Scotland River Temperature Monitoring Network:

The Scottish Government
Riaghaltas na h-Alba

A national resource for understanding, assessing and managing the effects of climate change on Scotland's Atlantic Salmon rivers

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http://www.gov.scot/Topics/marine/Salmon-Trout-Coarse/Freshwater/Monitoring/temperature

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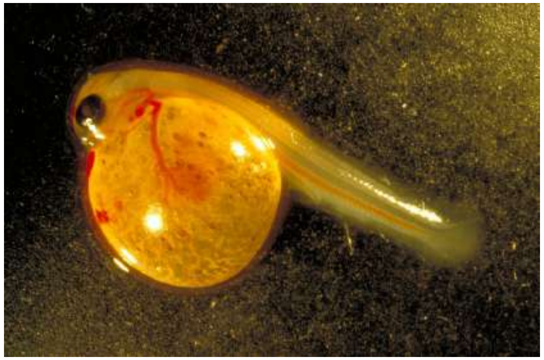
Background and management context

River temperature is important to the health of cold water adapted fish like trout and salmon

Under climate change we expect rising river temperatures, potentially affecting fish populations



Bankside woodland a potential mitigation option

Requires information on:

- Where are temperatures going to be hottest?

- Which rivers and regions will change the most under climate change?

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SRTMN Objectives

AIM: Understand and predict river temperatures (Tw) across Scotland and assess climate change effects on Tw

- Ob1: Design a large scale long-term quality controlled temperature monitoring network
- Ob2: Develop large-scale statistical models
- Ob3: Develop management tools to inform mitigation
- Ob4: Assess long-term monitoring to assess trends in Tw

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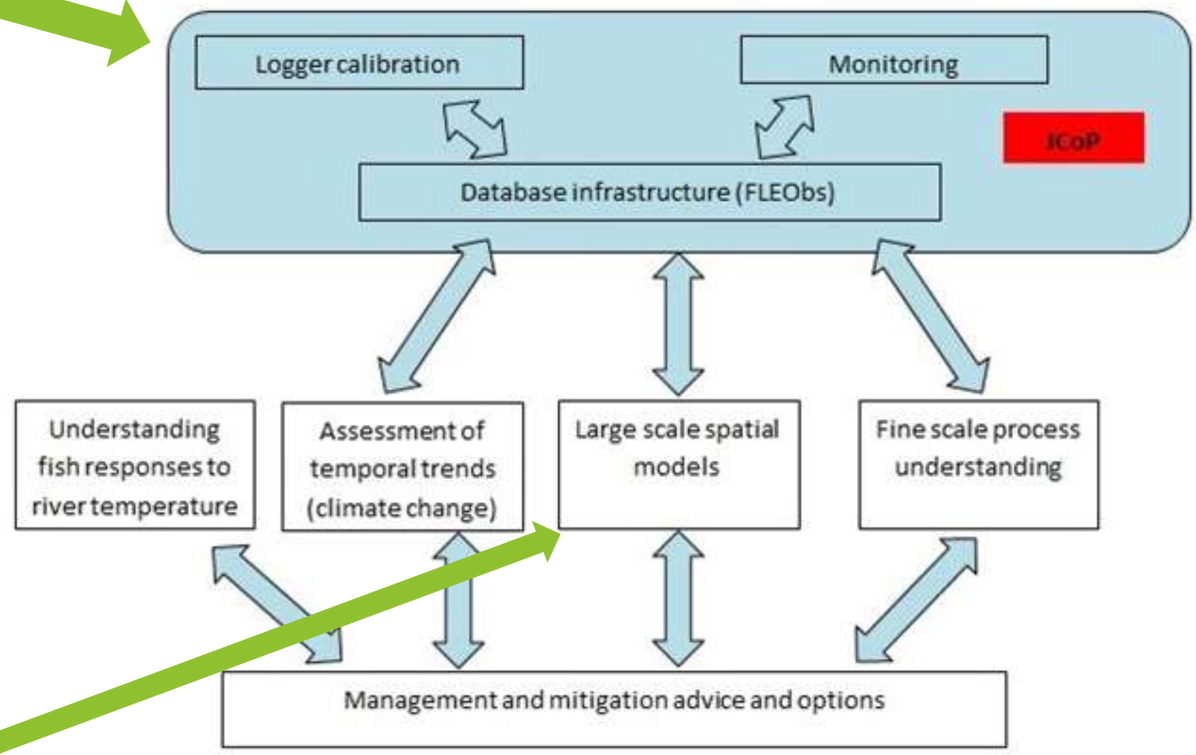
What do you need to generate this information?

1. **High quality river temperature data at big spatial scale**
   Scotland River Temperature Monitoring Network

2. **Information on the rivers where river temperature is collected**
   e.g. how big the river is, what altitude is it, does it have woodland on the banks

3. **Scotland scale statistical models to let us predict river temperature in unmonitored locations**



MSS River Temperature Research Programme

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https://www2.gov.scot/Topics/marine/Salmon-Trout-Coarse/Freshwater/Monitoring/temperature

Delivery via a national ~ local collaboration

Following Joint Code of Practice for Research

Monitoring network design

Development of standard operating procedures

Logger (re)calibration

Caithness DSFB

Brora DFSB

Ayrshire Rivers Trust

The River Dee

Spey Fishery Board

Argyll Fisheries Trust

The Tweed Foundation

Logger deployment and permissions requests

Granting Permission

Logger maintenance / checking post floods

Logger download (data collection) and return

Data quality control

Data storage

Data analysis & publication

Decision support tools

SRTMN Annual Reporting

Local decision making and management e.g. riparian tree planting

University of Birmingham

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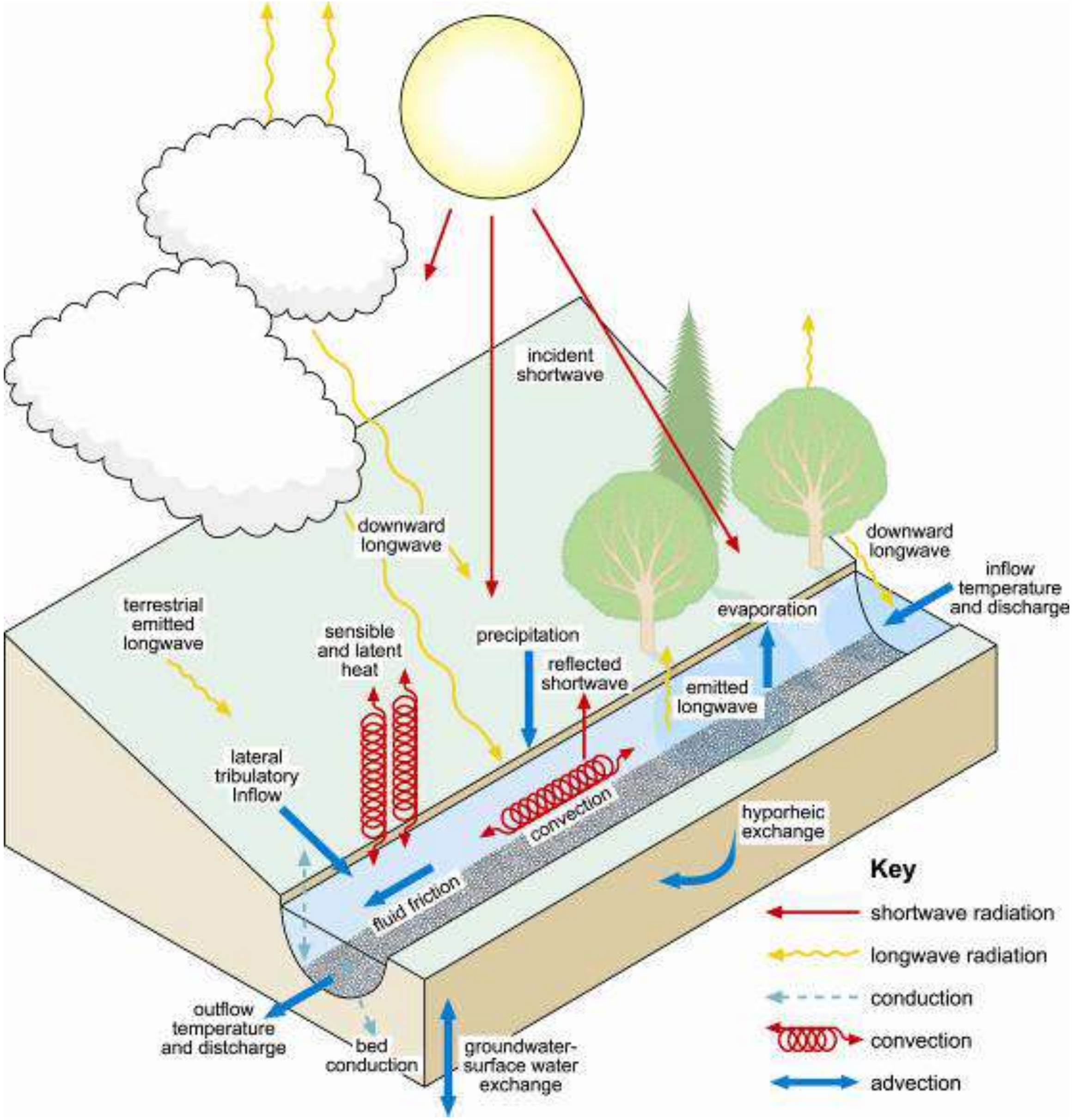
Local trusts and boards

