream temperature was generally warmest at OS and coolest at CS. Energy gains at all sites were dominated by shortwave radiation, whereas losses where principally due to longwave and latent heat flux. The magnitude of shortwave radiation received at the water surface was strongly dependent upon vegetation type, with OS and SNS woodland sites receiving approximately 6× and 4× (respectively) the incoming solar radiation of CS. Although CS lost less energy through longwave or latent fluxes than the other sites, net surface heat flux was ordered OS > SNS > CS, mirroring the stream temperature results. These findings demonstrate that energy fluxes at the air-water inter-

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Channel shading models

- **Comparisons of shading in forested and unforested channels of different characteristics**

- **Importantly, they do not consider hydrology and hydraulics**

JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION
Vol. 44, No. 6 AMERICAN WATER RESOURCES ASSOCIATION December 2008

GUIDELINES FOR RIPARIAN VEGETATIVE SHADE RESTORATION BASED UPON A THEORETICAL SHADED-STREAM MODEL[1]

David R. DeWalle[2]

ABSTRACT: C
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Shaded-Strean
10.1111/j.1752

JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION
Vol. 46, No. 2 AMERICAN WATER RESOURCES ASSOCIATION April 2010

MODELING STREAM SHADE: RIPARIAN BUFFER HEIGHT AND DENSITY AS IMPORTANT AS BUFFER WIDTH[1]

David R. DeWalle[2]

ABSTRACT: A theoretical model was developed to explore impacts of varying buffer zone characteristics on shading of small streams using a path-length form of Beer's law to represent the transmission of direct beam solar radiation through vegetation. Impacts of varying buffer zone height, width, and radiation extinction coefficients (surrogate for buffer density) on shading were determined for E-W and N-S stream azimuths in infinitely long stream sections at 40°N on the summer solstice. Increases in buffer width produced little additional shading beyond buffer widths of 6-7 m for E-W streams due to shifts in solar beam pathway from the sides to the tops of the buffers. Buffers on the north bank of E-W streams produced 30% of daily shade, while the south-bank buffer produced 70% of total daily shade. For N-S streams an optimum buffer width was less-clearly defined, but a buffer width of about 18-20 m produced about 85-90% of total predicted shade. The model results supported past field studies showing buffer widths of 9-11 m were sufficient for stream temperature control. Regardless of stream azimuth, increases in buffer height and extinction coefficient (buffer density) were found to substantially increase shading up to the maximum tree height and stand density likely encountered in the field. Model results suggest that at least 80% shade on small streams up to 6-m wide can be achieved in mid-latitudes with relatively narrow 12-m wide buffers, regardless of stream azimuth, as long as buffers are tall (≈30 m) and dense (leaf area index ≈6). Although wide buffers may be preferred to provide other benefits, results suggest that increasing buffer widths beyond about 12 m will have a limited effect on stream shade at mid-latitudes and that greater emphasis should be placed on the creation of dense, tall buffers to maximize stream shading.

(KEY TERMS: stream shading; Beer's law; forest extinction coefficients; stream azimuth; leaf area index; buffer zone width; buffer zone height.)

DeWalle, David R., 2010. Modeling Stream Shade: Riparian Buffer Height and Density as Important as Buffer Width. *Journal of the American Water Resources Association* (JAWRA) 46(2):323-333. DOI: 10.1111/j.1752-1688.2010.00423.x

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Processes based Tw models

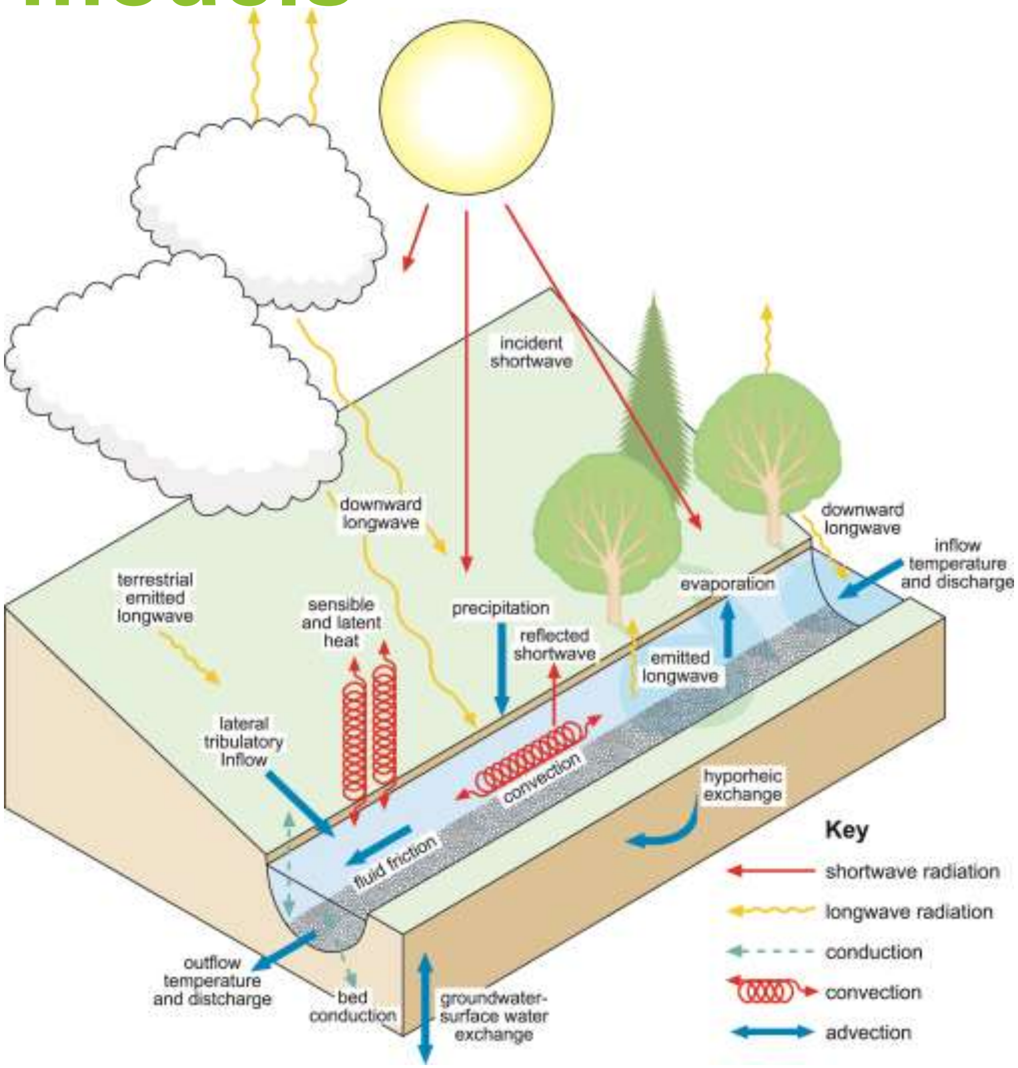

Figure from Hannah *et al* 2008

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River temperature modelling: A review of process-based approaches and future directions

