



Past and future joint trends in river temperature and flow: implications for diadromous fish

Anthony MAIRE¹ – **Hanieh SEYEDHASHEMI**² – **Elorri AREVALO**^{3,4} –
Marion LEGRAND⁵ – **Florentina MOATAR**² – **Hilaire DROUINEAU**³

(1) EDF R&D – LNHE – Chatou (France)

(2) INRAE – UR RiverLy – Lyon-Villeurbanne (France)

(3) INRAE – Unité EABX – Bordeaux-Cestas (France)

(4) AZTI Marine Research - BRTA – Sukarrieta (Spain)

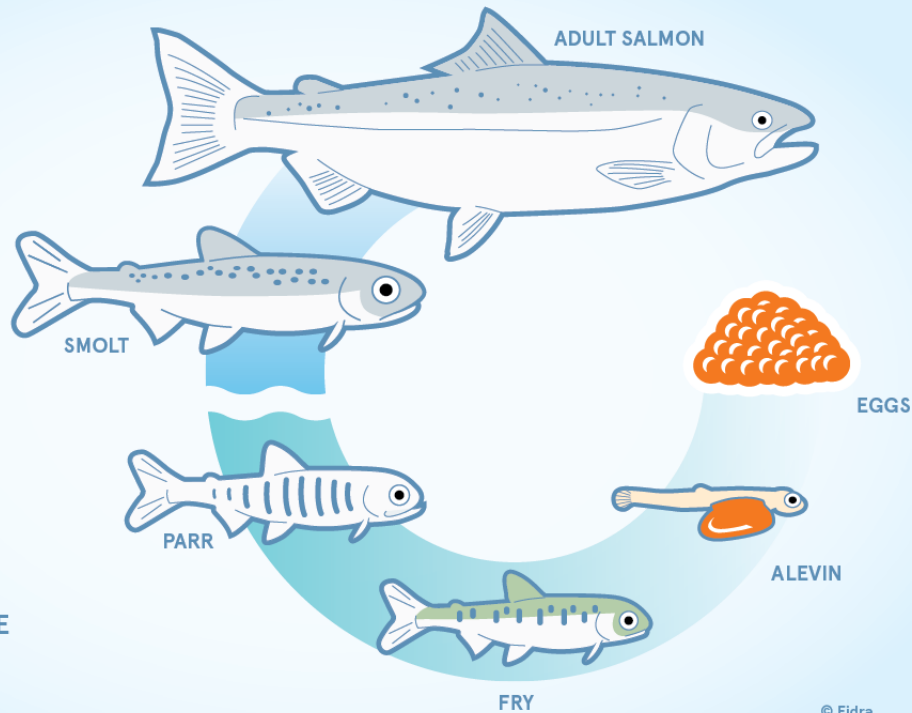
(5) Loire Grands Migrateurs (LOGRAMI) – Orléans (France)



