Why are our grayling getting shorter?

Explaining growth patterns in European grayling near their southern range limit

Stephen D. Gregory[1], Tea Bašić[2], Jessica E. Marsh[1,3], Richard J. Cove[4]

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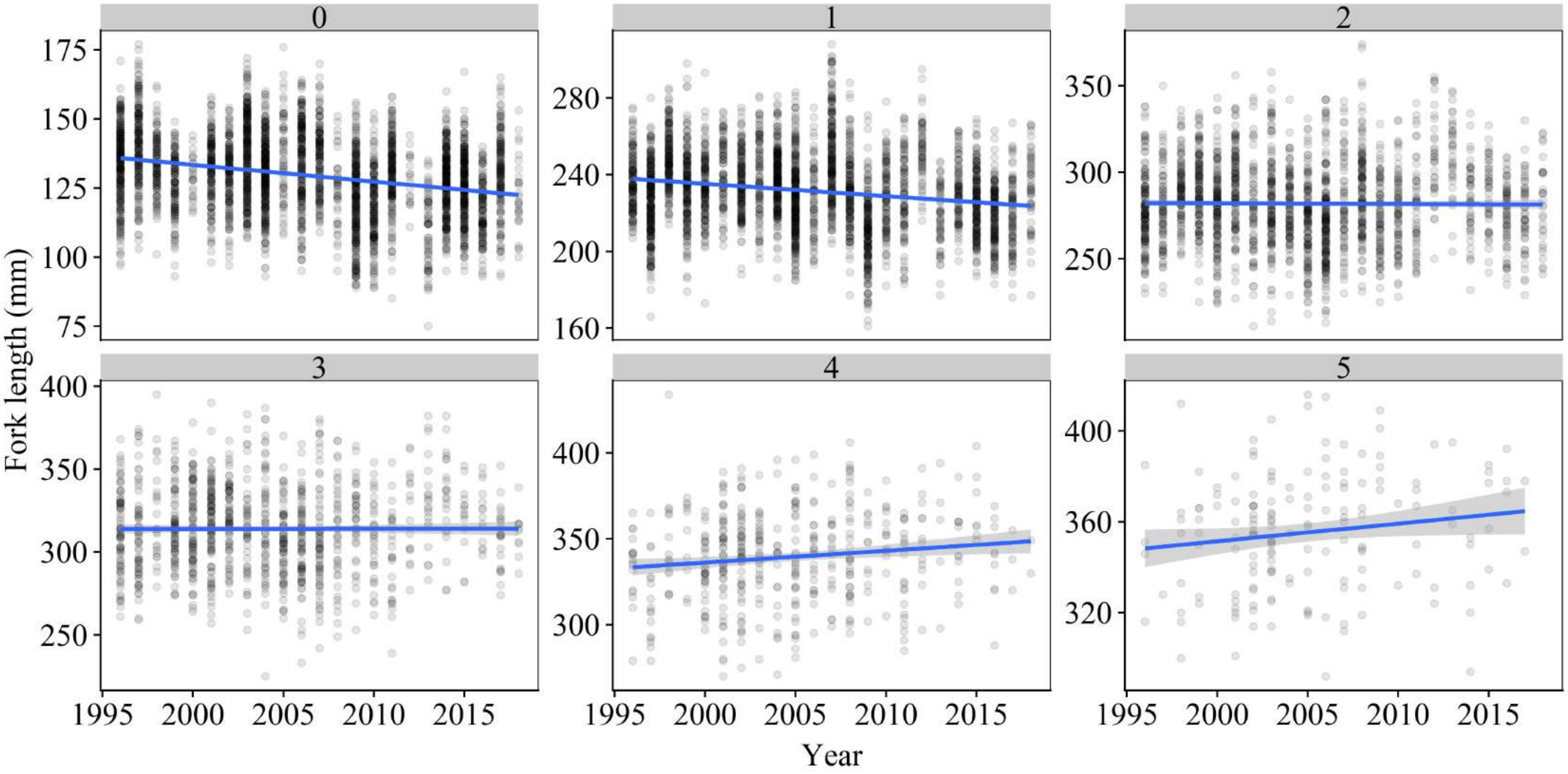
Wylye grayling are getting shorter



Wylye Grayling Survey (WGS)

- Annual electrofishing surveys since 1996
  - 23 years!