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ABSTRACT

River temperature has a major influence on biophysical processes in lotic environments. River temperature is expected to increase due to climate change, with potentially adverse consequences for water quality and ecosystems. Consequently, a better understanding of the drivers of river temperature space-time variability is important for developing adaptation strategies. However, existing river temperature archives are often of low resolution or short timespans, and the analysis of patterns or trends can therefore be difficult. In light of these limitations, researchers have increasingly used models to generate river temperature estimates suitable for addressing fundamental and applied questions in river science. Of these models, process-based approaches are well suited to helping improve knowledge of the mechanisms controlling river temperature, because of their ability to explore the energy (and water) fluxes responsible for temperature patterns. While process-based modelling approaches can often be more data intensive than their statistical counterparts, they offer significant advantages with regard to simulating the impacts of projected land-use or climate change, and can provide valuable insights for informing the development of statistical models at larger scales. However, a wide range of process-based river temperature models exist, and choosing the most appropriate model for a given investigation requires careful consideration. In this paper, we review the foundations of process-based river temperature modelling and critically evaluate the features and functionality of existing models with a view to helping river scientists better understand their utility. In conclusion, we discuss key considerations and limitations of currently available process-based models and advocate directions for future research. We hope that this review will enable river researchers and managers to make informed decisions regarding model selection and spur the continued refinement of process-based temperature models for addressing fundamental and applied questions in the river sciences.

1. Introduction

River temperature is one of the most important river habitat variables (Caissie, 2006; Hannah and Garner, 2015), controlling biogeochemical processes (Durance and Ormerod, 2009; Kaushal et al., 2010), ecosystem dynamics (Durance and Ormerod, 2007; Bärlocher et al., 2008; Dugdale et al., 2016) and water quality (Finlay, 2003; Bloomfield et al., 2006; Delpla et al., 2009). Quantifying river temperature is therefore key for improved understanding of fluvial environments. River temperature regimes in most locations are expected to change as a result of future climate change (van Vliet et al., 2013; Caldwell et al., 2015; Hannah and Garner, 2015; Muñoz-Mas et al., 2016) and other anthropogenic drivers (e.g. abstraction, impoundment, land-use change; Poole and Berman, 2001; Hester and Doyle, 2011). However, shortcomings in several key aspects of river temperature research mean that little is currently known about the complex nature of future temperature variability. River temperature science has in the past been based on data with low spatial and temporal resolution, frequently collected as a side product of water quality and/or ecological sampling. Water temperature data quality is consequently highly variable and elucidating the controls of river temperature remains difficult (Webb et al., 2004; Jonsson and Jonsson, 2009; Watts et al., 2015). Efforts have been made to resolve this using novel temperature logger networks (e.g. Isaak et al., 2010; Jackson et al., 2016; Boyer et al., 2016) or remote sensing techniques (see Dugdale, 2016). While such investigations are fast becoming the new norm, process-based understanding has not always kept pace with methodological development, and the exact mechanisms controlling river temperature heterogeneity remain difficult to isolate (Hannah and Garner, 2015). Further research into river temperature dynamics is consequently of key importance with regard to

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Bridging the gap between simple shading models and more complex deterministic river temperature models that incorporate a wider range of heat exchange, hydrological and hydraulic process

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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 challenging. It is therefore important that planting can be prioritized to areas where it is most needed and can be most effective in reducing river temperatures. The effects of riparian woodland on channel shading depend on complex interactions between channel width, orientation, aspect, gradient, tree height and solar geometry. Subsequent effects on river temperature are influenced by water volume and residence time. This study developed a deterministic river temperature model, driven by energy gains from solar radiation that are modified by water volume and residence time. The resulting output is a planting prioritization metric that compares potential warming between scenarios with and without riparian woodland. The prioritization metric has a reach scale spatial resolution, but can be mapped at large spatial scales using information obtained from a digital river network. The results indicate that water volume and residence time, as represented by river order, are a dominant control on the effectiveness of riparian woodland in reducing river temperature. Ignoring these effects could result in a sub-optimal prioritization process and inappropriate resource allocation. Within river order, effectiveness of riparian shading depends on interactions between channel and landscape characteristics. Given the complexity and interacting nature of controls, the use of simple universal planting criteria is not appropriate. Instead, managers should be provided with maps that translate complex models into readily useable tools to prioritize riparian tree planting to mitigate the impacts of high river temperatures.

KEYWORDS
deterministic modelling, management, riparian woodland, river temperature, solar radiation, trees