BACKGROUND

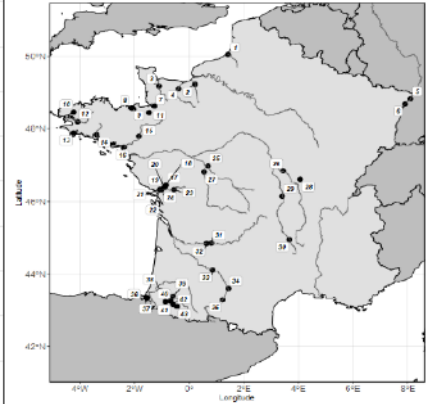
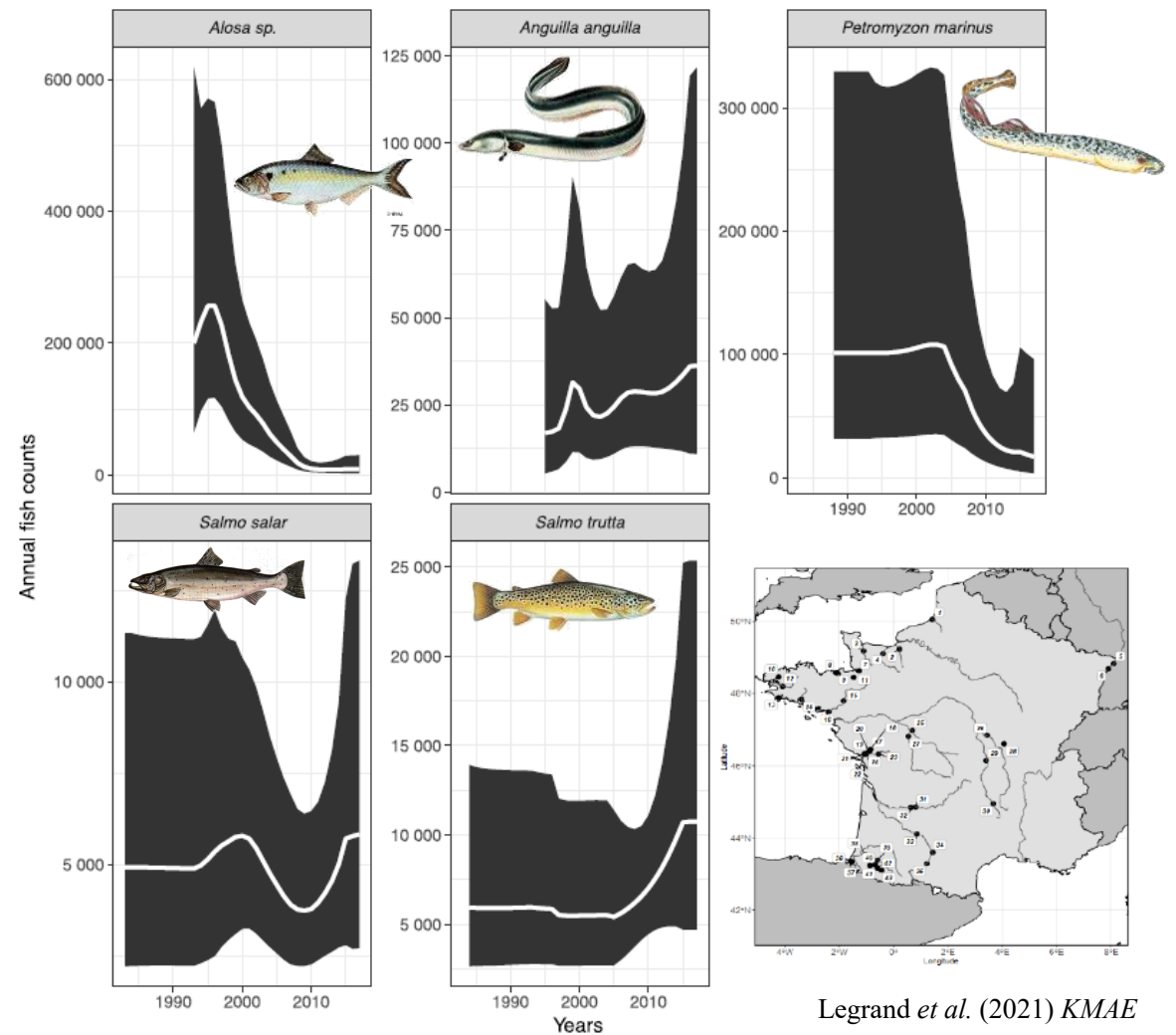
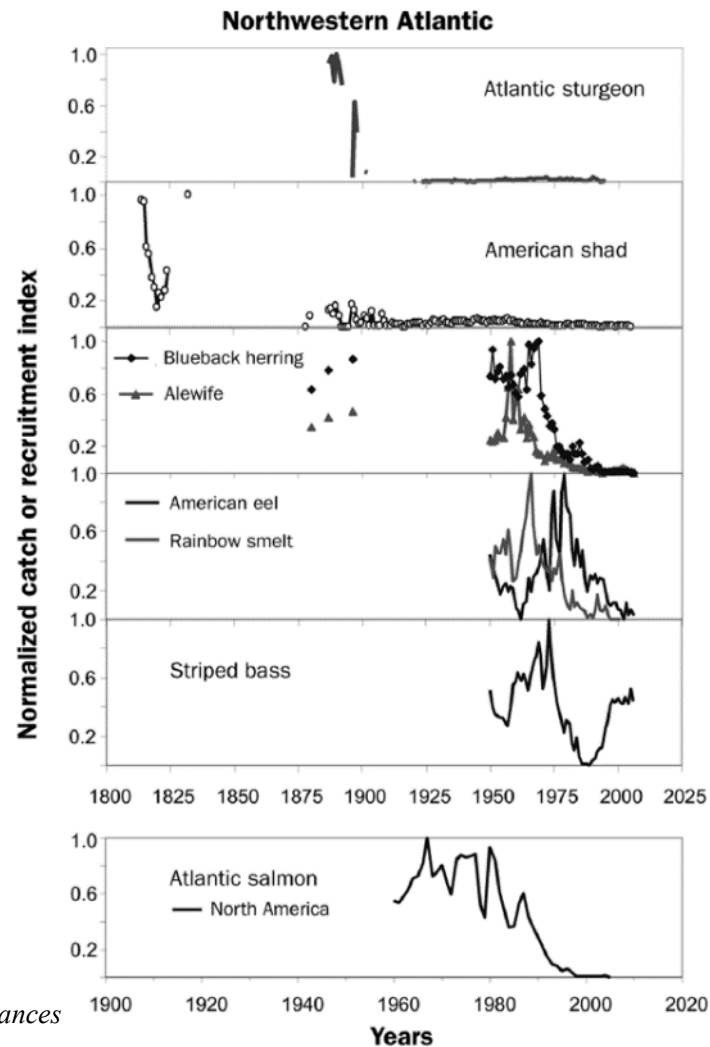
➤ **Diadromous fish species** → subject to a wide range of pressures

Salmon lifecycle



BACKGROUND

- **Diadromous fish species** → subject to a wide range of pressures
- **Contrasting population trends depending on the species** → many declines are reported