- ≈12K records from 9K individual grayling
  - fork length & weight
  - scales

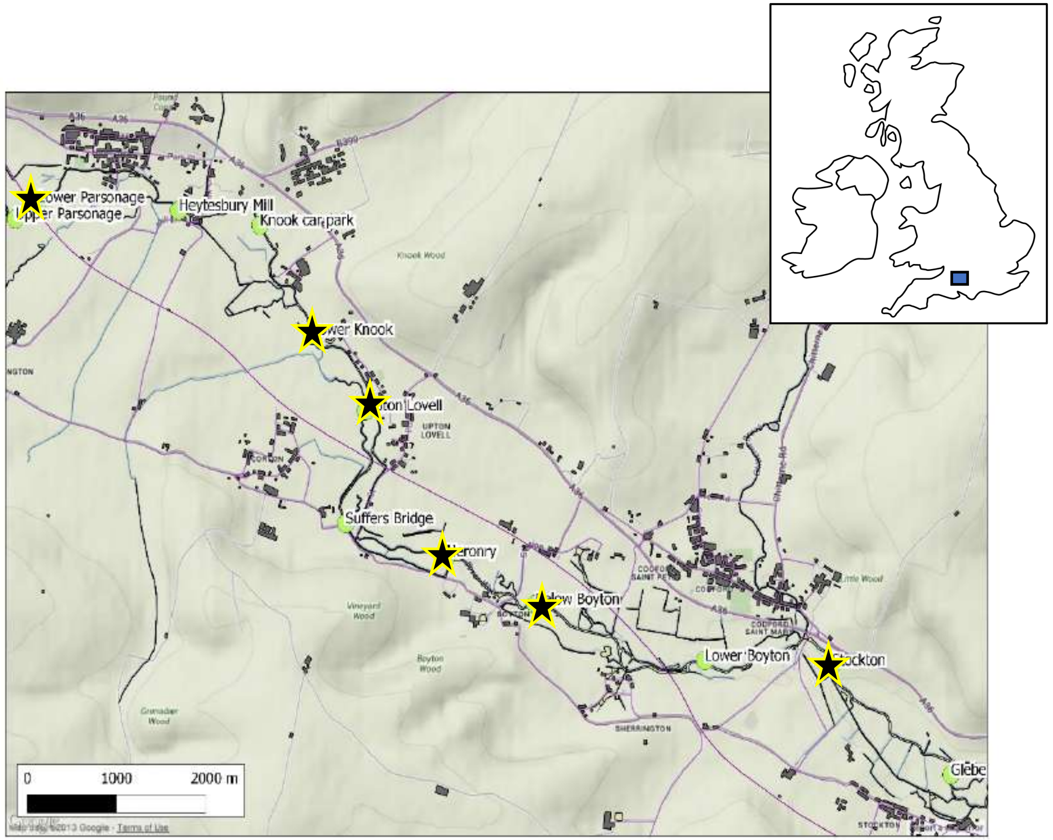
- River conditions
  - daily temperature
  - sub-daily flow

Wylye Grayling Survey (WGS)

- e/f surveys with “stop nets”

- Single run survey
  - relative number
  - since 1996

- Multiple run survey
  - actual density
  - since 2009

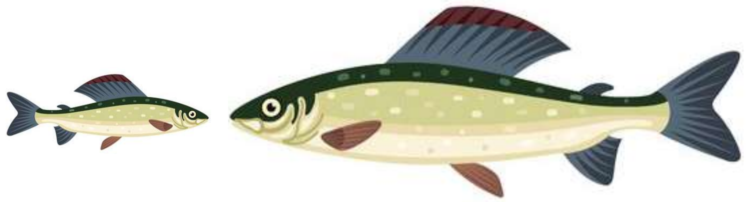


Trout!

Wylye Grayling Study

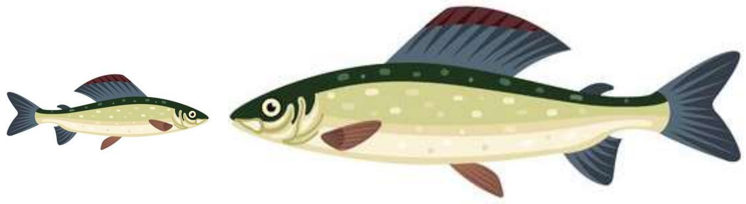
- 2009 – ongoing
- Multiple run e/f surveys
- Six sites
- ≈7500 individual length & weight records

Aims



Build and compare models to explore how environmental variables explain patterns in length-at-age

Aims



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1) von Bertalanffy growth function

2) Include environmental variables

3) Model building & comparison

4) Model inference

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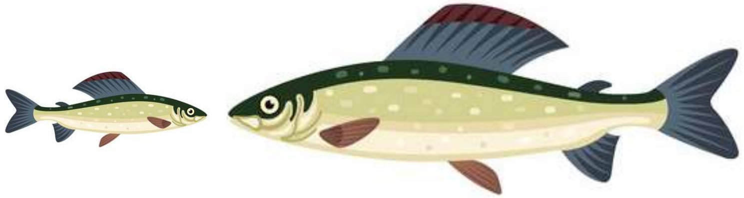