Land owners & stakeholders

Network design: Controls on river temperature

Complex energy and heat exchange processes

Not possible to monitor and model at national scales



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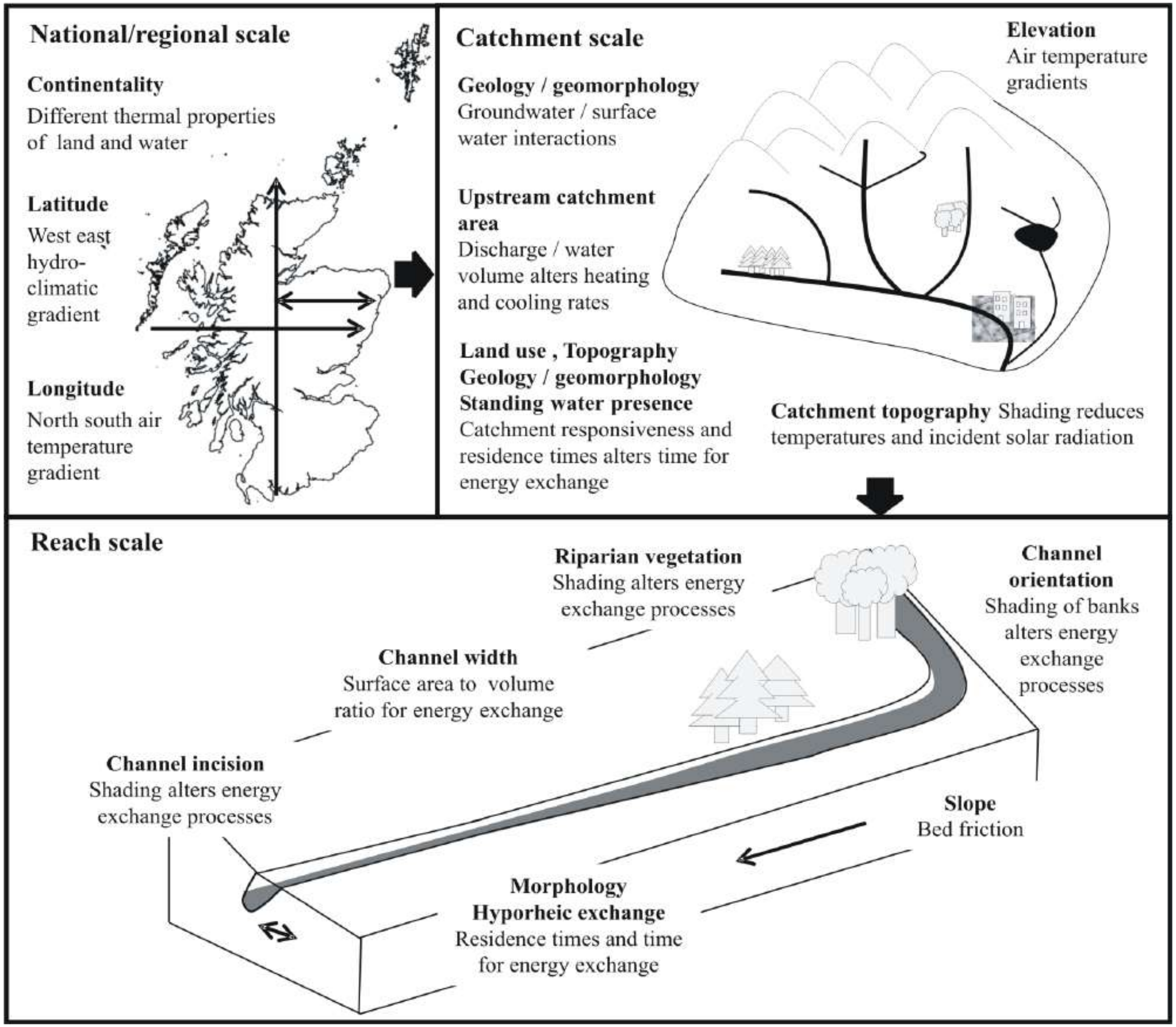
Data collection: How can we use the landscape to explain controls ?

Strategically designed the Scotland River Temperature Monitoring Network to cover the environmental range of characteristics that influence river temperature

Proxies for processes



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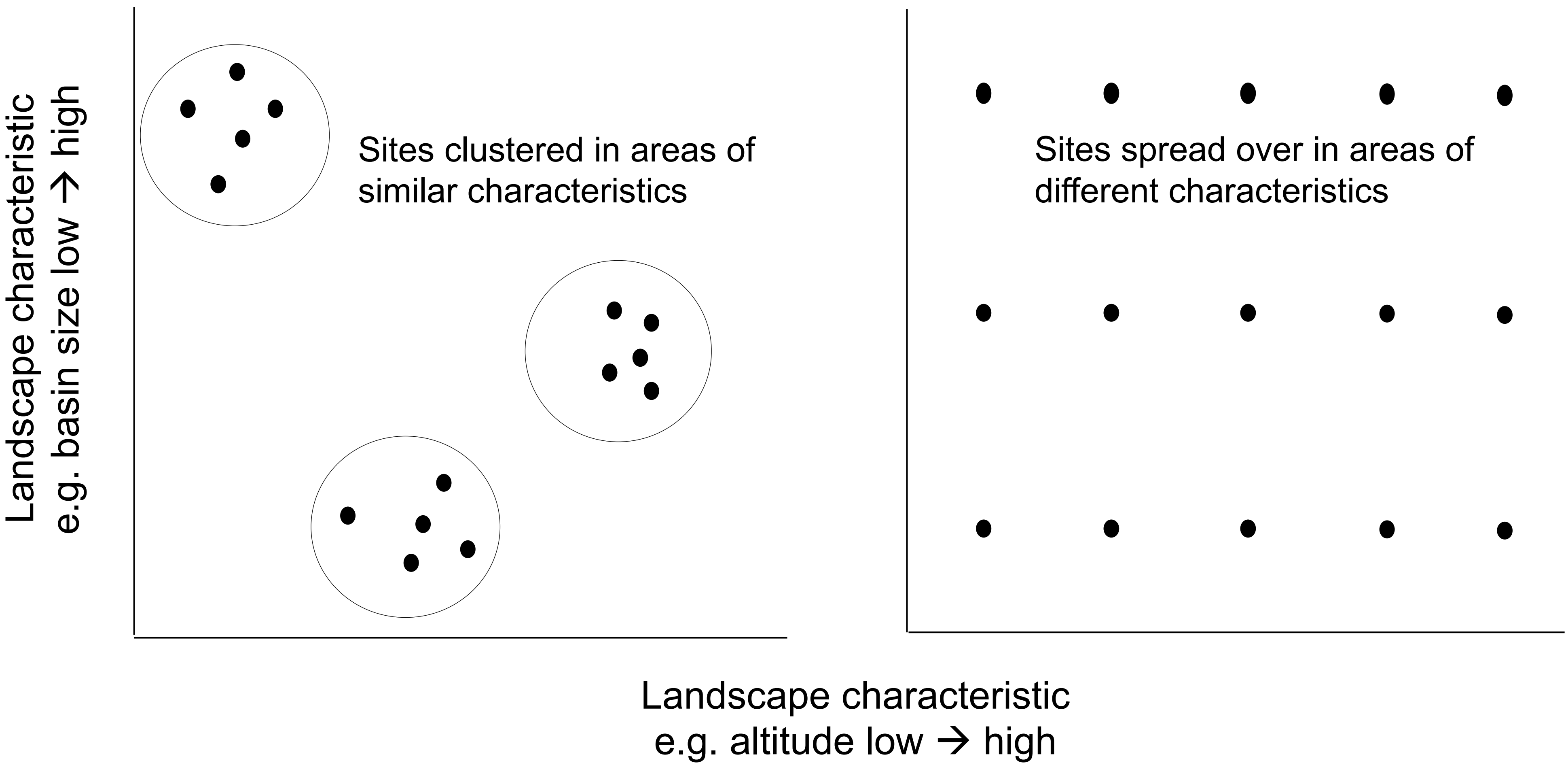
Network design: selecting sites to cover different river characteristics



Feedback from local collaborators on:

Site suitability in terms of practicality

Requests for permission to deploy

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What do we use to monitor?

A calibrated Tingtag datalogger

Measures the water temperature every 15 minutes

Downloaded twice a year

It can log for **339 days and 17 hours** before it becomes full!