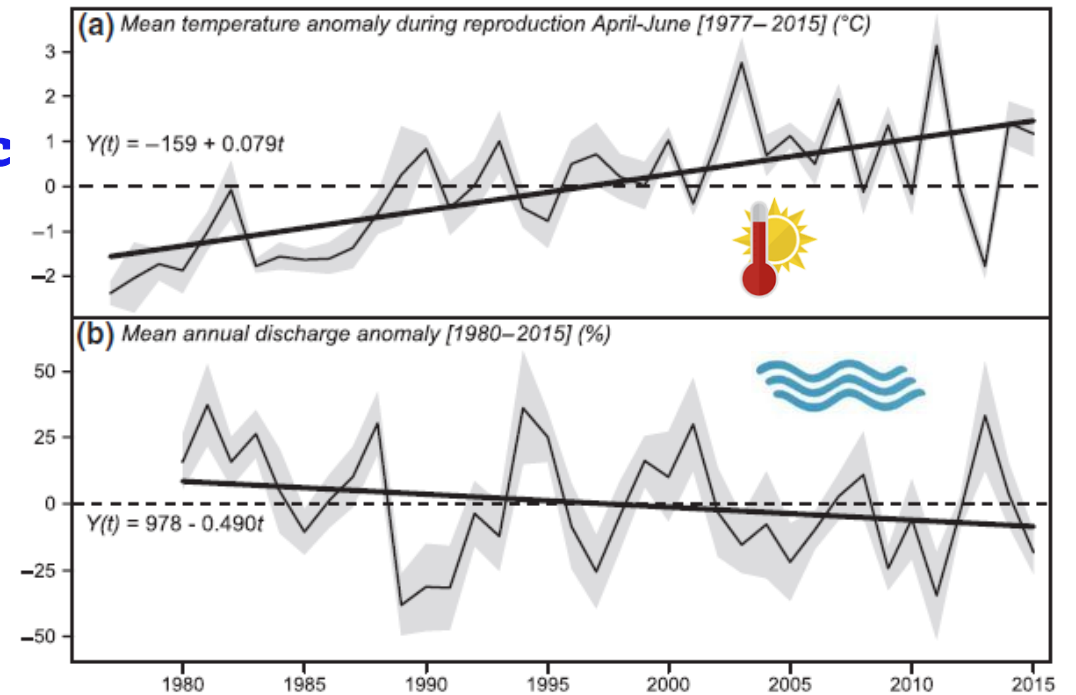
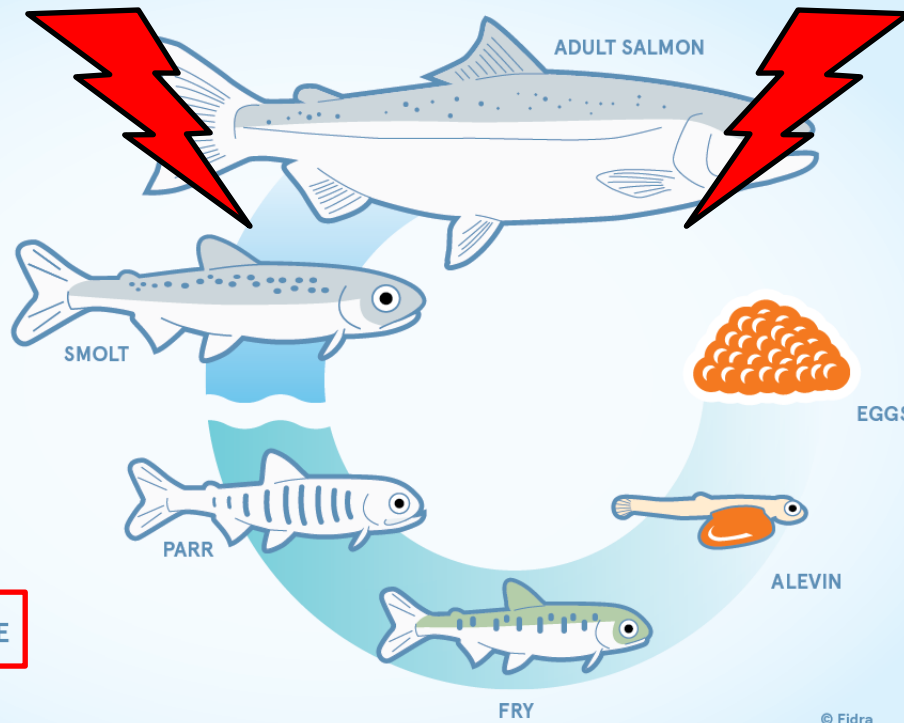
BACKGROUND

- Environmental triggers of their migration → e.g. water temperature, discharge, photoperiod
- Global changes → modify some of these environmental cues

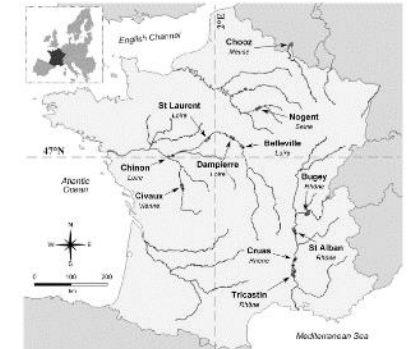
Downstream migration:
March-June
9°C < Water temperature
Medium discharge

Spawning migration:
February-October
5°C < Water temperature < 25°C
Discharge fluctuations