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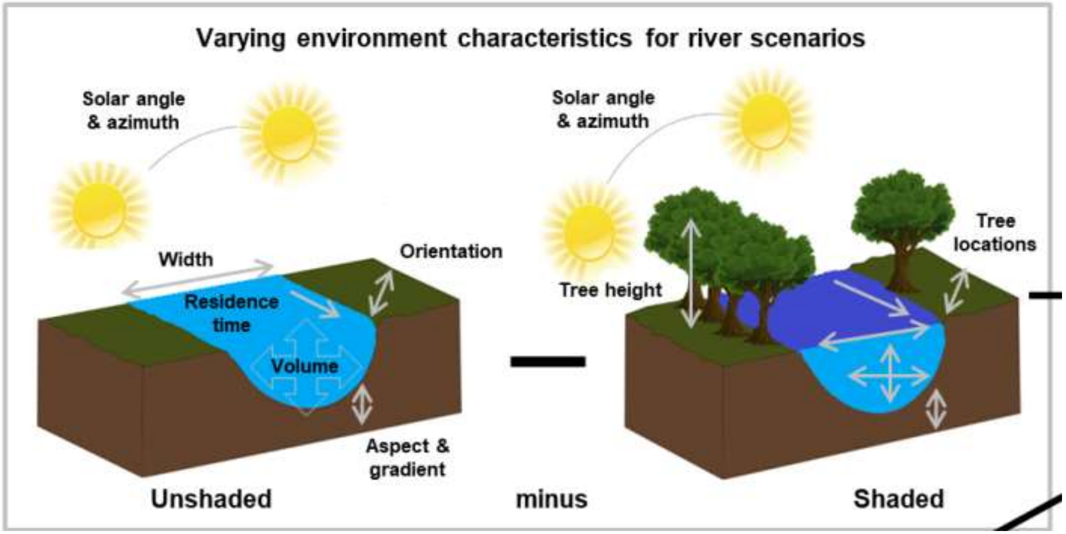
What factors influence the effects of riparian woodland on stream temperature?

- Discharge (water volume)
- Mean column velocity (how much time does water spend in shaded reach)
- Channel width (how much radiation is received, and how much of the channel is shaded)
- Channel orientation and aspect (how does orientation of vegetation and channel interact with solar position to affect receipt of radiation)
- Channel gradient (solar angles)
- Tree height, location and density



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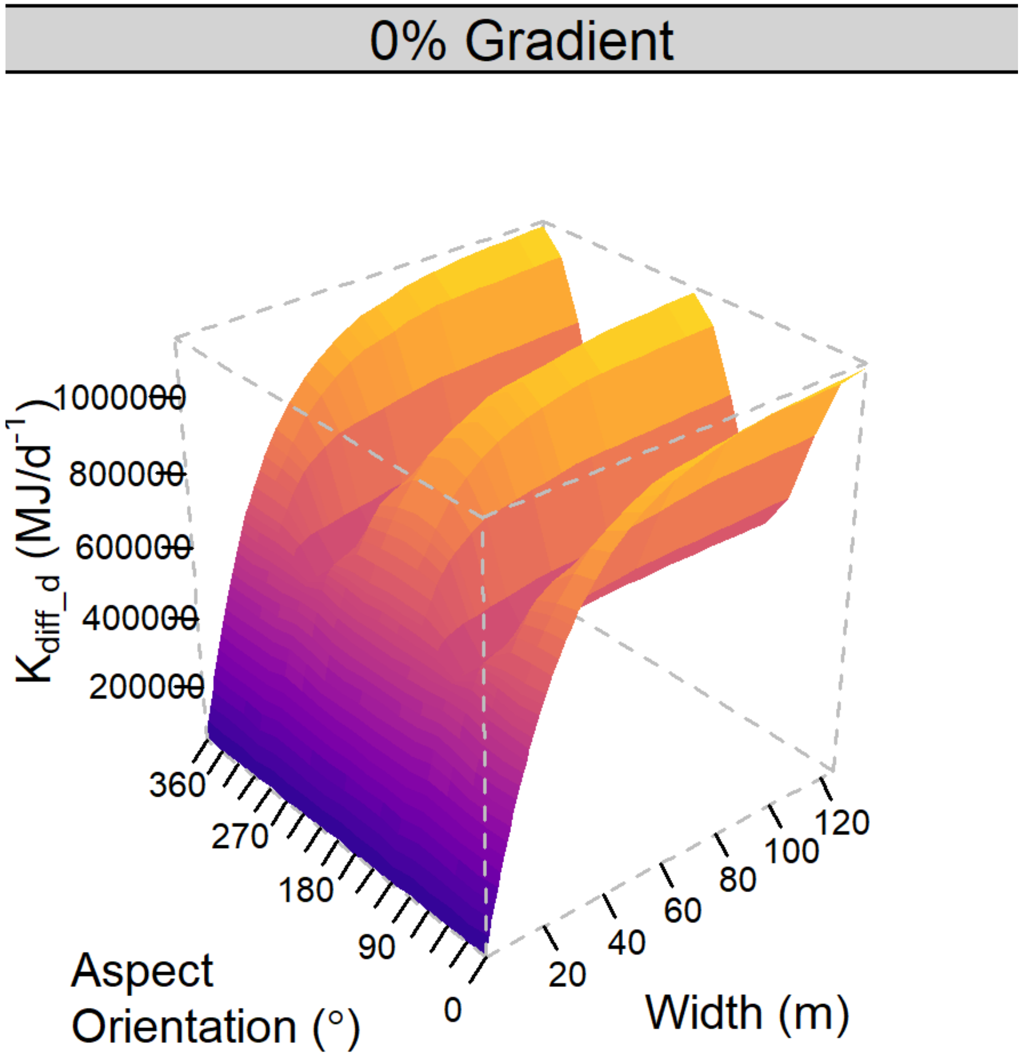
Daily radiation differences K_{diff_d}

no trees – trees on both banks

Positive effect of width on K_{diff_d} for lower river widths (< ca. 40m) where trees can shade whole channel

K_{diff_d} highest for N-S / S-N channels and lowest for E-W / W-E channels

Small effect of gradient - north facing rivers less shading than south facing slopes



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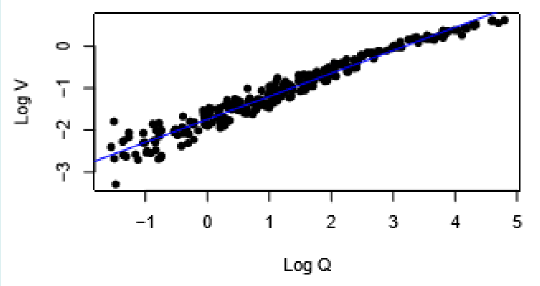
Effects of hydrology and hydraulics

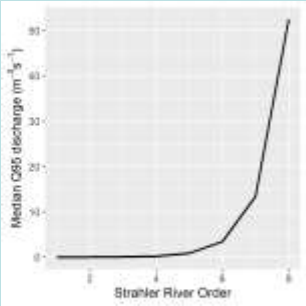
Hydrology and hydraulics (river order)