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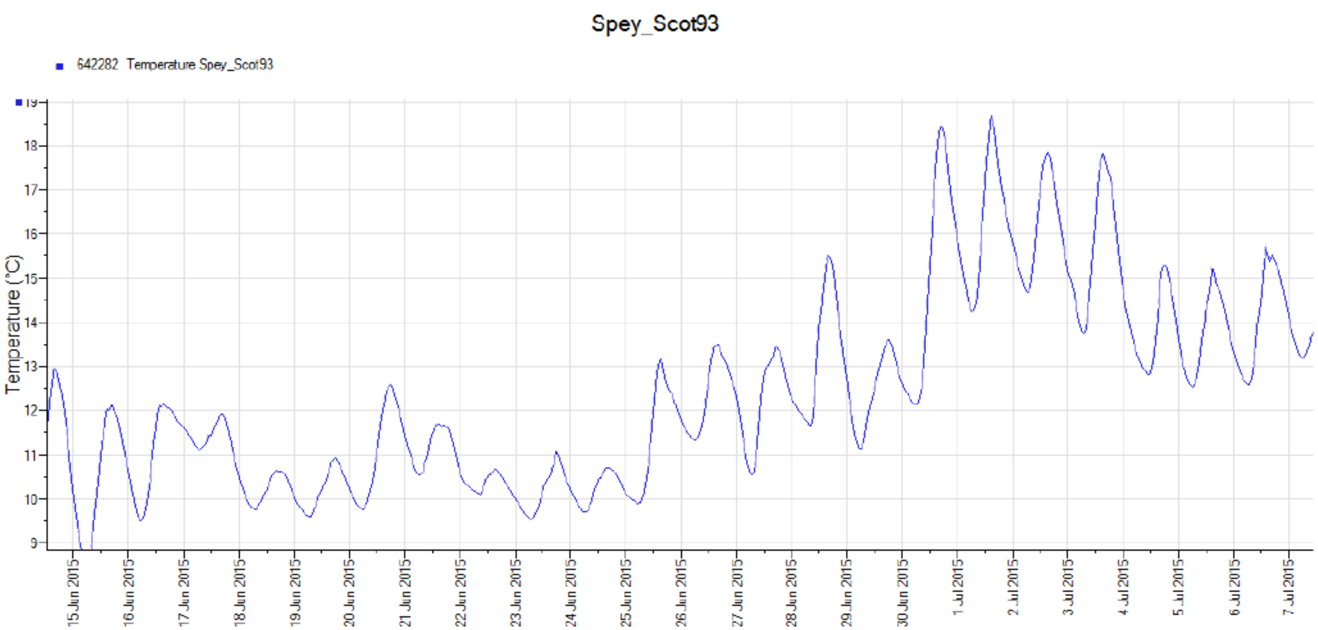
How can you ensure good data?

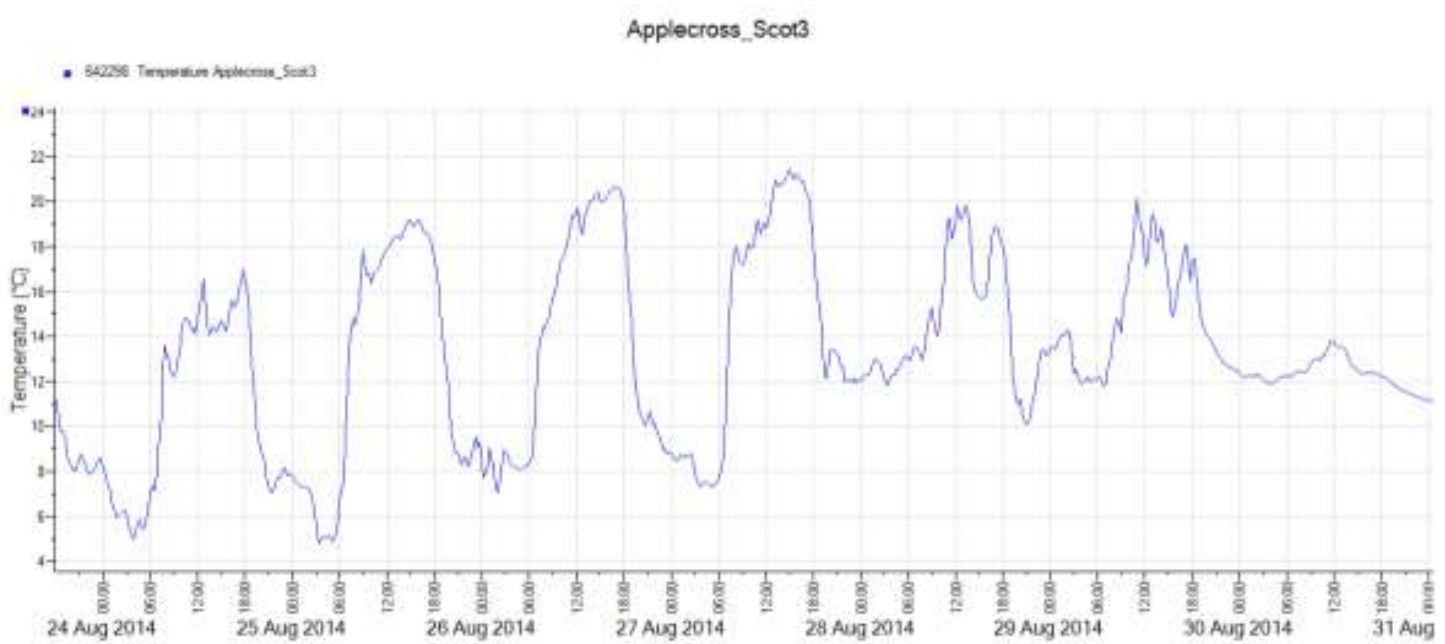


Data sheets

Visual checks

Correct data using our calibrations

https://www2.gov.scot/Topics/marine/Salmon-Trout-Coarse/Freshwater/Monitoring/temperature/QualityControl



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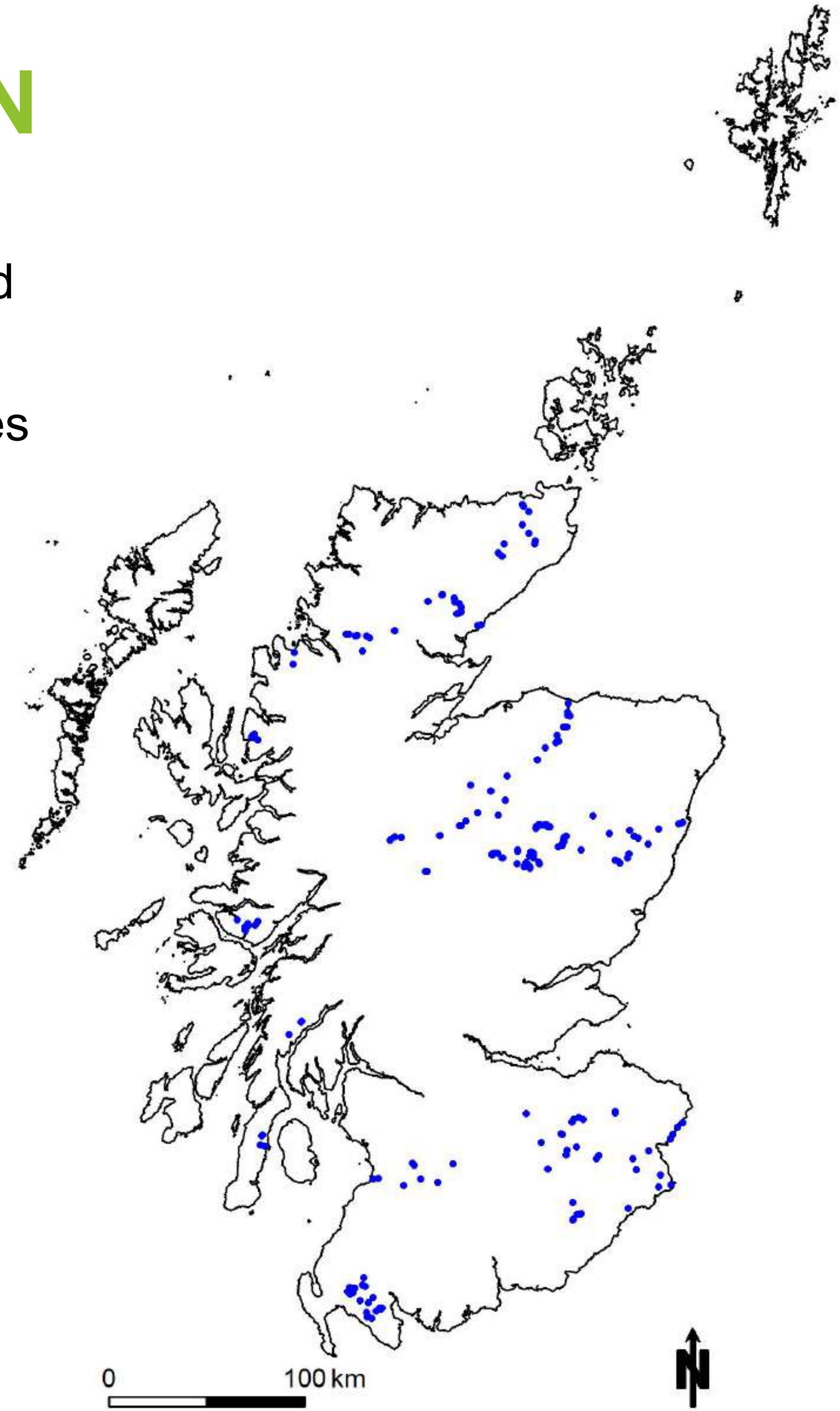
SRTMN