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von Bertalanffy growth

$$E(L|t) = L_\infty\left(1 - e^{-K(t - t_0) + \epsilon}\right)$$

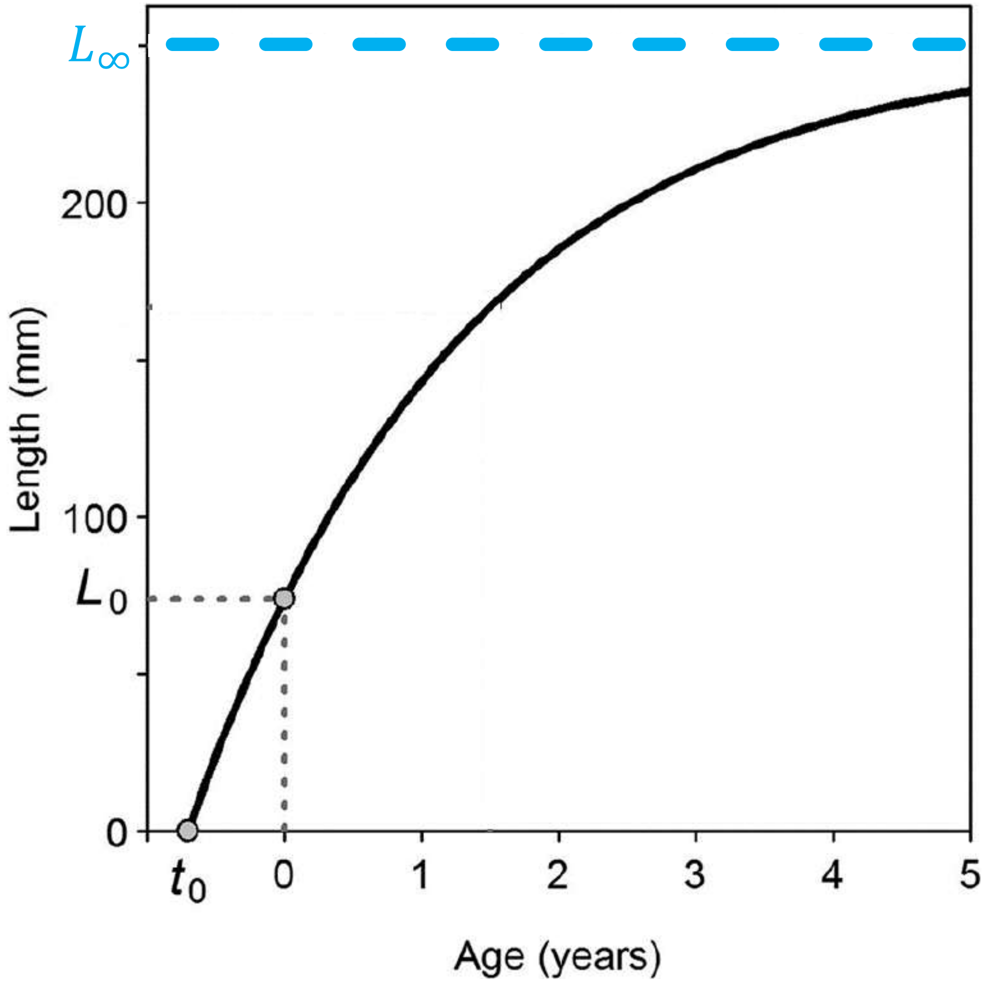
where

- $E(L|t)$ is the expected length L of fish age t
- L_∞ is the expected length of the oldest fish
- K is the Brody (growth-like) coefficient
- t_0 is the fish age when it has length 0mm

von Bertalanffy growth

$$E(L|t) = L_\infty\left(1 - e^{-K(t-t_0)+\epsilon}\right)$$

L_∞ enforces an upper average limit on L



von Bertalanffy growth

$$E(L|t) = L_\infty\left(1 - e^{-K(t-t_0)+\epsilon}\right)$$

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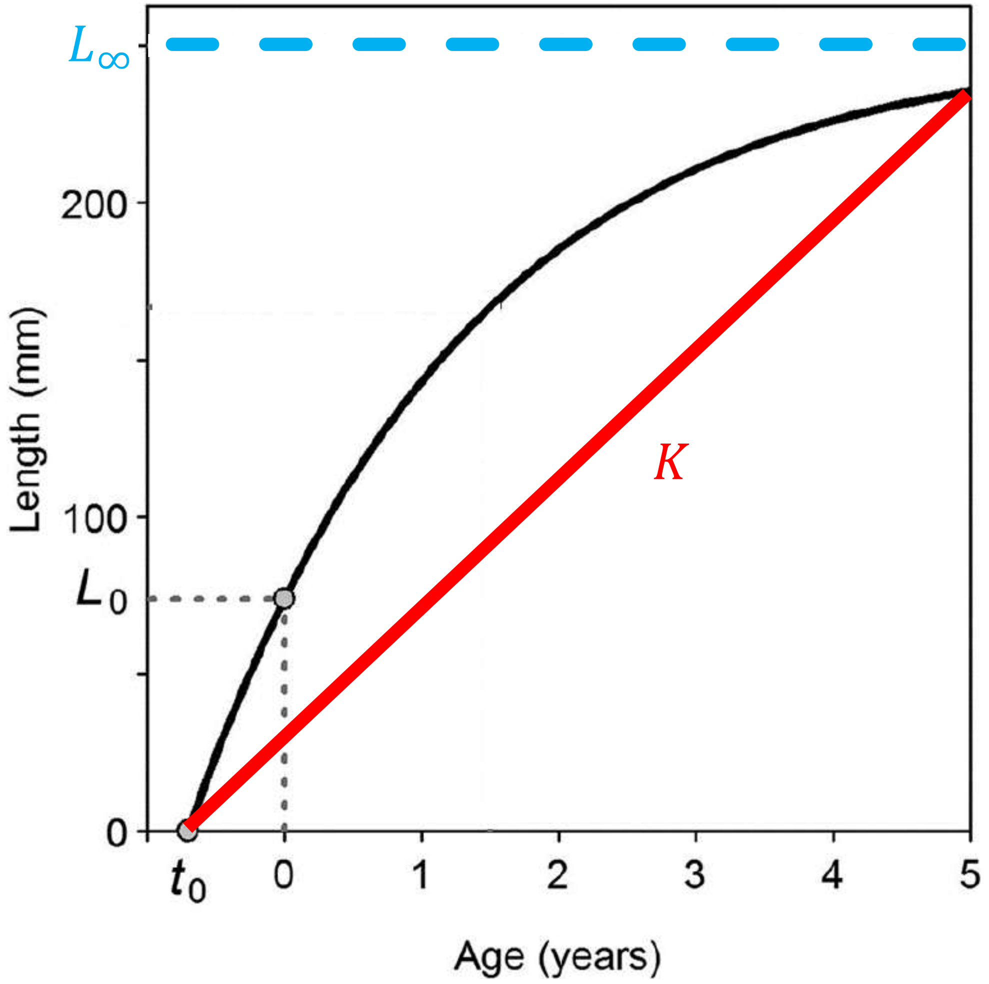
K is the slope of mean age on length