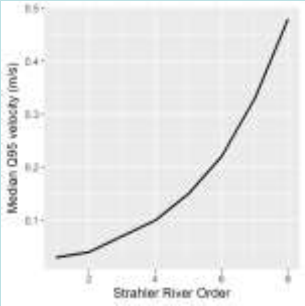
NRFA Flow Statistics Q95

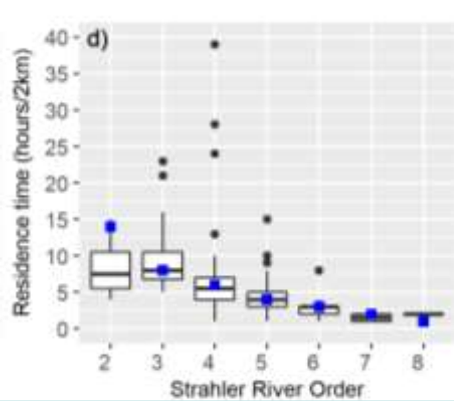


SEPA gauging Data (Q & V) → Obtain River Order → Model Velocity ~ Q → Mean column velocity at Q95

Model average Q and V by river order







Solar Arc model → Kdiff: difference from no tree baseline shortwave → Tw gain over reach (assuming no losses) → Tdiff: difference from no tree baseline

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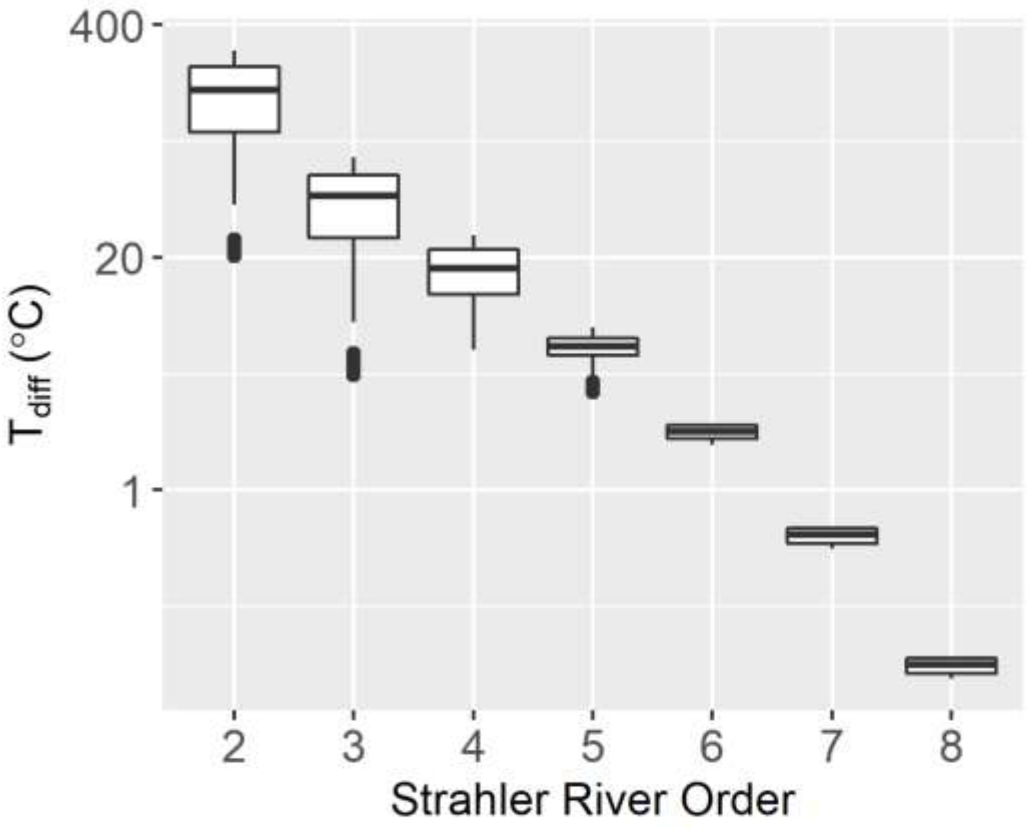
Temperature differences T_{diff}

Large water volumes and short residence times in higher order rivers offset the greater differences in solar radiation receipt (shading) generating smaller differences in temperature

Within river orders, variability in T_{diff} is controlled by width, orientation, aspect and gradient