- First strategically designed national river temperature monitoring network in the world
- Deployed alongside local rivers and fisheries trusts and boards beginning in 2014
- Supported by local landowners granting permission for logger deployment
- Highly successful collaboration between government and local stakeholders
- 223 sites across 13 catchments
- >23,000,000 Tw observations in FleObs



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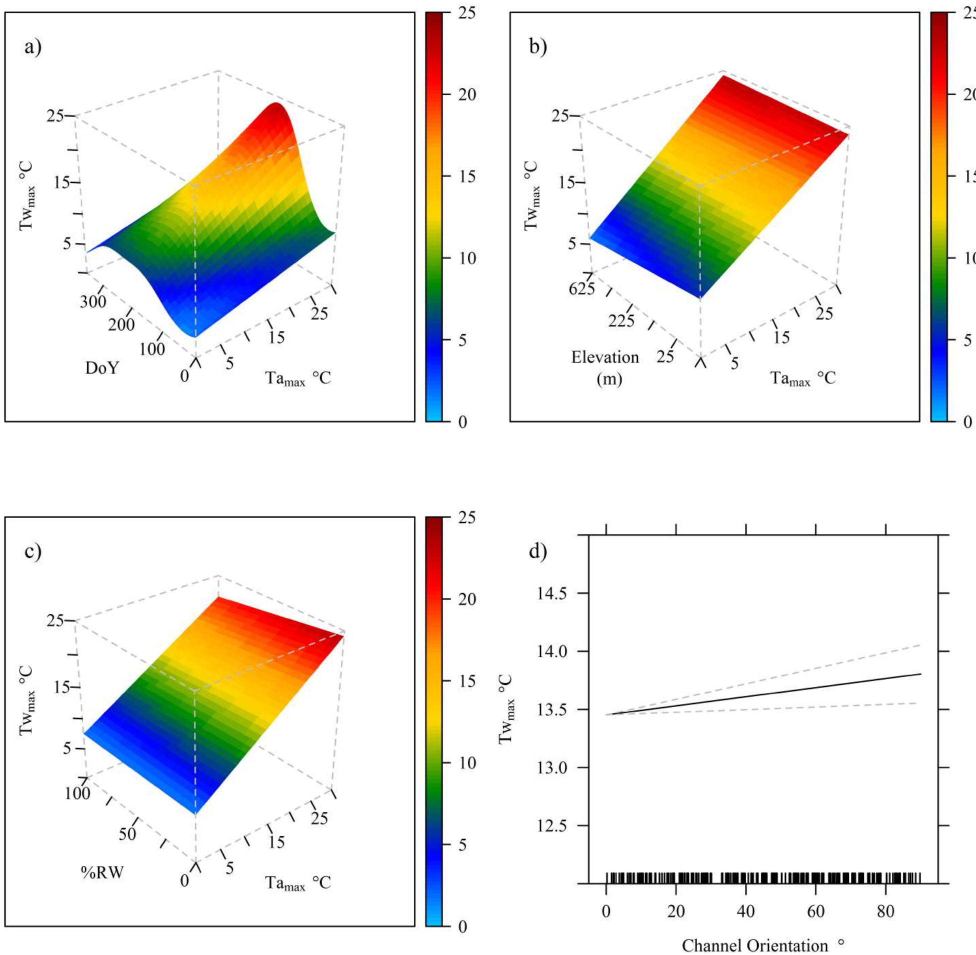
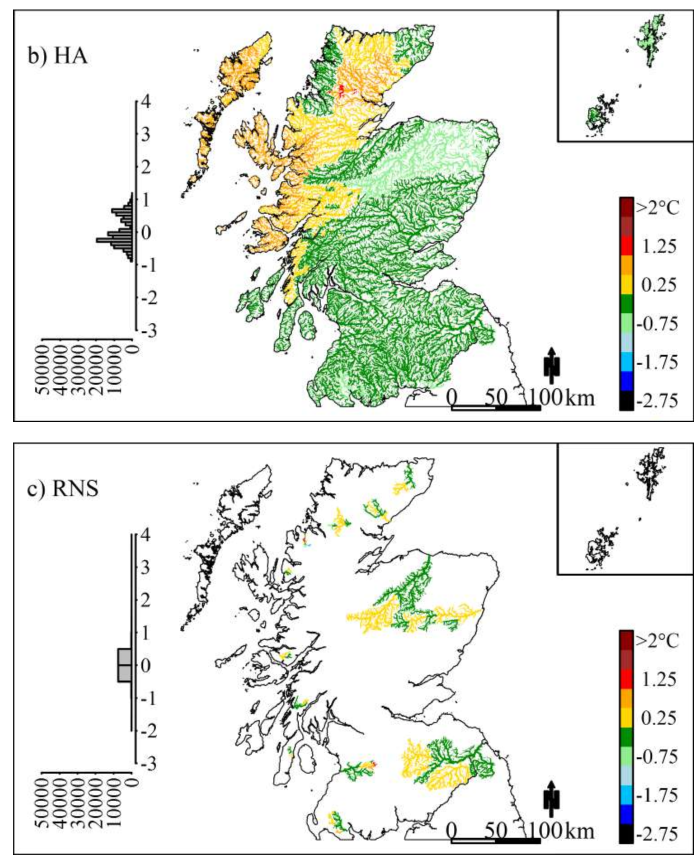
How do we predict river temperature in unmonitored locations?

Large-scale spatio-temporal statistical models

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





- Uses the relationship between river temperature and the air temperature, day of the year, location and characteristics of the landscape / river to explain temperature variability
  - A river with trees on the banks may be cooler than one without
  - A small river will heat up faster and also cool down faster than a big river

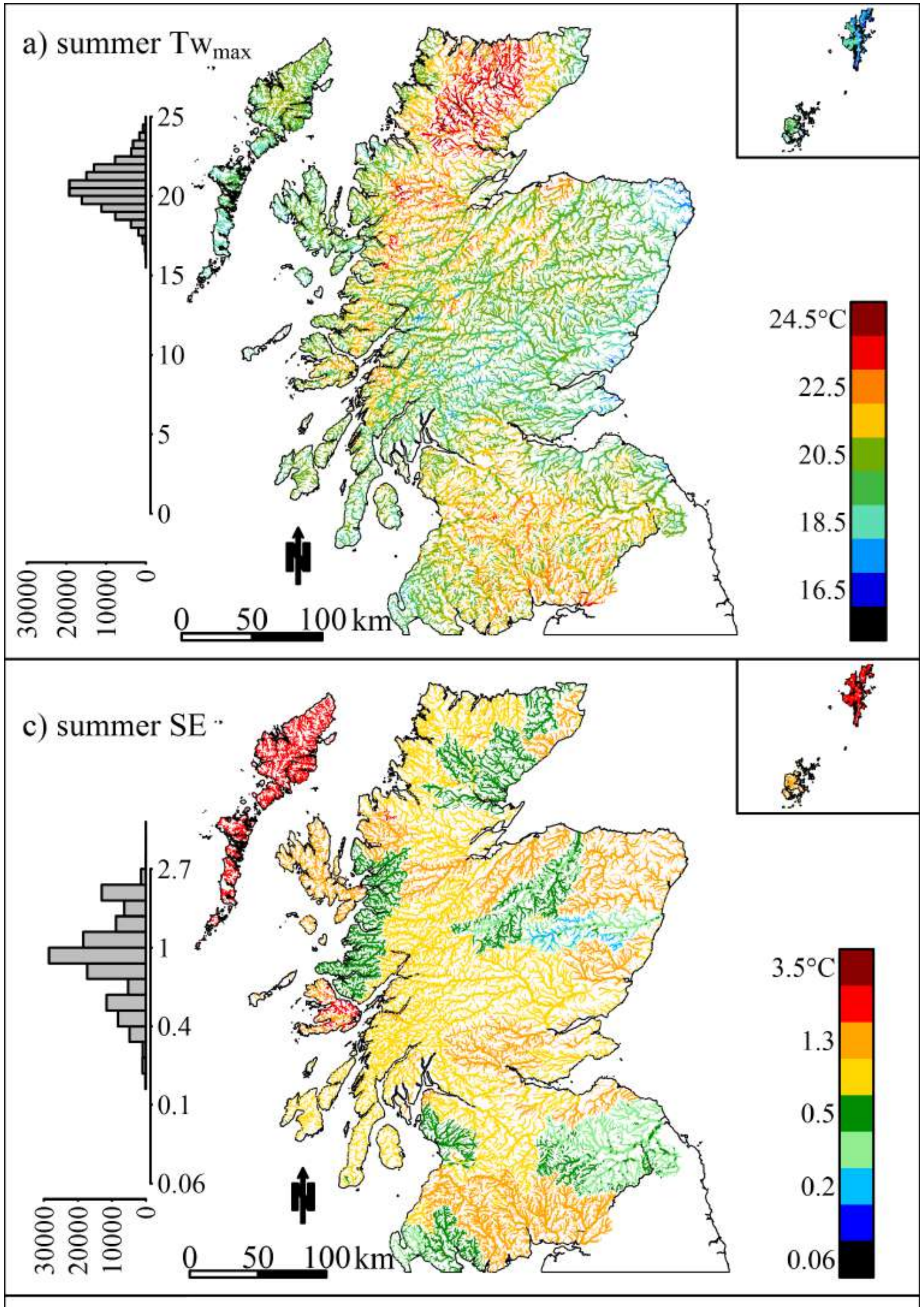
- Predict to new locations using the air temperature, day of the year, location and landscape characteristics