Salmon lifecycle



Maire et al. (2019) *Freshw. Biol.*



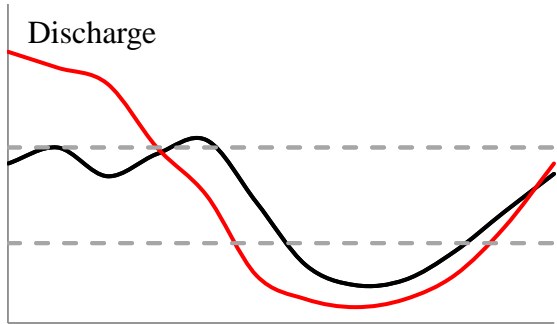
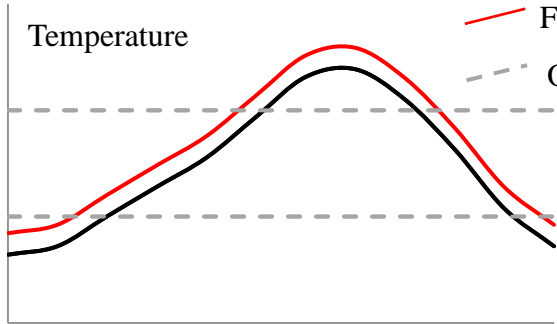
BACKGROUND-OBJECTIVES

➤ **Global changes** → affect the suitable environmental window for fish to migrate

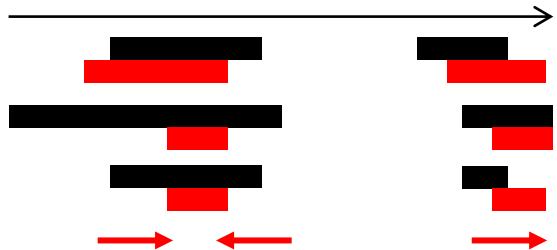
➔ **Possible impact on the completion of species life cycle, on population dynamics and ultimately on their regional and global persistence**

Arevalo *et al.* (2020) *STOTEN*

— Current conditions
— Future conditions
- - - Optimal theoretical conditions



Time →



Optimal thermal conditions

Optimal hydrological conditions

Optimal joint conditions

Research questions:

1. How to detect and quantify joint temporal trends in two or more parameters?
2. How water temperature and discharge have jointly changed over the past decades and what are the implications for the migration of diadromous fish in rivers?
3. What are the consequences of potential match-mismatch effects on past, present and future environmental suitability for fish migration in the Loire catchment in France?

Post-doc Elorri Arevalo
2019-2020



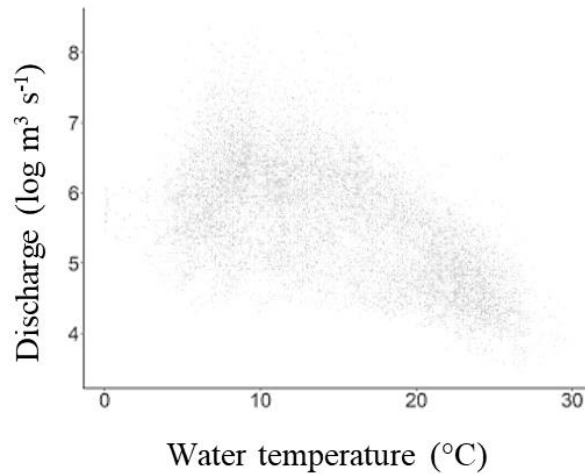
Post-doc Hanieh Seyedhashemi
2022-2023



THE 'CHOC' METHOD

* *CHange of OCcurrence analysis on multivariate time-series*

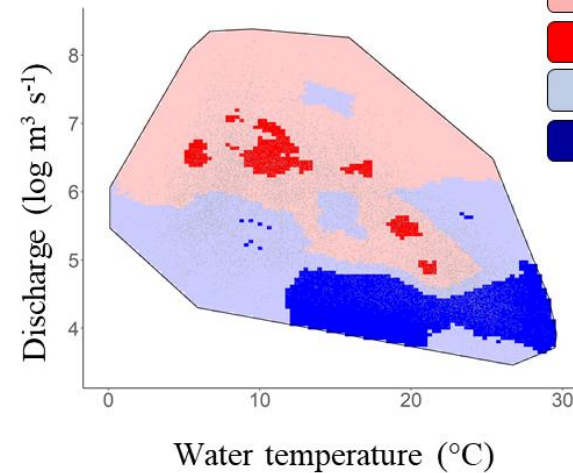
Long-term bivariate data
e.g. 1980-2015



Science of the Total Environment 748 (2020) 141260

Choc method *

Kernel density estimations
Mann-Kendall trend tests



Associations that ...