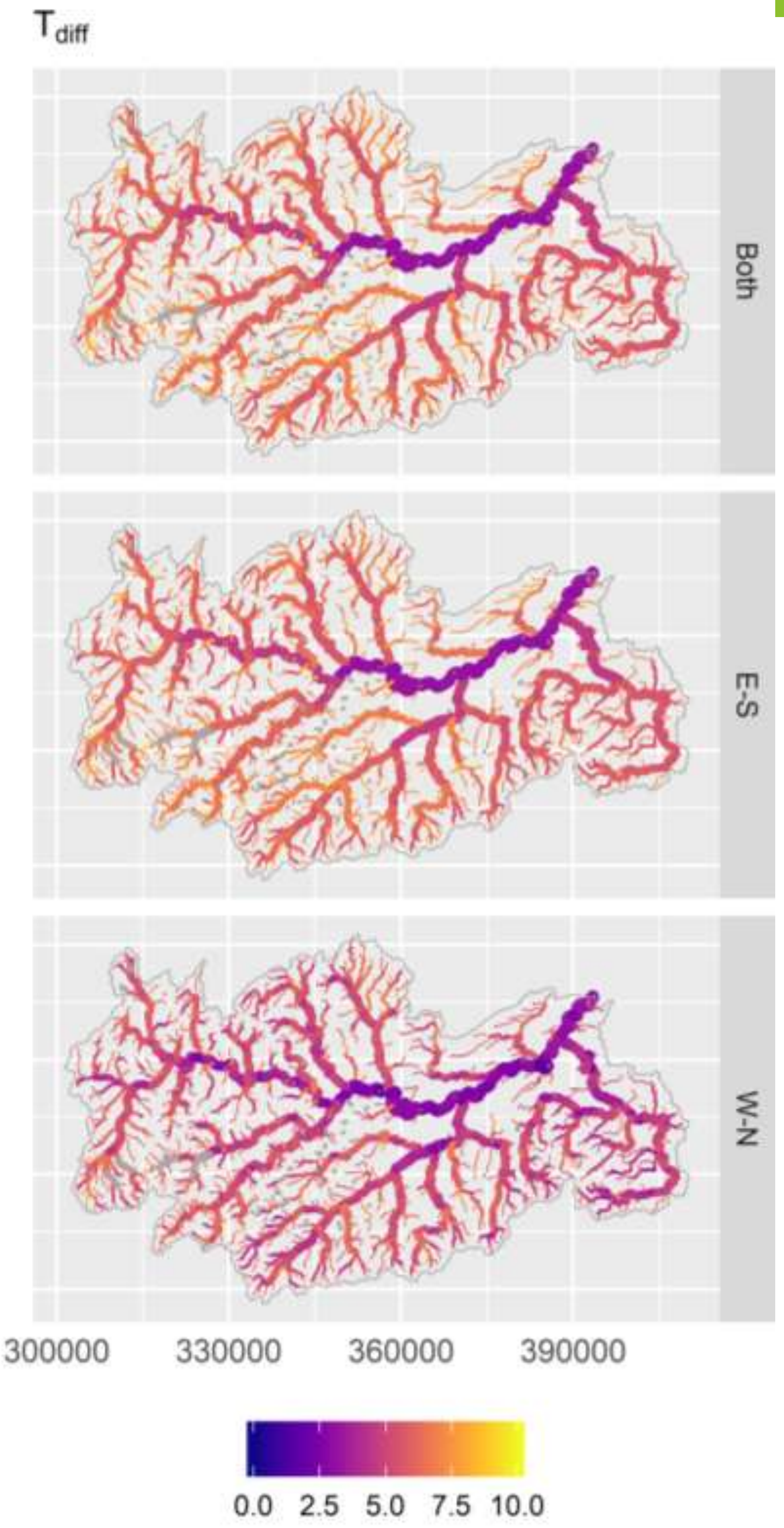
Planting Potential

T_{diff} prioritises ↓ in temperature over a given reach

Greatest effect in smaller rivers characterised by lower water velocities, longer residence times and smaller water volumes

Small effect in large rivers

Within river order variability driven by short-wave energy receipt controlled by width, orientation, aspect & gradient



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Combining criteria into a single planting prioritisation score

Riparian Woodland Prioritisation Scores for Scotland

- SRTMN and planting potential layers can be used individually to target constrained resources

- Released tools as they became available over a number of years

- Feedback from trusts and boards was wanted a single simple layer which combines performance criteria 1) where is hottest 2) where will change most and 3) where trees can reduce temperatures most

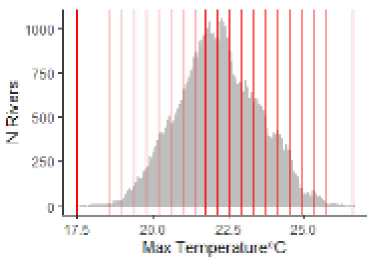
- Numerous ways to combine, present and rescale depending on policy and management goals

Method for developing Riparian Woodland Prioritisation Scores

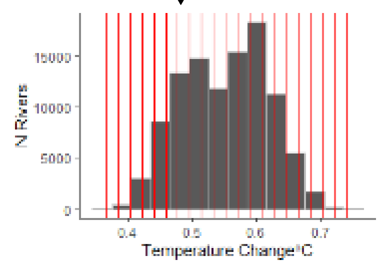
Performance criteria

generate 20 categories / ranks equally distributed across the range (omitting outliers +/- 3 times SD)

Max Temperature

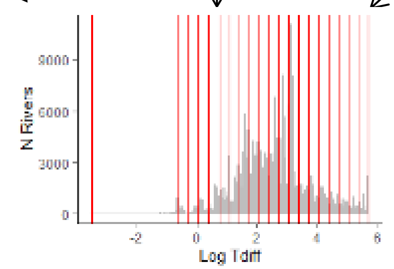


Climate sensitivity



Tdiff (planting prioritisation)

Both Banks | **ES Banks** | **WN Banks**



Riparian Woodland Prioritisation Scores – National

(theoretical range 1-20)

1 is low priority - low Tw, weak climate sensitivity & only a small Tw ↓ gained from planting trees

Both Banks | **ES Banks** | **WN Banks**

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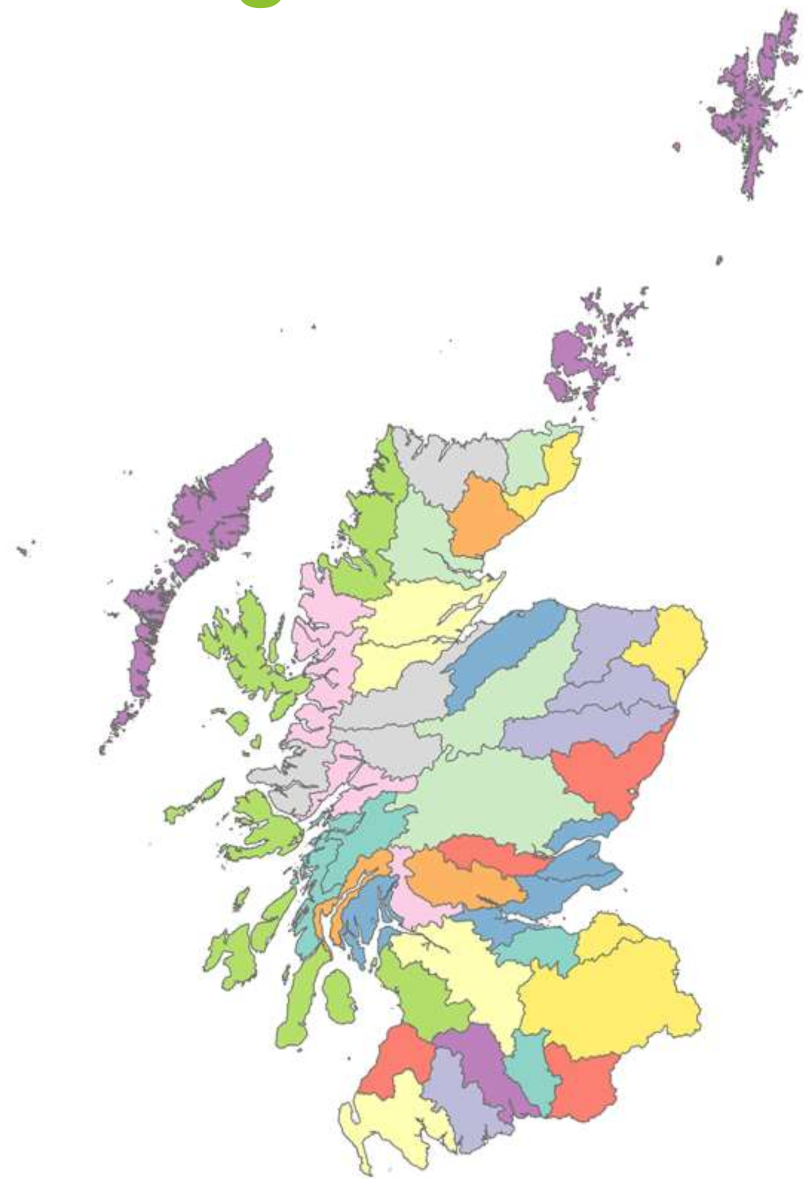
Currently recommended tool for prioritising riparian tree planting at national scale