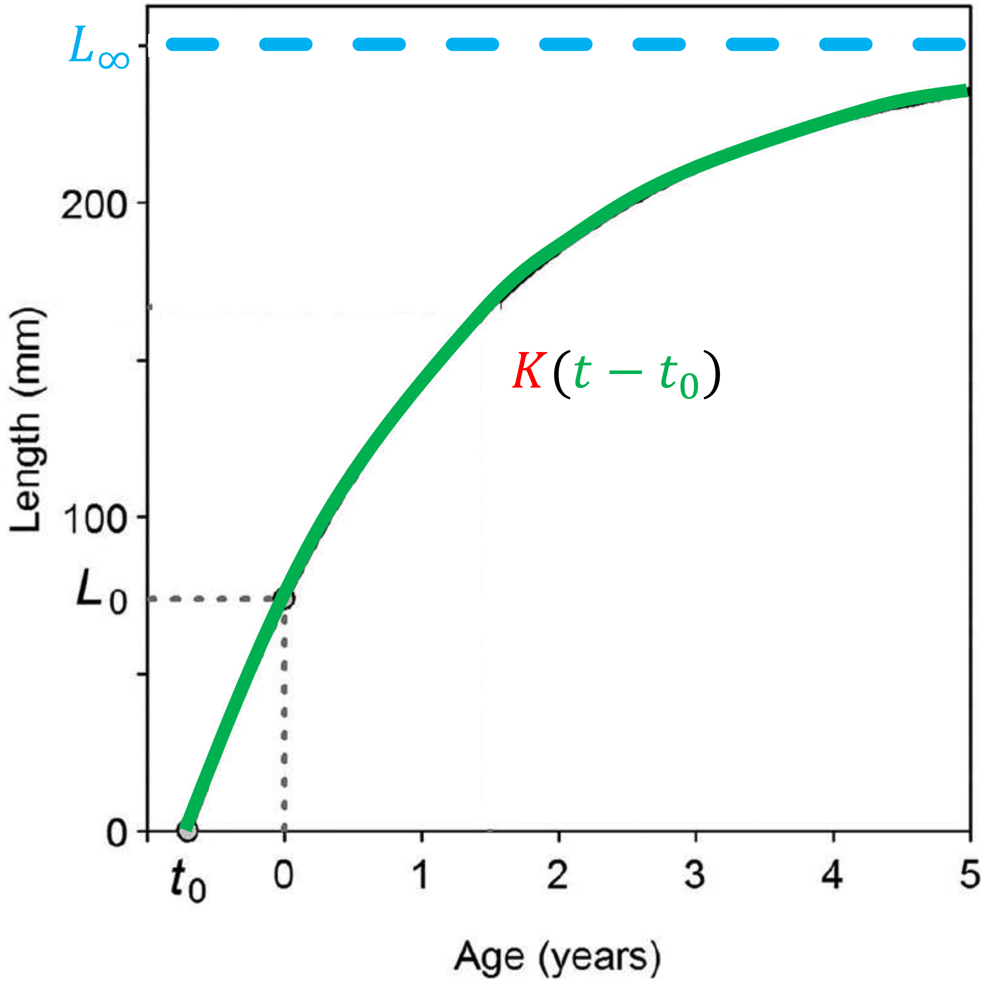
von Bertalanffy growth

$$E(L|t) = L_\infty\left(1 - e^{-K(t - t_0) + \epsilon}\right)$$

L_∞ enforces an upper average limit on L

K is the slope of mean age on length

$t - t_0$ modifies K to give curve based on t



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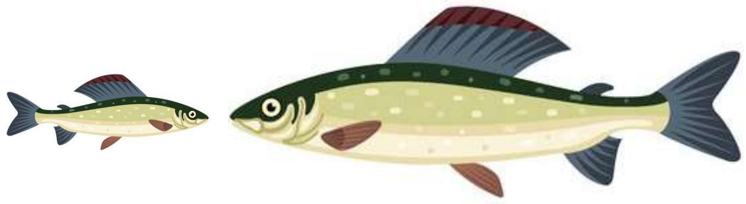

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Brody growth coefficient $K(t - t_0)$

Can be modified to include:

- Seasonality e.g., Pauly & Morgan 1987
- Development stage e.g., Soriano et al. 1992
- Reproduction e.g., Minte-Vera et al. 2016
- Covariates e.g., Bal et al. 2011

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$$K = K^*(t - t_0)f(T)g(D)$$

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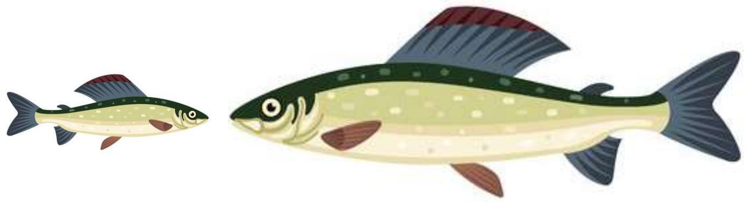
Effect of water temperature and density of juvenile salmonids on growth of young-of-the-year Atlantic salmon *Salmo salar*

