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Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our Editorial Policies and the Editorial Policy Checklist.

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a	Confirmed	
☐	☒	The exact sample size (*n*) for each experimental group/condition, given as a discrete number and unit of measurement
☐	☒	A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
☐	☒	The statistical test(s) used AND whether they are one- or two-sided *Only common tests should be described solely by name; describe more complex techniques in the Methods section.*
☐	☒	A description of all covariates tested
☐	☐	A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
☐	☒	A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
☐	☐	For null hypothesis testing, the test statistic (e.g. *F*, *t*, *r*) with confidence intervals, effect sizes, degrees of freedom and *P* value noted *Give P values as exact values whenever suitable.*
☒	☐	For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☐	☒	For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
☐	☐	Estimates of effect sizes (e.g. Cohen's *d*, Pearson's *r*), indicating how they were calculated

Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	NDVI data was collected using the MODISTools R package, while average air temperature of each site was taken from Climate Research Unit (v. 4.06) dataset, the R package geosphere was used to determine photoperiod at each site. All remaining data was gathered in the field.
Data analysis	Data was gathered, processed, and analyzed in R (v4.6.1) and Rstudio using the packages: tidyverse, lme4, coxme, RespR, performance, and cowplot

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio guidelines for submitting code & software for further information.

Data

Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our policy

All data and code are provided with the submission and will be freely available within the Essex repository upon acceptance.

Research involving human participants, their data, or biological material

Policy information about studies with human participants or human data. See also policy information about sex, gender (identity/presentation), and sexual orientation and race, ethnicity and racism.

Reporting on sex and gender	No human participants or biological material were included in this study.
Reporting on race, ethnicity, or other socially relevant groupings	No human participants or biological material were included in this study.
Population characteristics	No human participants or biological material were included in this study.
Recruitment	No human participants or biological material were included in this study.
Ethics oversight	No human participants or biological material wereincluded in this study.

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☐ Behavioural & social sciences ☒ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Ecological, evolutionary & environmental sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	Parr of Atlantic salmon (Salmo salar) and brown trout (Salmo trutta) were captured by electrofishing in six rivers spanning Spain to Iceland. In each river, individual fish (n = 72-252 depending on the river) were placed into a respirometry chamber to measure their metabolism using a MiniDOT logger (PME, USA). Individuals were then removed and placed under anesthesia using either clove oil or 2-phenoxyethanol. Fork length and mass were then measured, a scale sample was taken to infer both age and growth, and a PIT tag implanted to track survival and migration (though fish in Spain were not tagged due to a lack of tracking infrastructure). Wet weight of the fish and water temperature at the time of the experiment were used to correct metabolic rates to a uniform mass and temperature. Average water temperature of the river, average air temperature, and surrounding NDVI were the used to characterize the environmental conditions of each river system. Within each river, fish were measured in 2-4 experimental "runs" per day over multiple days, thus experimental run was nested within day nested within river. Fish were then left at least two annual migration periods or "smolt runs" to migrate downstream after which we modeled: 1) For all fish, the linear relationship between ln(mass and -corrected metabolism) and temperature with an interactive effect of river. 2) For all fish, the linear relationship between growth and all two-way interactions of ln(mass and temperature-corrected metabolism), average river temperature, and species with random effects for run nested within day nested within river and age class (estimated from scales) nested within river. The most parsimonious model was then selected after backward stepwise model selection with this final model compared with a polynomial model including the same terms to test for a non-linear effect. 3) For all tagged fish, the relationship between survival and all two-way interactions of age, ln(mass), mean river temperature, and ln (mass and temperature corrected metabolism) with a random effect for river using a binomial GLMER, before selecting the most parsimonious model using backward stepwise selection. 4) For all surviving and migrating salmon, the relationship between normalised migration timing and all two-way interactions of ln (mass and temperature-corrected metabolism), mean river temperature, ln(mass) normalized by age within river, and age normalized within river, alongside a random effect for river, before selecting the most parsimonious model using backward stepwise selection.
Research sample	We sampled Atlantic salmon (Salmo salar) and brown trout (Salmo trutta) of both sexes ranging from <1 to 4 years old within six river systems: the Cares (Spain) (n = 171, mean river temperature = 9.7°C), Frome (England) (n = 184, mean river temperature = 12.5°C), Tweed (Scotland)(n = 176, mean river temperature = 9.0°C), Deveron (Scotland)(n = 188, mean river temperature = 7.2°C), Vesturdalsá (Iceland)(n = 252, mean river temperature = 4.2°C), and Sunnudalsá (Iceland)(n = 72, mean river temperature = 3.0°C). We chose these rivers as they contain tracking infrastructure and spanned close to the full thermal range of the species. These species were selected as they comprise the most common salmonids across this region and are of great conservation relevance. The groups are each meant to represent populations of salmonids native to the rivers in which they were captured.
Sampling strategy	Sampling was carried out as above with all available individuals >50mm included, previous repeated experiments using this respirometry technique followed by power analysis had suggested minimum sample sizes of 63 individuals to detect a medium effect size (cohen d = 0.5). However to maximize power and anticipating additional noise across the field sites we measured as many individuals as possible over the sampling period for each river (n = 72-252 depending on the river).
Data collection	Metabolic data was recorded on minidot loggers and then processed by the lead author (Peter Betts). Tag ID was automatically detected by a PIT reader and inputted to an Excel sheet, while length and mass of individual fish was recorded on an Excel sheet by a range of field assistants including almost all co-authors (Peter Betts, Eoin O'Gorman, Colin Bull, Rasmus Lauridsen). Tag detections were recorded by local partner organizations (GWCT, AST, Six Rivers Project Iceland) with all detections sent to the lead author. All