- tend to become scarce
- are significantly scarcer
- tend to be more frequent
- are significantly more frequent



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journal homepage: www.elsevier.com/locate/scitotenv



An innovative bivariate approach to detect joint temporal trends in environmental conditions: Application to large French rivers and diadromous fish

Elorri Arevalo ^{a,*}, Géraldine Lassalle ^a, Stéphane Tétard ^b, Anthony Maire ^b, Eric Sauquet ^c, Patrick Lambert ^a, Alexis Paumier ^a, Bertrand Villeneuve ^a, Hilaire Drouineau ^a

R package: <https://github.com/Irstea/chocR>

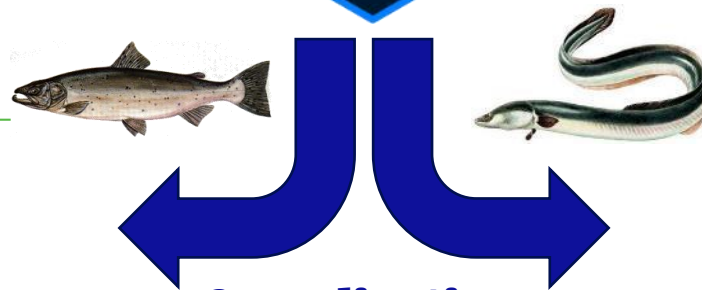
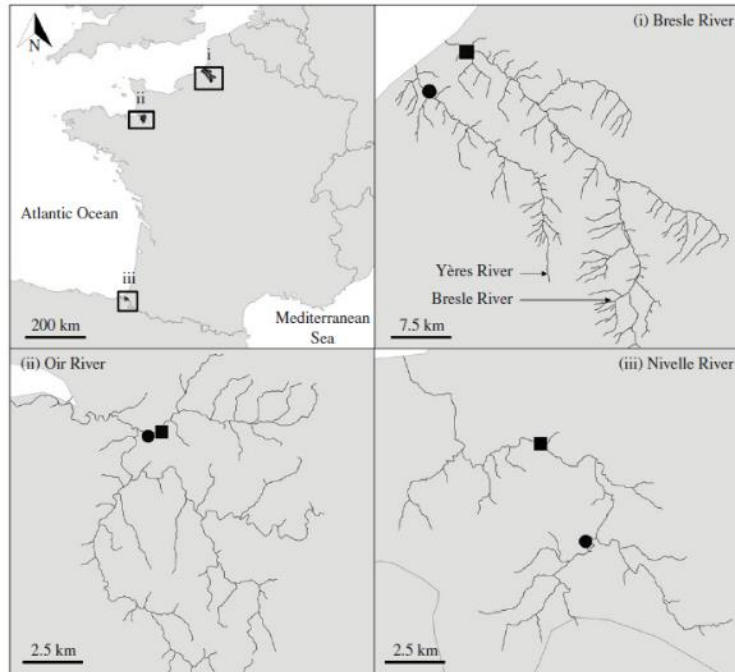
Arevalo *et al.* (2020) *STOTEN*
Drouineau *et al.* (2021) *R package*

RESULTS - POST-DOC ELORRI AREVALO

PROCEEDINGS B

Does global change increase the risk of maladaptation of Atlantic salmon migration through joint modifications of river temperature and discharge?

Elorri Arevalo¹, Anthony Maire², Stéphane Tétard³, Etienne Prévost⁴, Frédéric Lange⁴, Frédéric Marchand⁵, Quentin Josset^{6,7,8} and Hilaire Drouineau¹



2 applications

Arevalo *et al.* (2020) *STOTEN*
Arevalo *et al.* (2021a) *Sci. Rep.*
Arevalo *et al.* (2021b) *Proc. B*



scientific reports

Joint temporal trends in river thermal and hydrological conditions can threaten the downstream migration of the critically endangered European eel

Elorri Arevalo^{1,2,3}, Hilaire Drouineau¹, Stéphane Tétard^{2,3}, Caroline M. F. Durif⁴, Ola H. Diserud⁵, W. Russell Poole⁶ & Anthony Maire³