Combined ranking layers – regional scale

- Re-scale of national ranks
- Get range of ranks for each hydrometric area in Scotland
- Rescale observed values to each region and generate 1 to 20 Riparian Woodland Prioritisation Scores for each HA
- Gives potential score of 1-20 in each region



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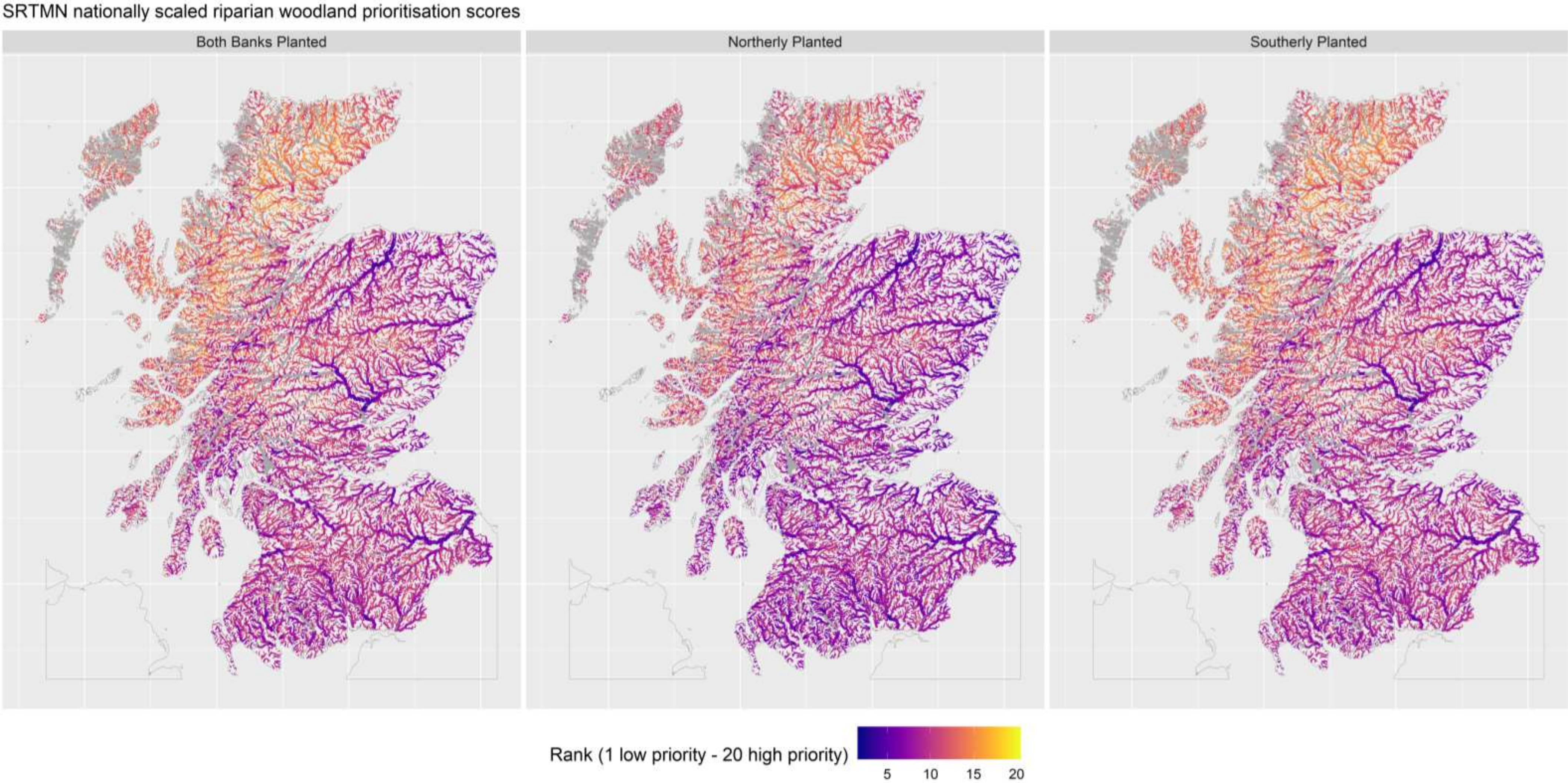
Currently recommended tool for prioritising riparian tree planting at local / within hydrometric area scale