G. Bal*†, E. Rivot*‡, E. Prévost§||, C. Piou§|| and J. L. Baglinière*‡

Environmental drivers of growth

Type	Name	Description	Influence
Temp.	Mean growing temperature	Mean water temperature during growing period from peak emergence to autumn survey	+
	Growing degree days	Sum of mean daily water temperatures above 6oC during growing period from peak emergence to autumn survey	+
Flow	Mean growing flow	Mean water flow during growing period from peak emergence to autumn survey	–
Density	Conspecific abundance	Estimated density of all ages of European grayling during autumn survey	–
	Heterospecific abundance	Estimated density of all ages of brown trout during autumn survey	–

Aims



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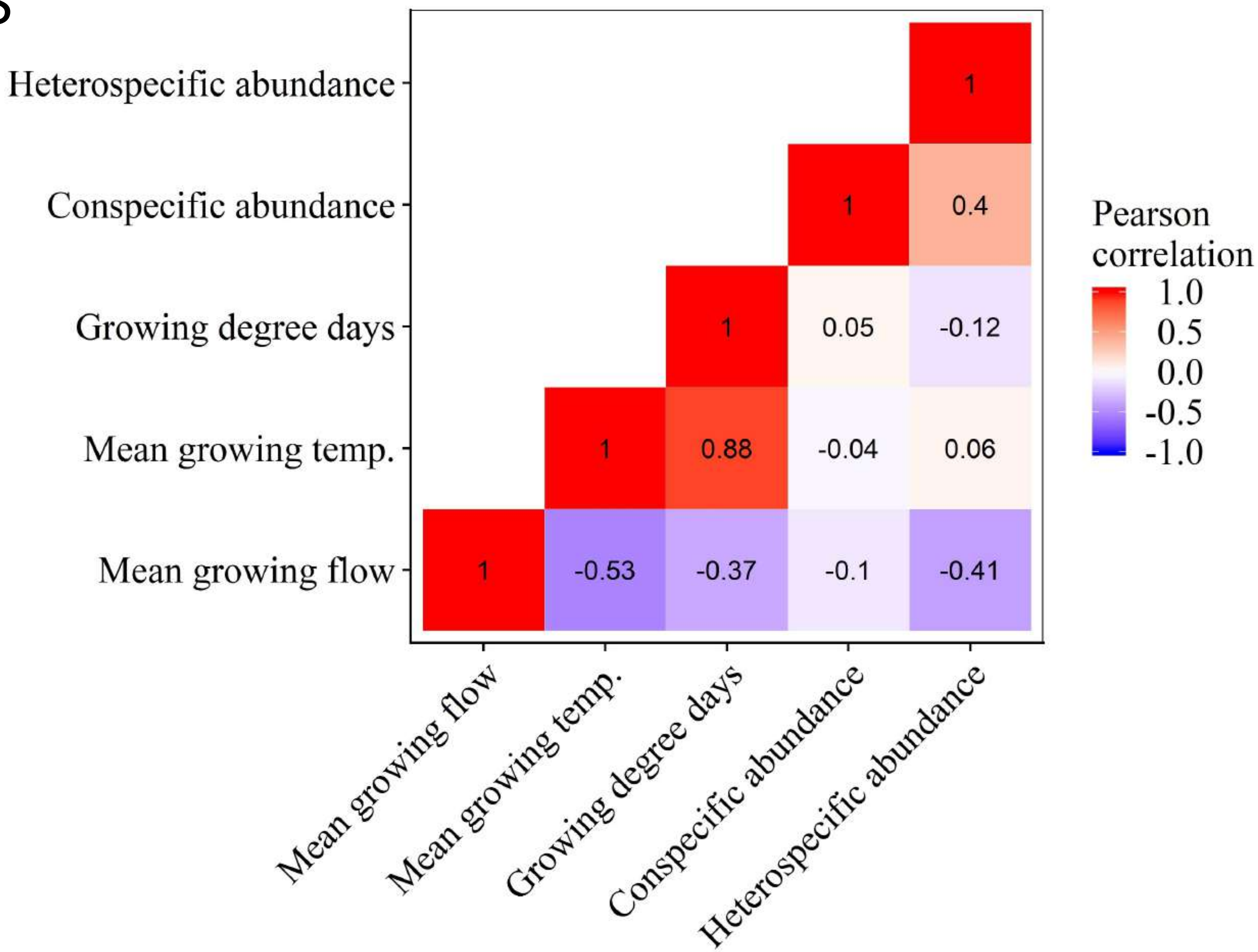
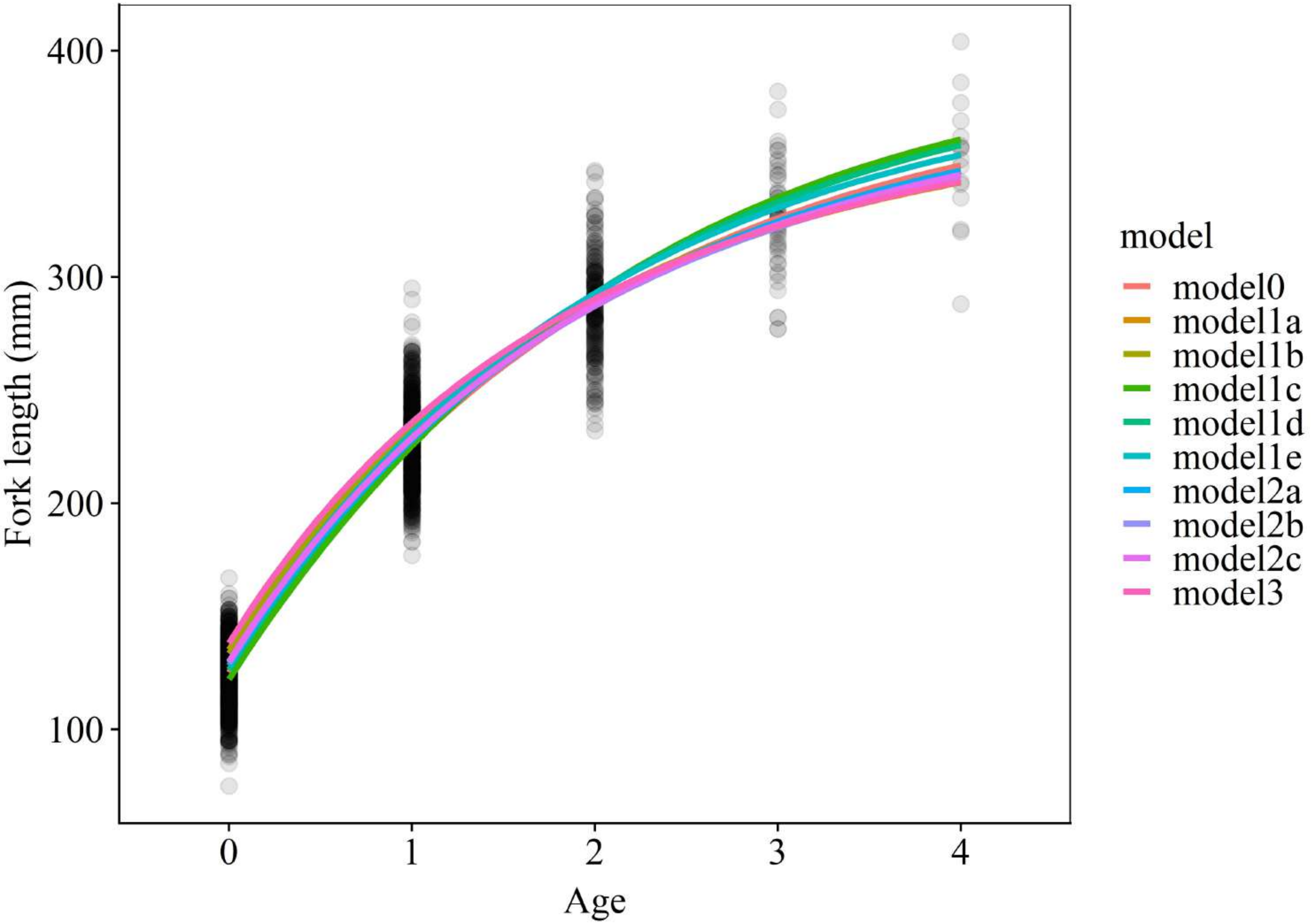
Results