Predictions and associated uncertainty for single day 2015/16

Results:

Warmest temperatures in low altitude (high Ta), unshaded rivers

Prediction error is lowest in catchments with data and highest in the islands

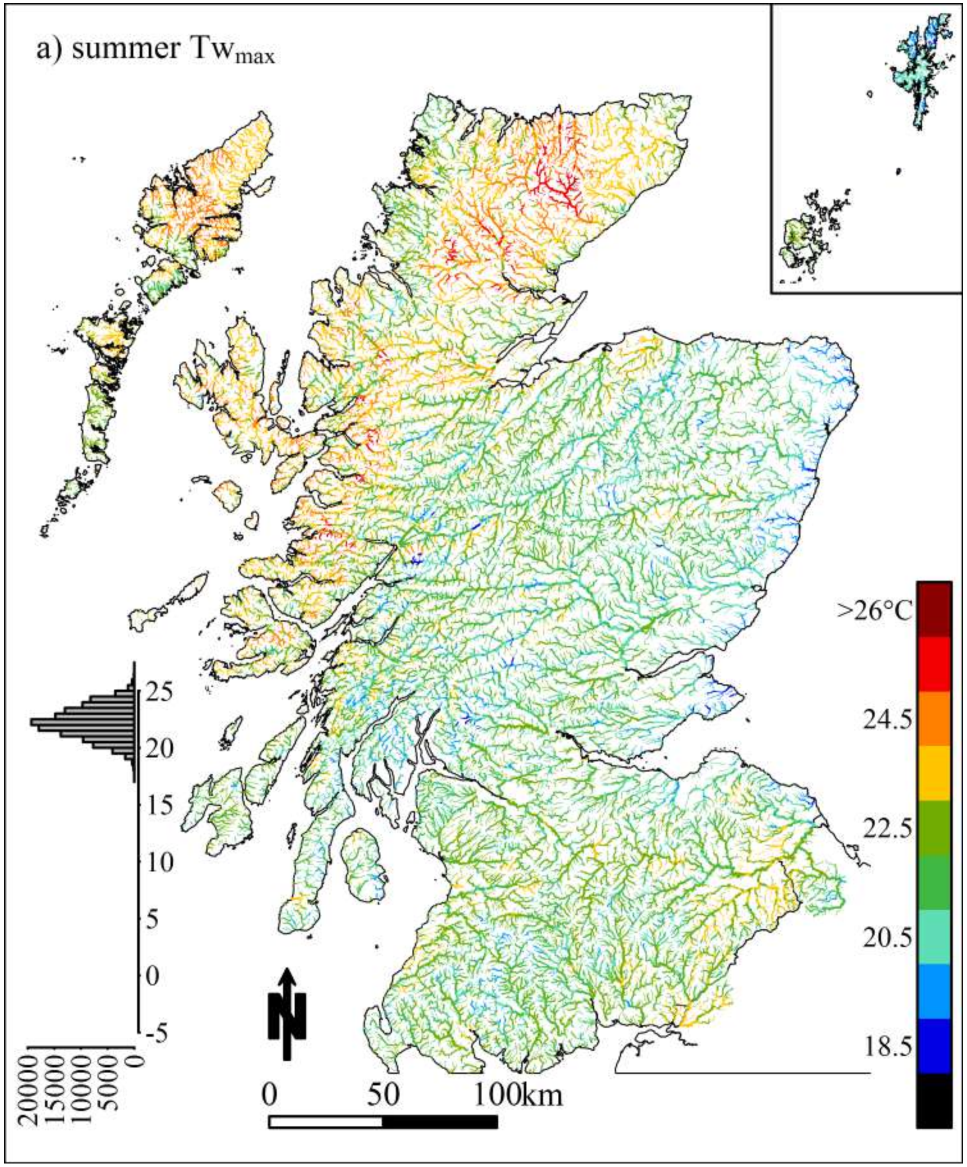


Predictions of where is hottest

Results:

Spatial patterns reflect air temperature, landscape covariates and location

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



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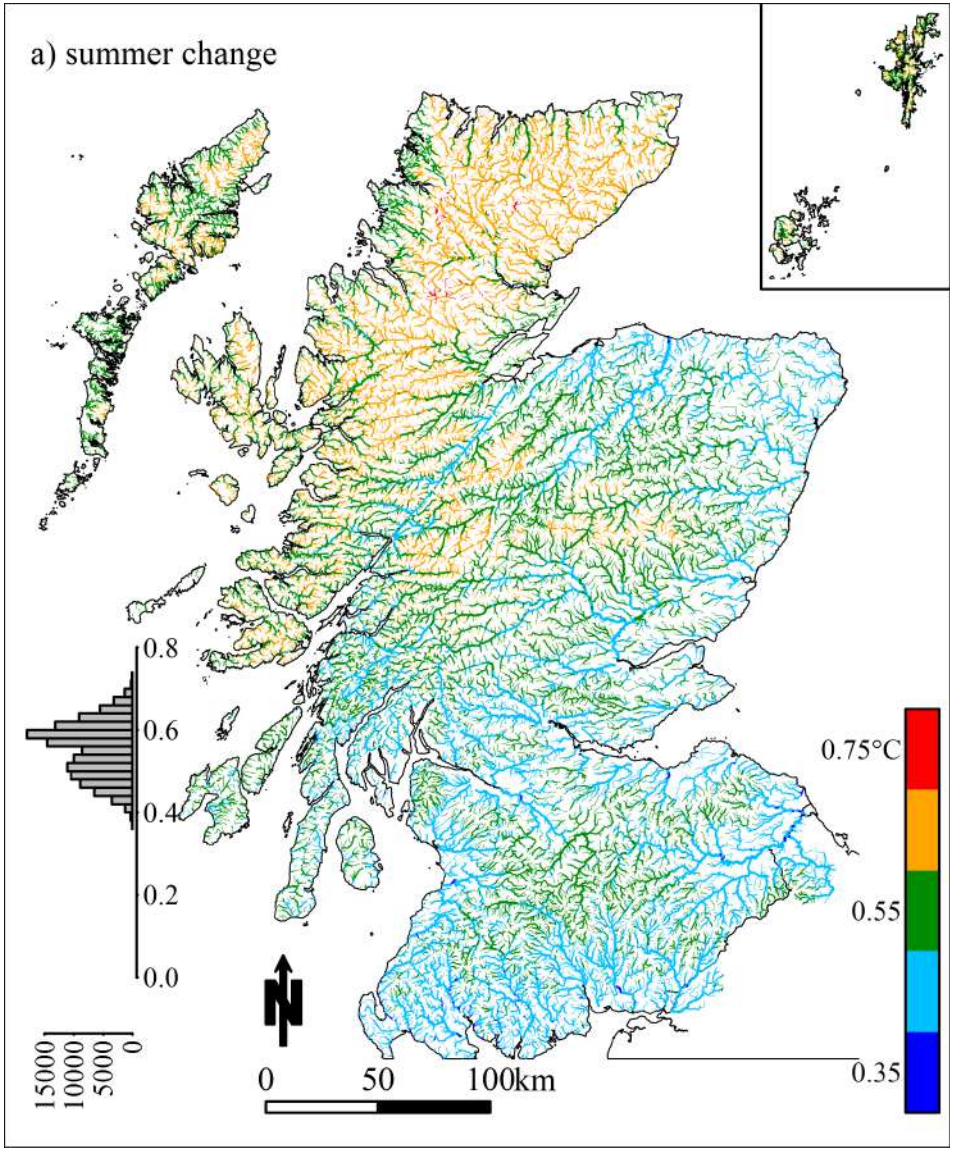
Predictions of climate sensitivity

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



How do I decide where to plant trees?

Spatial Scale

Catchments to kilometres

Kilometres to metres

Decide planting objective

Protect the rivers that are hottest

Identify hottest locations

NMPi layer; SRTMN – Predictions of maximum daily river temperatures for the hottest year in the last 20 years (2003).

Protect the rivers that will change the most

Identify locations with will change most

NMPi layer; SRTMN – Predictions of the change in river temperature that would result from a 1° C increase in air temperature

Assess characteristics of the identified locations

Identify locations with the most ‘shade-able’ characteristics

MSS Topic Sheet; Where should we plant trees to protect rivers from high water temperatures?