Combined ranking layers – nationally scale



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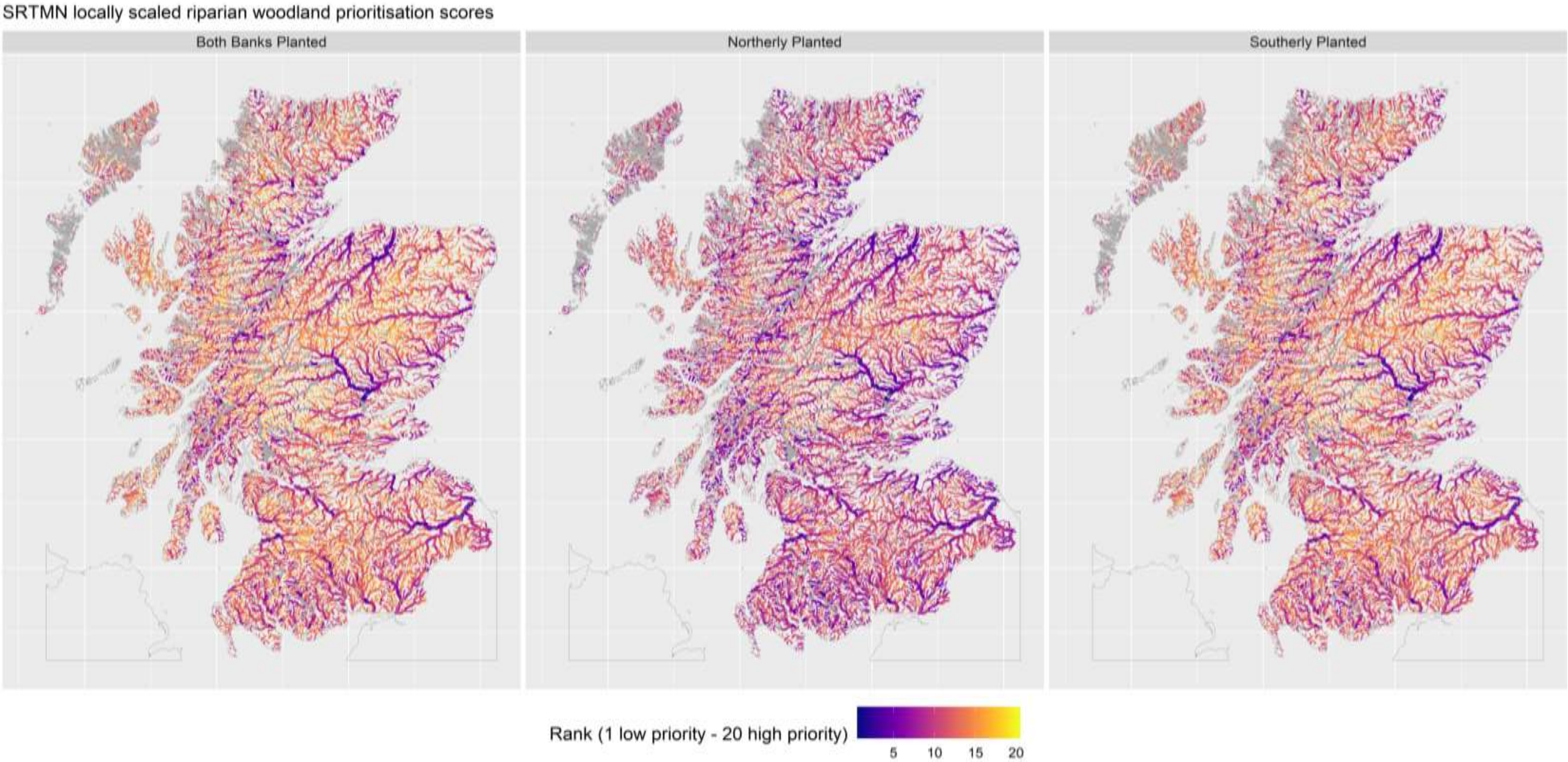
Allows comparison between areas across Scotland

Combined ranking layers – locally scaled (hydrometric area)



Cannot compare between hydrometric areas when using locally scaled data

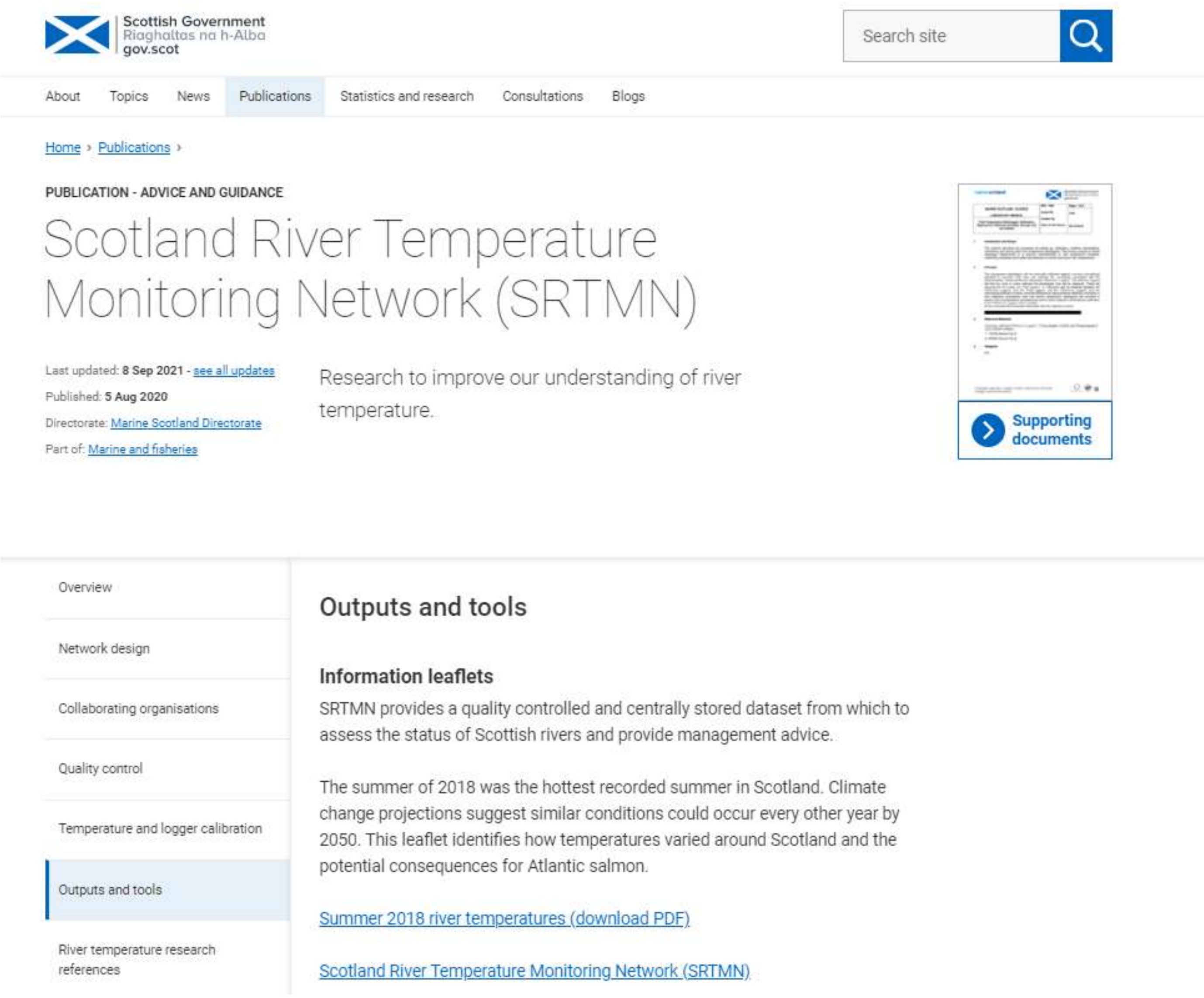
How can I access these tools?