Heterospecific abundance
Conspecific abundance
Growing degree days
Mean growing temp.
Mean growing flow
1
1
0.4
1
0.05
-0.12
1
0.88
-0.04
0.06
1
-0.53
-0.37
-0.1
-0.41
Pearson correlation
1.0
0.5
0.0
-0.5
-1.0
Mean growing flow
Mean growing temp.
Growing degree days
Conspecific abundance
Heterospecific abundance

Results

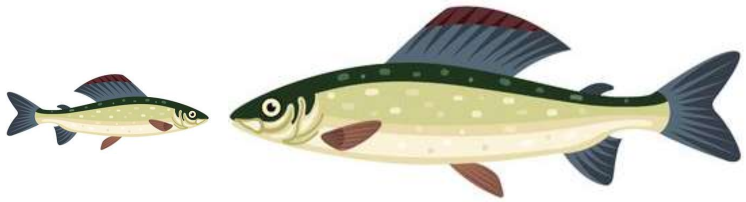


Fork length (mm)
400
300
200
100
0
1
2
3
4
Age
model
model0
model1a
model1b
model1c
model1d
model1e
model2a
model2b
model2c
model3

Results

Model	Terms	$elpd_{loo}$ (se)	p_{loo} (se)	$looic$ (se)	δ_{looic}
3	**Mean growing temperature & Conspecific & heterospecific abundance**	**-7742.33 (36.65)**	**5.89 (0.49)**	**15484.65 (73.29)**	**0**
1a	Mean growing temperature	-7760.03 (35.48)	5.41 (0.55)	15520.06 (70.97)	35.41
1d	Mean growing temperature & flow	-7770.67 (35.85)	5.97 (0.46)	15541.34 (71.70)	56.69
1e	Mean growing temperature & Growing degree days	-7775.18 (35.11)	5.84 (0.47)	15550.37 (70.22)	65.72
1b	Growing degree days	-7797.09 (35.07)	5.33 (0.54)	15594.18 (70.13)	109.53
1c	Mean growing flow	-7815.05 (35.67)	6.32 (0.53)	15630.1 (71.33)	145.45
2c	Conspecific & heterospecific abundance	-7856.54 (36.49)	7.32 (0.48)	15713.08 (72.98)	228.43
2b	Heterospecific abundance	-7859.42 (36.40)	6.05 (0.53)	15718.84 (72.80)	234.19
2a	Conspecific abundance	-7862.65 (36.24)	5.81 (0.44)	15725.31 (72.49)	240.66
0	Null	-7871.41 (36.12)	4.06 (0.32)	15742.82 (72.24)	258.17