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NMPi

https://marinescotland.atkinsgeospatial.com/nmpi/default.aspx?layers=1576

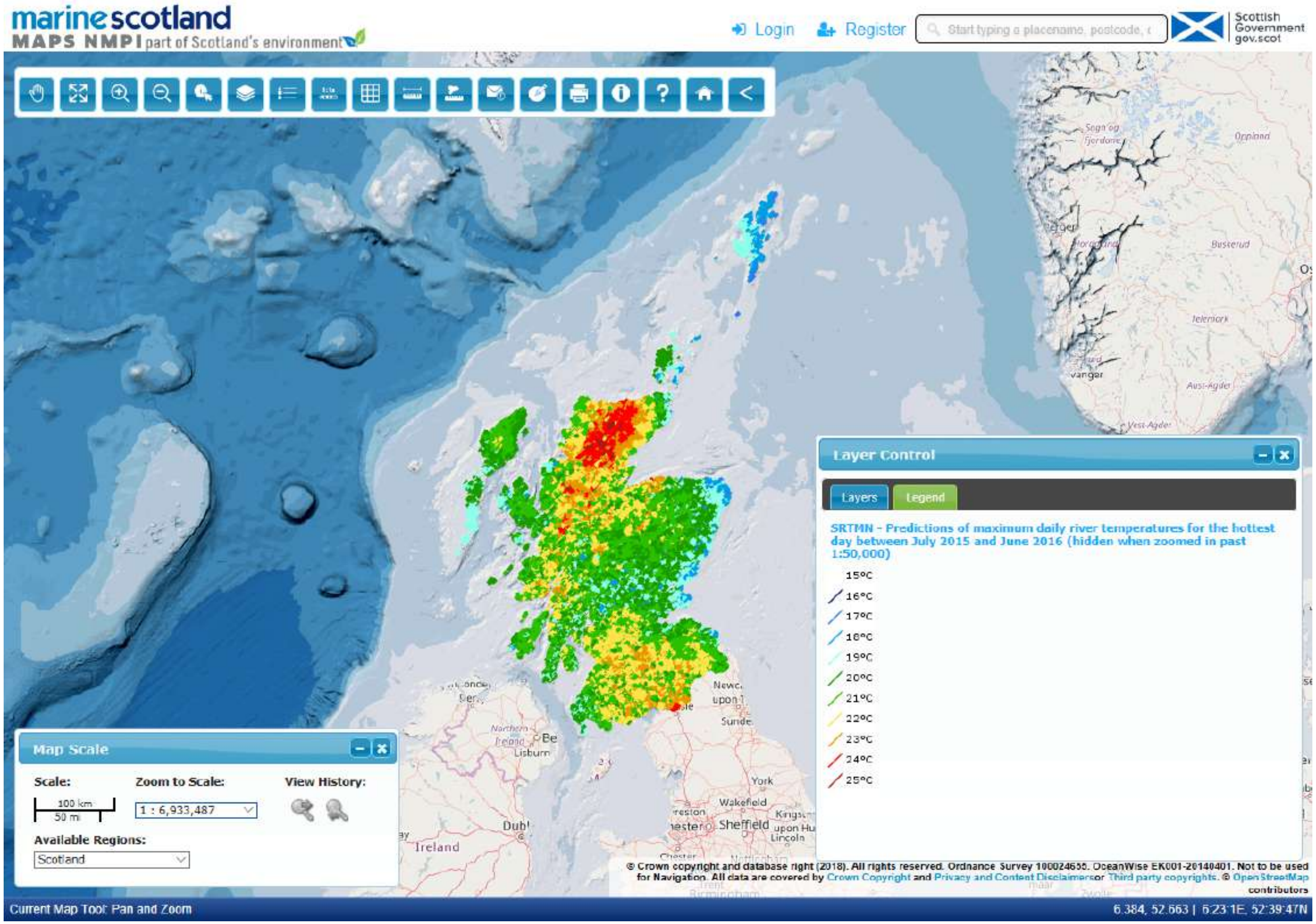
http://marine.gov.scot/information/scotland-river-temperature-monitoring-network-srtmn-predictions-river-temperature-and

Zoom

Print maps

Save images to add to reports or funding applications

Add/overlay other NMPI layers



Planting advice from our deterministic modelling

- Decisions on planting at larger spatial scales should be informed by maps of predicted water temperature and climate sensitivity from statistical models

- Where a southerly bank is available for planting then less tree cover is needed to reduce river temperatures

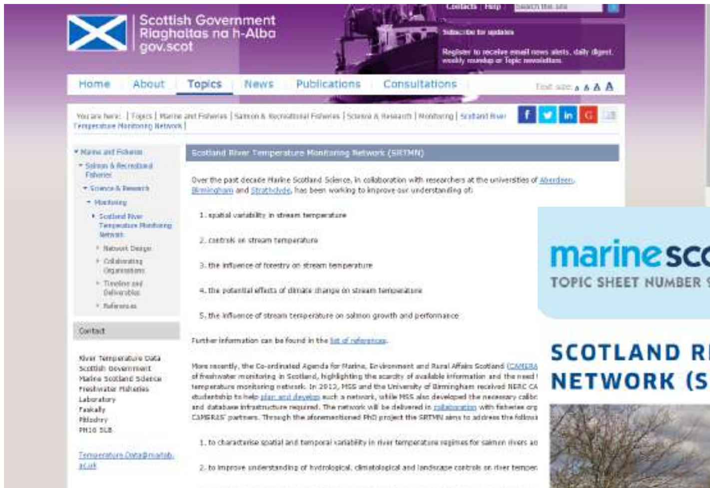
- Where a southerly bank is not available (e.g. channels with a South–North orientation) then higher density, overhanging trees are required

- Planting has a greater effect in slower flowing rivers

- The benefits of planting are greater in medium sized rivers (ca. 10m width Holzapfel *et al.,* 2013) that are shallow and wide

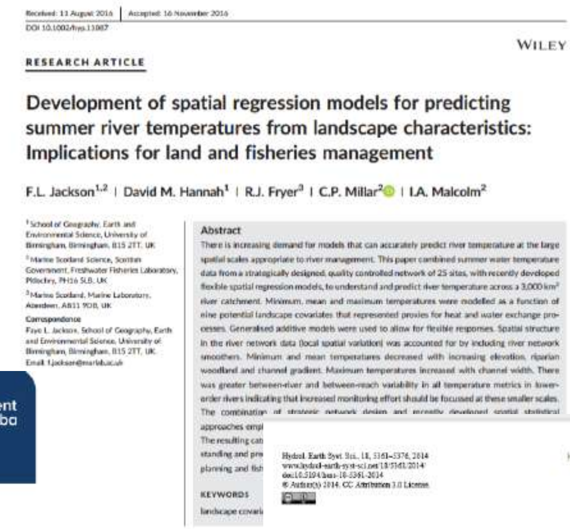
Where can I get more information?

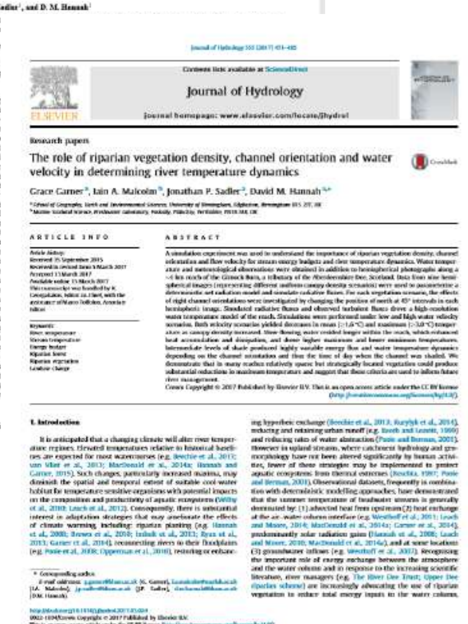
http://www.gov.scot/Topics/marine/Salmon-Trout-Coarse/Freshwater/Monitoring/temperature



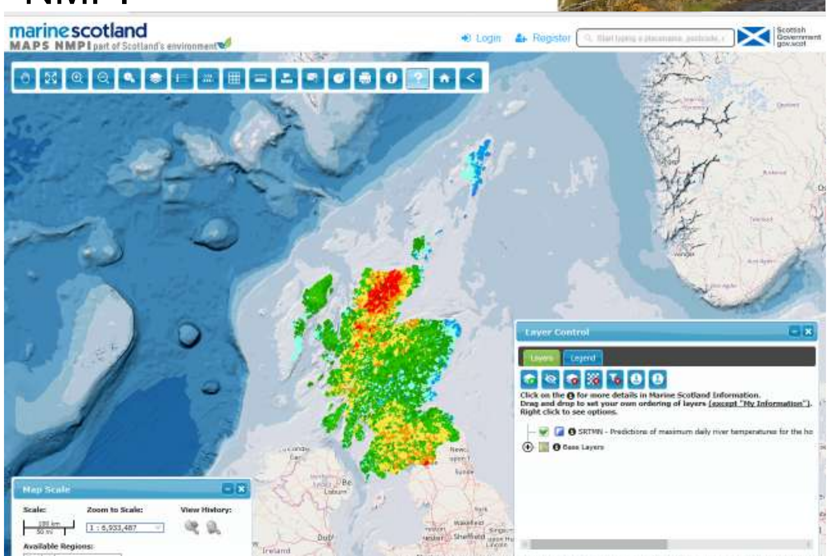
Topic sheets

Peer reviewed Papers





NMPI



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temperature.data@marlab.ac.uk