	remaining data was gathered and processed by the lead author with assistance from co-authors.
Timing and spatial scale	Sampling of sites was conducted in the Summers of 2023 and 2024 with all individuals measured once for metabolism, growth, and mass, at the time of sampling while PIT tags were then monitored from date of tagging until November 2025. Samples were taken from six rivers across four countries spanning the latitudinal gradient of Atlantic salmon.
Data exclusions	To ensure fish were of similar age classes and that each age class was sufficiently sampled, fish older than 4 years were excluded. Mature trout >50g were also excluded as these were no longer the target juvenile parr. In addition fish <50mm were excluded as they were too small to be tagged. These criteria were established ahead of sampling. After sampling, one fish was excluded as the chamber had been left exposed to the sun and had been heated throughout the measurement period, and one experimental run was excluded as it was disturbed by fishing activity which may have induced stress responses in the fish during the measurement period. For the metabolic rate experiments, we excluded any data where the linear regression of dissolved oxygen data during the experimental period had an r2 value < 0.8, this occurred in 2% of fish.
Reproducibility	We have not re-sampled and attempted to reproduce the study due to the large scale and long time frame required to gather it, but we have carried out sensitivity analyses on our core results to show that our findings are robust to the removal of certain sites or datum.
Randomization	Organisms were not allocated into groups or randomized but were instead measured within their natural rivers under natural conditions, with sampling run within sampling day within river forming our groups for statistical analyses which we controlled for using mixed effect modeling.
Blinding	Blinding was not possible or relevant as fish were all measured in situ, with the relevant metrics and measurements e.g. metabolism, or growth rate, not known until data had been processed.

Did the study involve field work? ☒ Yes ☐ No

Field work, collection and transport

Field conditions	Fieldwork was conducted at 17 sites across the six rivers. Temperatures and weather depended on the day and field location but generally ranged from 8-20 °C, and from sunny to heavy rain.
Location	Sampling was conducted at 17 different sites across the six rivers (see Table S5 for exact coordinates) and rivers were generally ~0.5m in depth. Elevation was generally alittle above sea level and ranged from 38m (Frome) to 1000m (Cares).
Access & import/export	Location and timing of sites was selected with local experts to minimise disturbance of fish and not interfere with key times in their life cycle (e.g. breeding). In all cases, local landowner and national permissions were obtained for access to sites where required. Landowner permission was granted for all sampling on the Frome, Deveron, Tweed, Vesturdalsá, and Sunnudalsá, while permission to sample the Cares was granted by the national park authorities. Fish were released after sampling and import/export licenses were not required.
Disturbance	The study incurred minimal new disturbance to the local environments, researchers were careful to stick to established walking trails and to avoid excessive trampling of the vegetation or riverbanks during sampling. Fish may have been disturbed by the sampling procedure but this was minimized by the administration of anesthetic by trained personnel.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology and archaeology
☐	☒ Animals and other organisms
☒	☐ Clinical data
☒	☐ Dual use research of concern
☒	☐ Plants

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Animals and other research organisms

Policy information about studies involving animals; ARRIVE guidelines recommended for reporting animal research, and Sex and Gender in Research

Laboratory animals	No laboratory animals were used in this study.
Wild animals	Brown trout and Atlantic salmon (<1 to 4 years of age) were captured by electrofishing, then measured in-situ before being released back into the capture location after all measurements were taken and a suitable recovery period post-anaesthetic had been observed.
Reporting on sex	Sex information on our fish was not collected, but we expect our findings to apply to both sexes where we have sampled across populations
Field-collected samples	Samples collected in the field were not held in a laboratory but were measured and then immediately released.
Ethics oversight	Animal handling and processing procedures were approved by the GWCT Animal Welfare and Ethical Review Body and the University of Essex ethics board (ETH2324-192) and were carried out by licensed personnel under a UK Home Office ASPA licence (PPL PP9506723).

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Plants

Seed stocks	No seeds were used in this study
Novel plant genotypes	No seeds were used in this study
Authentication	No seeds were used in this study