Aims



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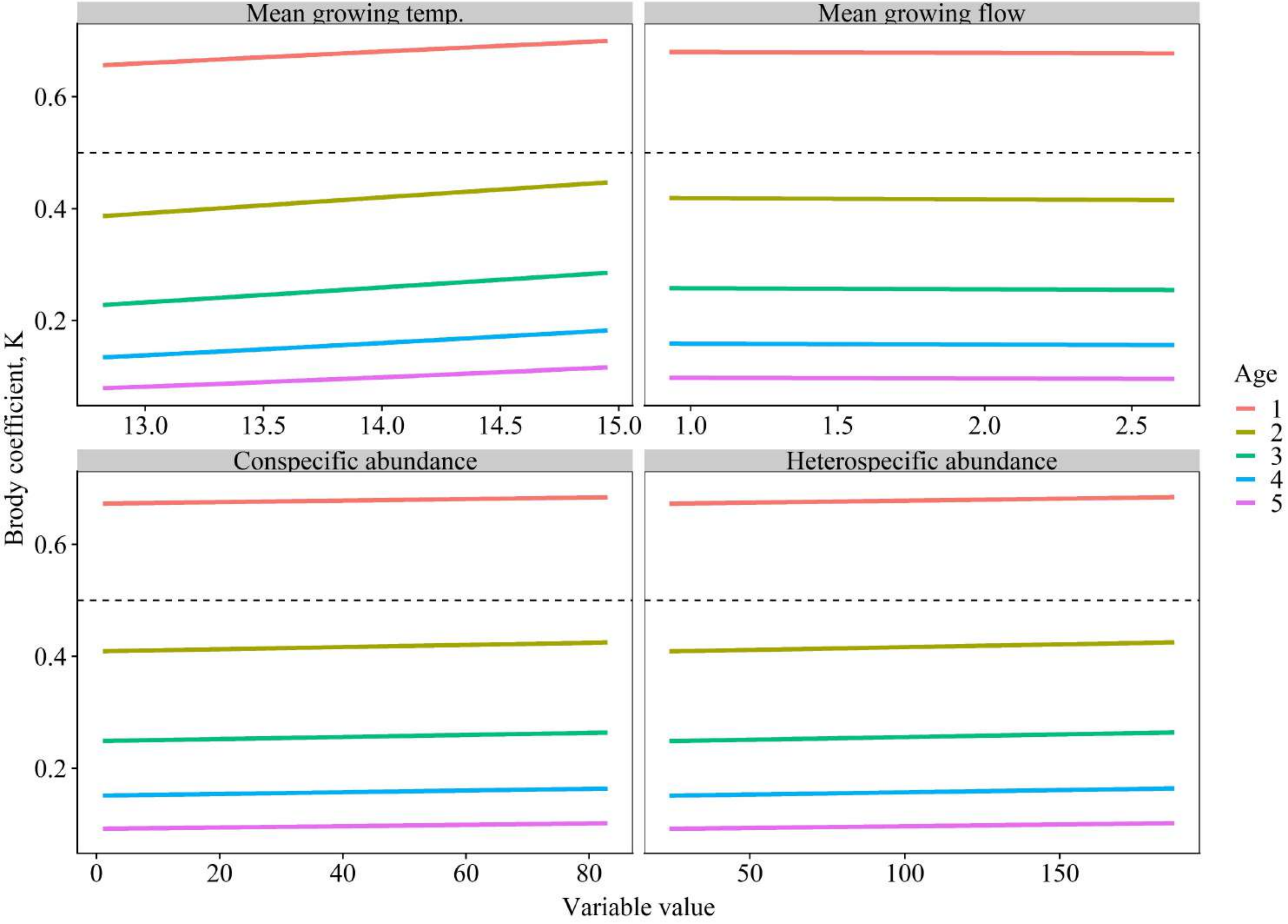
Inference

Type	Parameter	Effect direction	Estimate	Lower CI	Upper CI
Structural	K^*		1.489	1.203	1.833
	L_∞		391.418	381.637	401.867
	t_0		0.204	0.176	0.229
Environmental	β_{temp}	$++$	0.078	0.066	0.090
	β_{flow}	$-$	-0.006	-0.024	0.012
	β_{con}	$+$	0.001	0.000	0.001
	β_{hetero}	$+$	0.000	0.000	0.001



Mean growing temp.
Mean growing flow
Conspecific abundance
Heterospecific abundance
Brody coefficient, K
0.6
0.4
0.2
13.0
13.5
14.0
14.5
15.0
1.0
1.5
2.0
2.5
0
20
40
60
80
50
100
150
Variable value
Age
1
2
3
4
5

Discussion

- Temperature +ve for grayling growth
  - Similar findings for many other fish spp, incl trout

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  - Similar findings for many other fish spp, incl trout
- Flow –ve for grayling growth
  - Higher flow -> higher energy expenditure -> lower growth?

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- Temperature +ve for grayling growth
  - Similar findings for many other fish spp, incl trout
- Flow –ve for grayling growth
  - Higher flow -> higher energy expenditure -> lower growth?
- Grayling and trout abundance +ve grayling growth
  - Unexpected…
  - Good conditions favour high abundance and high growth?

Perspectives

- Generalise to hierarchical model
  - Treat 6 sites as: “independent”, “related” and “pooled”

- Further explore results
  - Consider seasonal explanatory variables?