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SRTMN Project Partners

- Marine Scotland Science (MSS) Freshwater Fisheries Laboratory
- River Dee Trust
- Tweed Foundation
- Caithness District Salmon Fishery Board
- River Brora District Salmon Fishery Board
- Kyle of Sutherland Fisheries Trust
- Argyll Fisheries Trust
- Ayrshire Rivers Trust
- Galloway Fisheries Trust
- Spey Foundation
- University of Birmingham
- Landowners

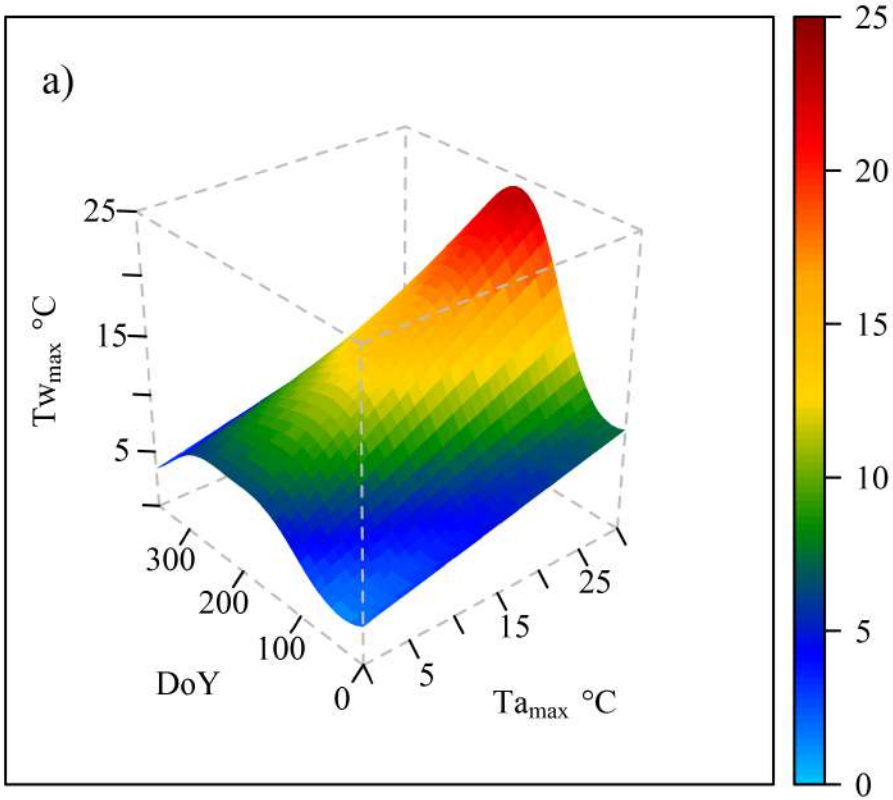
Ayrshire Rivers Trust

River Brora District Salmon Fishery Board

Caithness District Salmon Fishery Board

National Tw Model : Fixed effects interactions

DoY:Ta



- Steeper relationship in summer compared to winter
  - Lower flows more responsive

X axis – Covariate

Y axis – River temperature

Z axis – Air temperature

Affecting both slope and intercept

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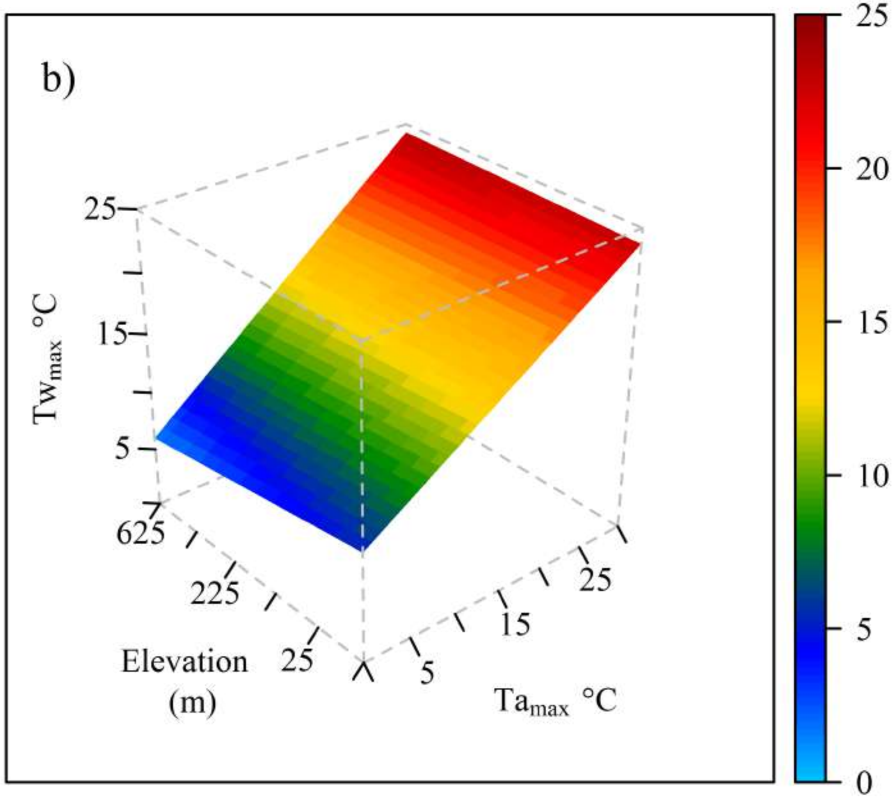
National Tw Model : Fixed effects interactions

Elevation:Ta



- Reduces river temperature further at low air temperatures
  - Snow cover / melt
- Negligible effect in summer

X axis – Covariate

Y axis – River temperature

Z axis – Air temperature

Affecting both slope and intercept

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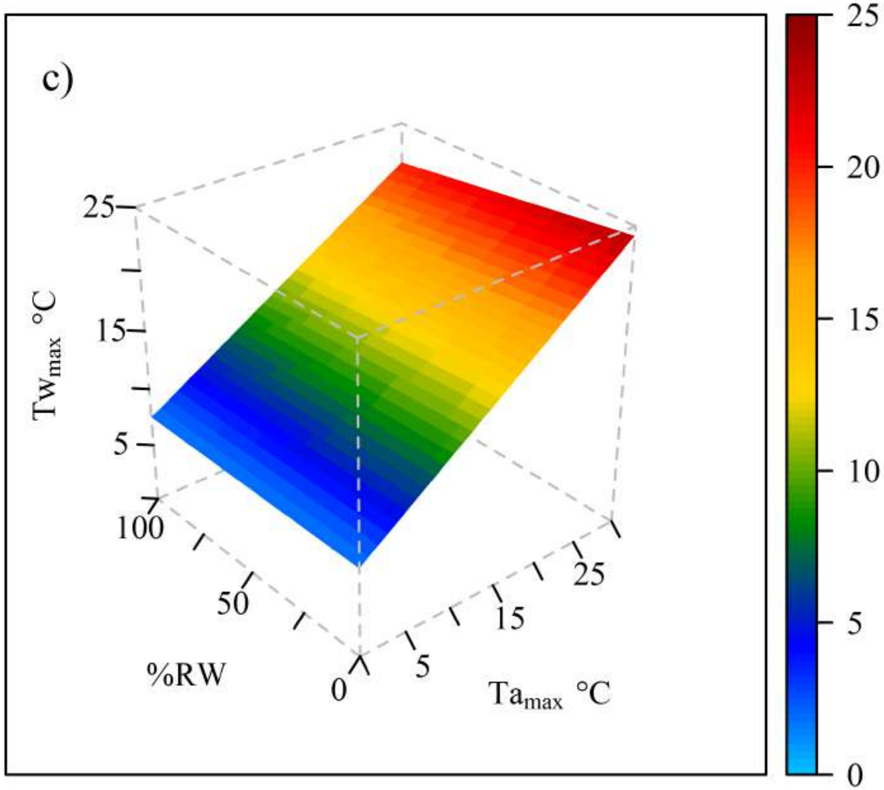
National Tw Model : Fixed effects interactions

Woodland:Ta



- At high air temperatures, greater %RW reduces river temperatures
  - Shading
- At low air temperatures, high %RW increases river temperatures
  - Reducing net radiative losses