Finding further information on tools

SRTMN Outputs and Tools webpage

https://www.gov.scot/publications/scotland-river-temperature-monitoring-network-srtmn/pages/outputs-and-tools/

Including instructions on how to use NMPI and how to use WMS layers



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https://fms.scot/events/sfcc-biologists-meeting/sfcc-biologists-meeting-presentations-2022-2/

Conclusions

- River temperature important control on salmonids likely to become an increasing problem under climate change

- Riparian woodland can reduce river temperatures

- Riparian Woodland Prioritisation Scores can be used to target constrained resources

- Scaling is possible at national or regional scales depending on objectives

- Possible to combine with other spatial datasets or tools (e.g. JHI Woodland Prioritisation tool)

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Where can I get more information?

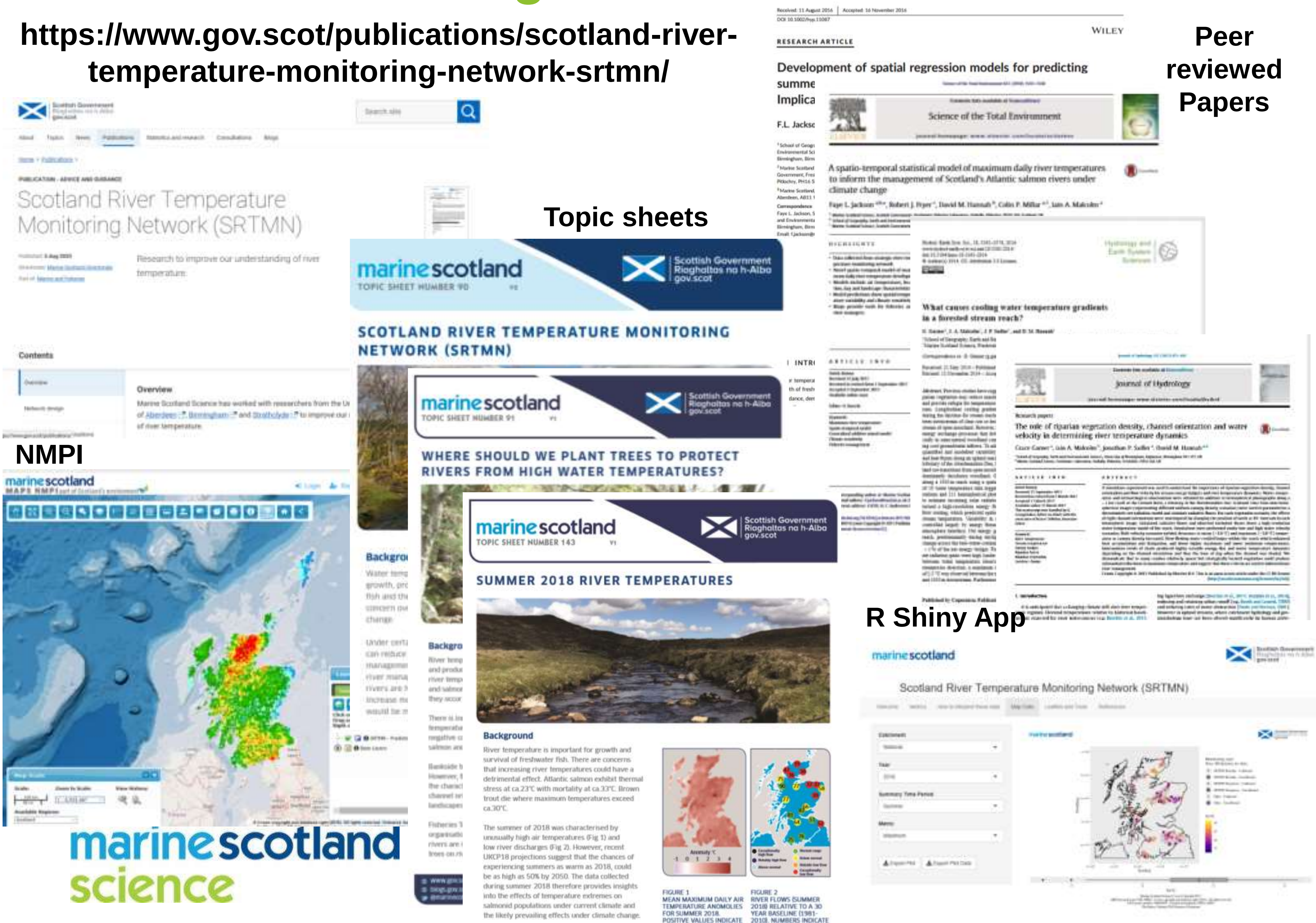
https://www.gov.scot/publications/scotland-river-temperature-monitoring-network-srtmn/

Peer reviewed Papers

Topic sheets

NMPI

R Shiny App



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