- Explore future climate change scenarios

Thanks

THE PISCATORIAL SOCIETY

The Grayling Research Trust

The Grayling Society
Promoting Awareness, Conservation & Angling for Grayling, Worldwide

Wylye Grayling Study

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Steve’s book club

Reviews:

★★★★★ “Fascinating!” – *A. Grayling*

★★★★ “Quite informative” – *A. Trout*

★★★★★ “Best book ever written” – *R. Cove*

Email
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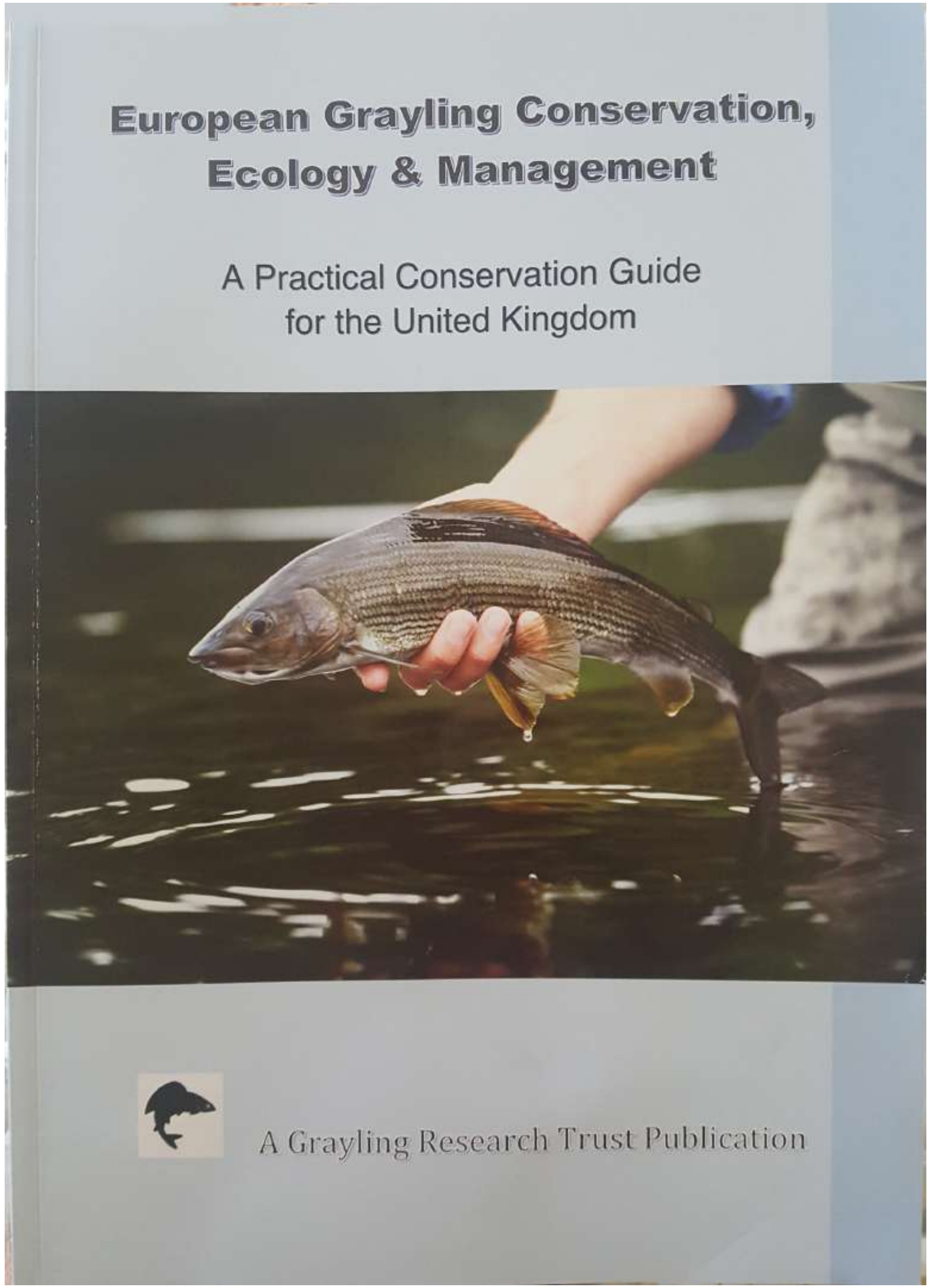

Todo

It is widely recognised that human activities have impacted abundances of wildlife populations, including fish. In some cases, the mechanism of the impact is unambiguous, such as large-scale harvesting of Atlantic salmon on their feeding grounds west of Greenland. In other cases, however, the mechanism of the impact is less clear. For example, human activities can cause unfavourable environmental conditions that impact individual fish body condition, with potential consequences to their subsequent survival. In this study, we explore the effects of environmental conditions on growth of individual European grayling in a southern English chalk stream because (1) grayling are sensitive to environmental conditions, and (2) this shrinking population is at the southern limit of their range, therefore vulnerable to climate change impacts. We describe the growth of a large sample of different age grayling marked and recaptured grayling at six sites monitored as a part of the long-term River Wylye Grayling Study (WGS). We build statistical models of varying complexity and compare them to isolate the combination of seasonal and annual temperature and flow metrics that best describes their growth. We then explore and discuss the implications of our findings for grayling and other salmonid growth under a changing climate.

Inference

$$E(L|t) = L_\infty \left(1 - e^{-K(t - t_0) + e\left(-\beta_{temp} * temp\right) + e(-\beta_{con} * con) + e(-\beta_{hetero} * hetero) + \epsilon}\right)$$