X axis – Covariate

Y axis – River temperature

Z axis – Air temperature

Affecting both slope and intercept

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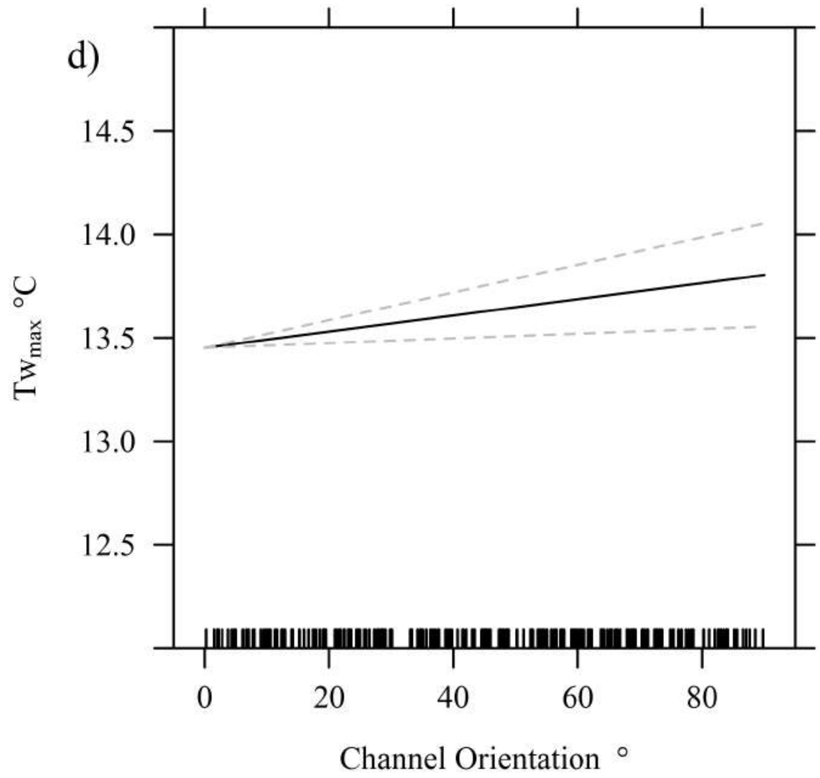
National Tw Model : Fixed effects

Orientation



- Increases river temperature in N/S reaches
  - Most exposed when solar radiation is greatest

X axis – Covariate

Y axis – River temperature

Affecting only intercept

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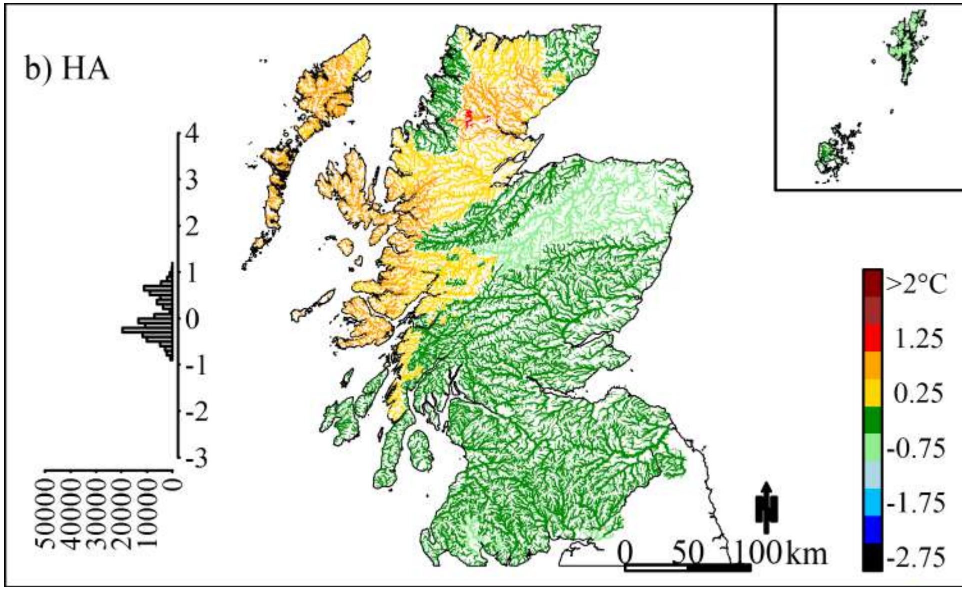
National Daily Maximum Tw Model : Fixed effects

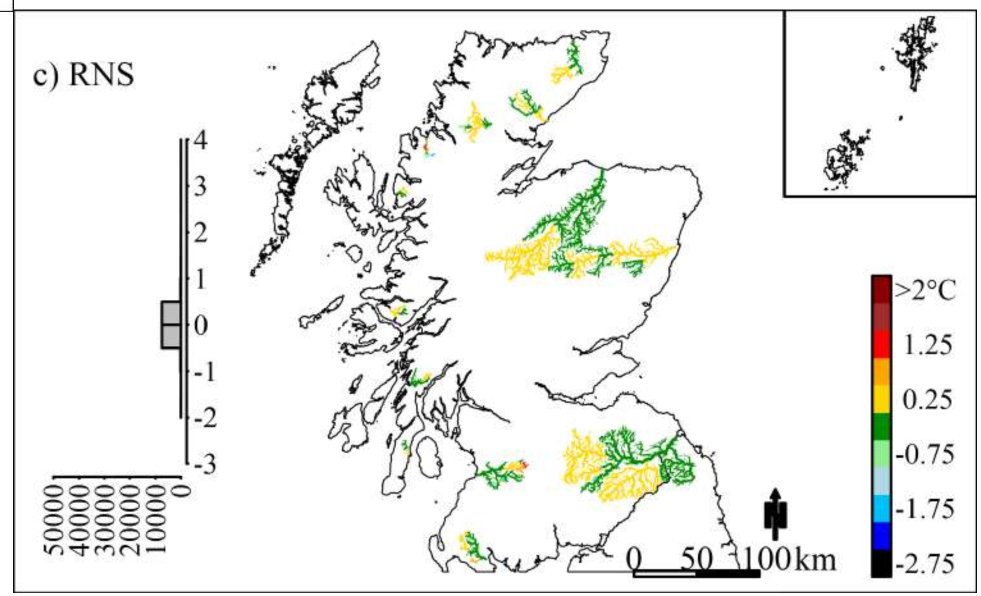


+ HAS + HAS:Ta_{max}

Large-scale (regional) spatially correlated variability, not explained by covariates

+ RNS:Catchment

Within river spatially correlated variability, not explained by covariates,



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Metrics

Methods for the metrics

Metrics are generated for each site from daily maximum, mean or minimum river temperatures depending on the metrics selected. Metrics are only generated where data is available for ≥ 95% of the time period.

Metric	Abbreviated Metric	Method
Temperature metrics		
Maximum	Maximum	Maximum observed river temperature over the time period selected
Mean	Mean	Mean observed river temperature over the time period selected
Minimum	Minimum	Minimum observed river temperature over the time period selected
Mean Maximum	Mean Maximum	Mean of the observed daily maximum river temperatures over the time period selected
Mean Minimum	Mean Minimum	Mean of the observed daily minimum river temperatures over the time period selected
Salmon growth metrics		
Days above optimal Tw for salmon growth	Optimal salmon growth	Number of days where mean daily river temperature is above 16 degrees (upper threshold for optimal growth of salmon given unlimited food resources) (Elliot and Hurley 1997) over the time period selected
Days above max for Tw salmon growth	Max salmon growth	Number of days where observed mean daily temperatures exceed 22·5 degrees (maximum temperature for growth of salmon given unlimited food resources) (Elliot and Hurley 1997) over the time period selected
Days below min for Tw salmon growth	Min salmon growth	Number of days where observed mean daily temperature is below 6 degrees (minimum temperature for growth of salmon given unlimited food resources) (Elliot and Hurley 1997) over the time period selected
Trout growth metrics		
Days above optimal Tw for trout growth	Optimal trout growth	Number of days where mean daily temperature is above 13.5 degrees (upper threshold for optimal growth of trout given unlimited food resources) (Forseth et al 2009) over the time period selected
Days above max Tw for trout growth	Max trout growth	Number of days where mean daily temperature is above 19.5 degrees (maximum temperature for growth of trout given unlimited food resources) (Forseth et al 2009) over the time period selected
Days below min Tw for trout growth	Min trout growth	Number of days where observed mean daily temperature is below 4 degrees (minimum temperature for growth of trout given unlimited food resources) (Forseth et al 2009) over the time period selected
Salmon stress metrics		
Days exceeding Tw threshold thermal stress for salmon	Salmon stress	Number of days where observed maximum daily temperature is above 23 degrees (where salmon begin to show behaviourial changes, such as seaking thermal refugia) (Breau et al 2007) over the time period selected
Days where there is an increased mortality risk of catch and release	Salmon catch and release risk	Days where minimum temperature exceeds 20 degrees (Breau 2012) over the time period selected
Salmon lethal limits		
Days above instantaneous lethal temperature for salmon	Salmon lethal	Number of days where observed daily maximum temperature is above ca.31 degrees (Elliot and Elliot 1995) over the time period selected
Trout lethal limits		
Days above instantaneous lethal temperature for trout	Trout lethal	Number of days where observed daily maximum temperature is above ca.30 degrees (Elliot and Elliot 1995) over the time period selected

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