DATA – LOIRE CATCHMENT

Syedhashemi *et al.* (2022) *HESS*
Syedhashemi *et al.* (2023) *ESSD*

Hydrology and
Earth System
Sciences



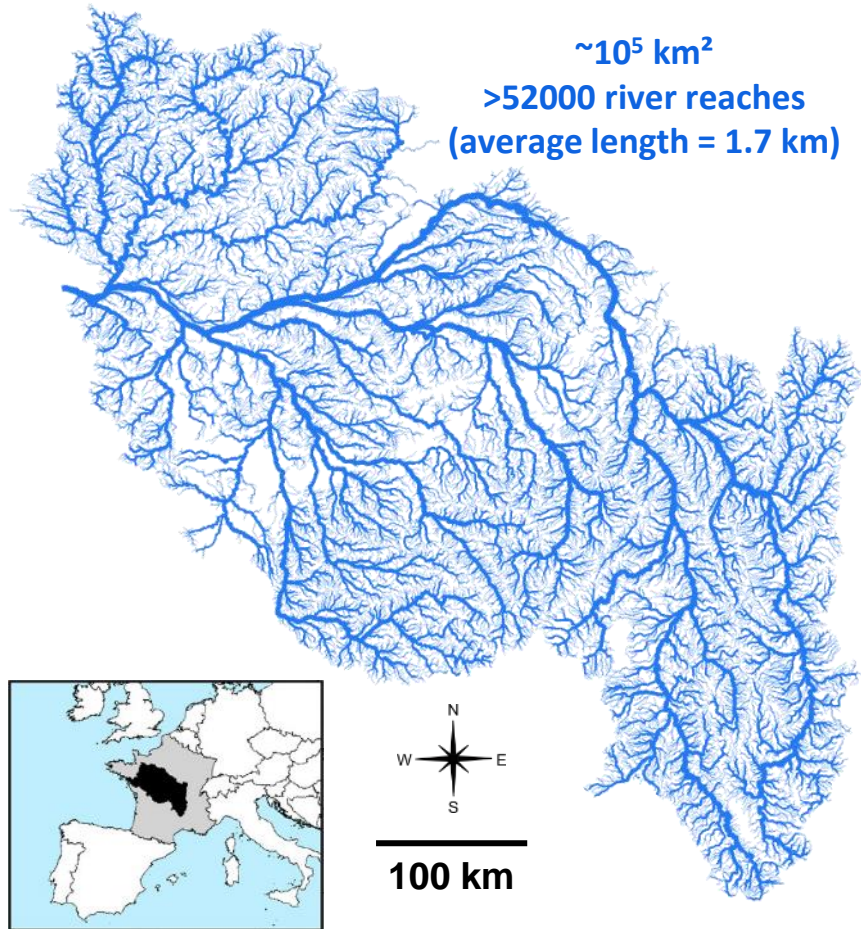
Regional, multi-decadal analysis on the Loire River basin reveals that stream temperature increases faster than air temperature

Hanieh Syedhashemi^{1,2}, Jean-Philippe Vidal¹, Jacob S. Diamond¹, Dominique Thiéry³, Céline Monteil⁴, Frédéric Hendrickx⁴, Anthony Maire⁴, and Florentina Moatar¹

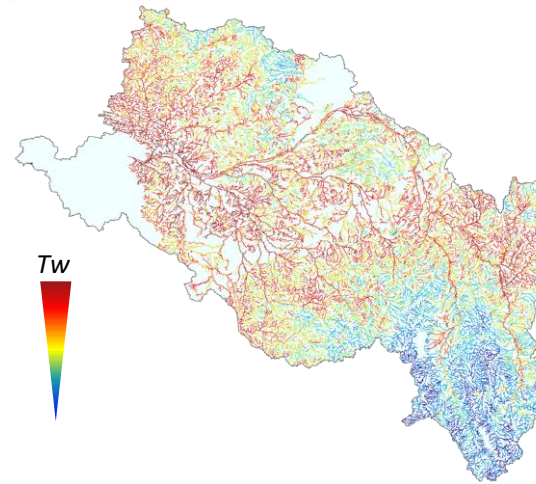
Past and future discharge and stream temperature at high spatial resolution in a large European basin (Loire basin, France)

Hanieh Syedhashemi^{1,2}, Florentina Moatar¹, Jean-Philippe Vidal¹, and Dominique Thiéry³

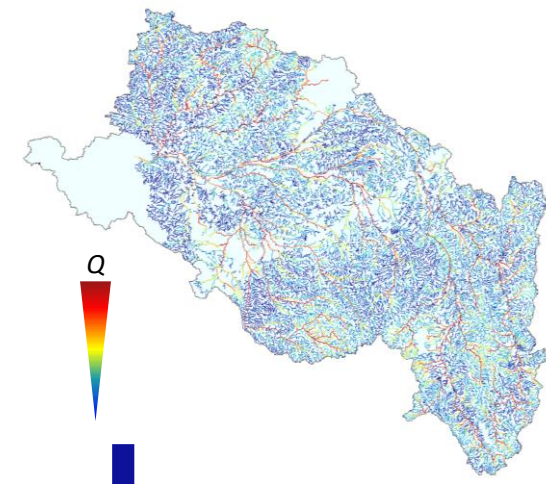
Open Access
Earth System
Science
Data
Discussions



Daily water temperature (T_w) data
T-NET thermal model



Daily discharge (Q) data
EROS hydrological model



Reconstructed past conditions (1963-2019)
Projected future conditions (2020-2100)

Use of discharge-derived current velocity (V) data (Morel *et al.*, 2020)

DATA – FISH PASSAGES (UPSTREAM MIGRATION)

Four fish counting station for upstream migration (dams)



Three anadromous species considered:

Atlantic salmon
Salmo salar



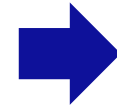
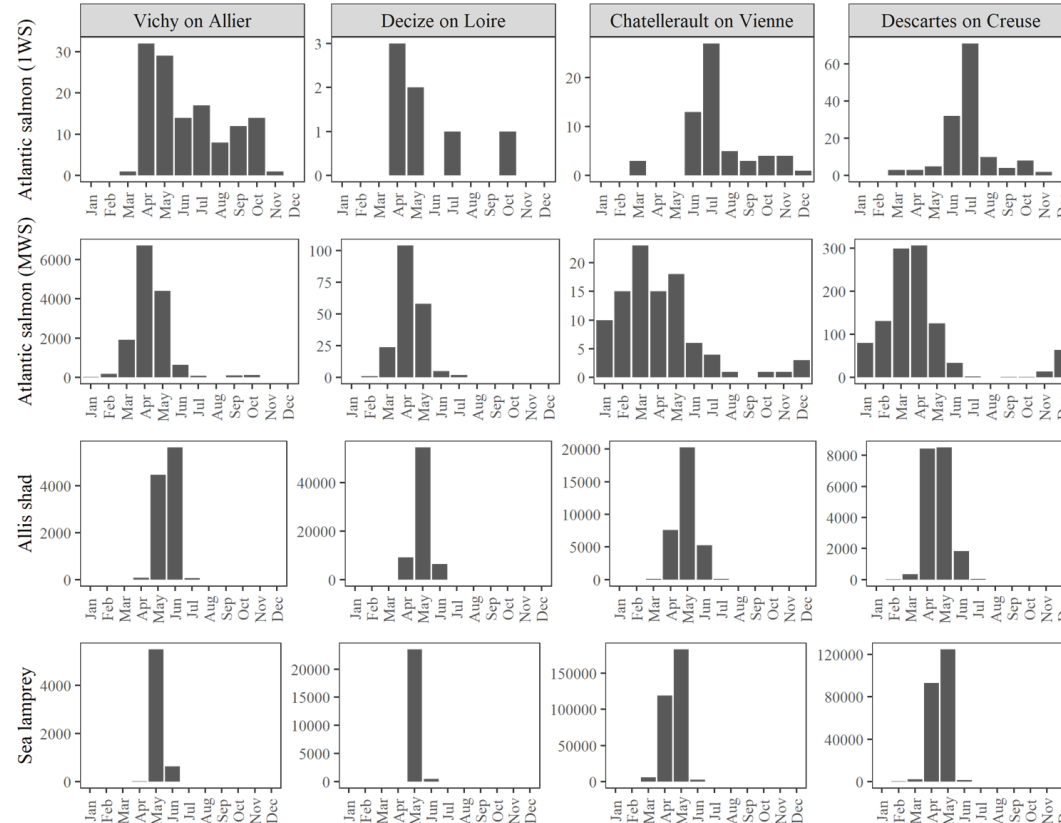
Allis shad
Alosa alosa



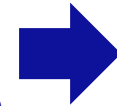
Sea lamprey
P. marinus



Identification of the migration season for each species



1 Winter at sea (1WS)

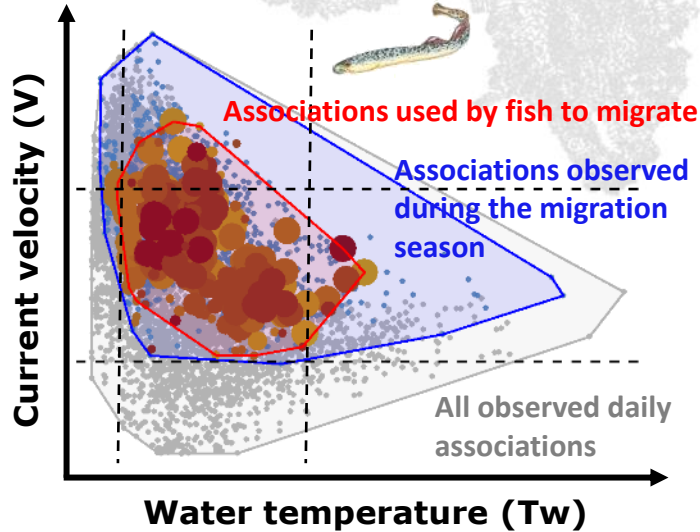
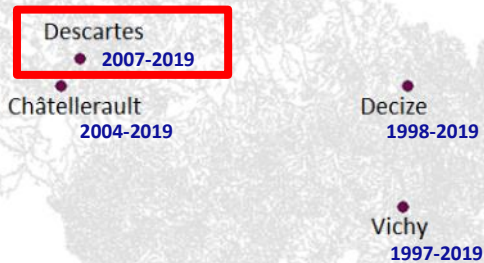


>1 Winter at sea (MWS)



DATA – FISH PASSAGES (UPSTREAM MIGRATION)

Four fish counting station for upstream migration (dams)



Data from Descartes on the Creuse River
Period: 2007-2019

Three anadromous species considered:

Atlantic salmon
Salmo salar



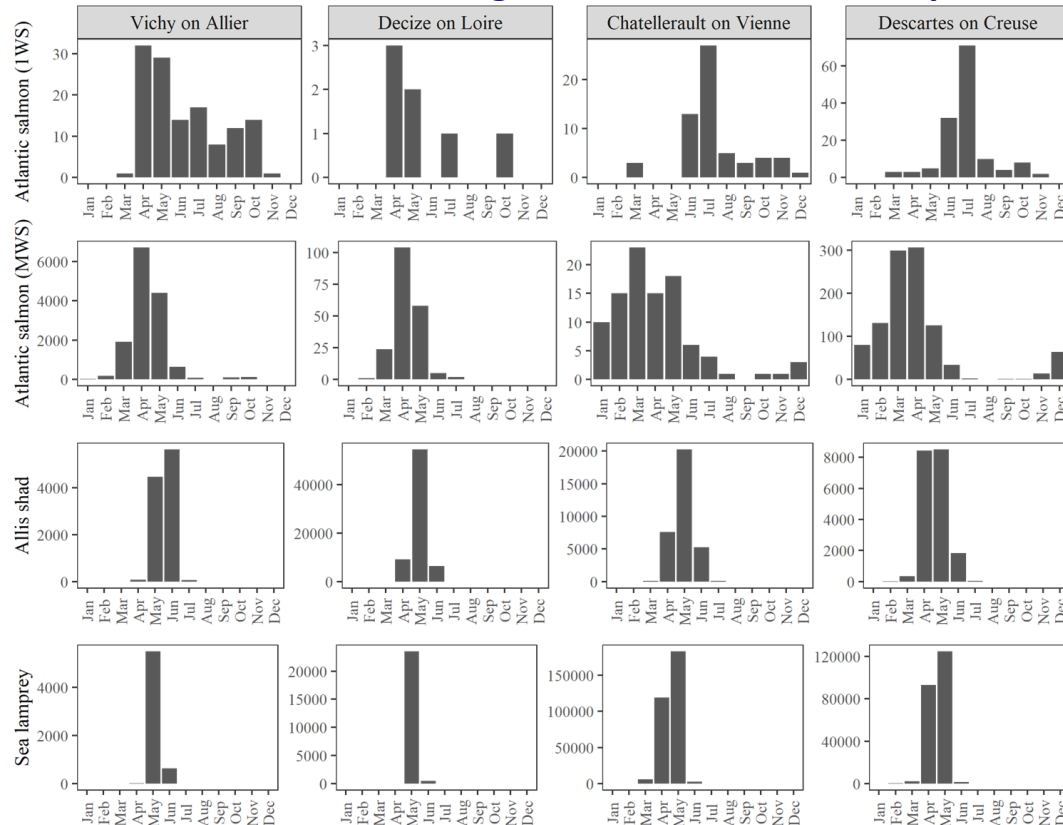
Allis shad
Alosa alosa





Sea lamprey
P. marinus



Identification of the migration season for each species



 **July-Dec.** → **1 Winter at sea (1WS)**

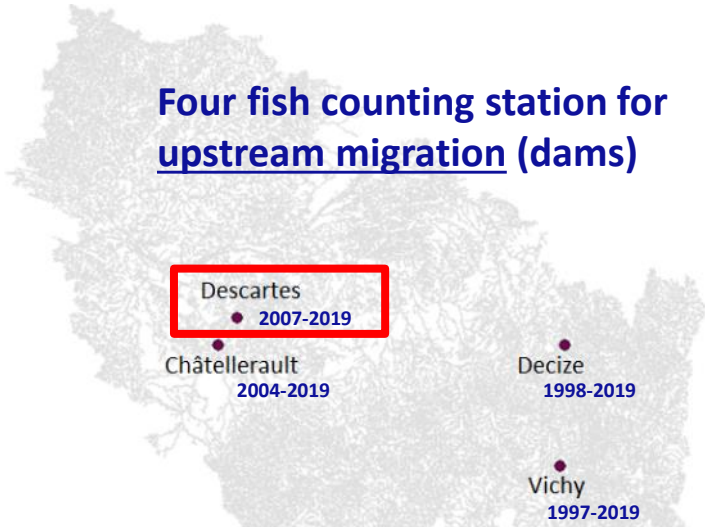
 **Feb.-June** → **>1 Winter at sea (MWS)**

 **March-June**

 **March-June**

DATA – FISH PASSAGES (UPSTREAM MIGRATION)

Four fish counting station for upstream migration (dams)



Three anadromous species considered:

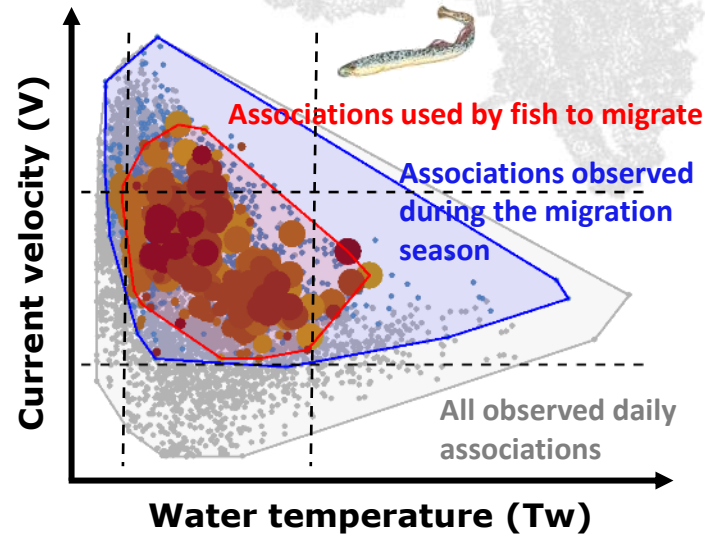
Atlantic salmon
Salmo salar



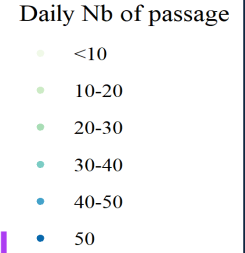
Allis shad
Alosa alosa



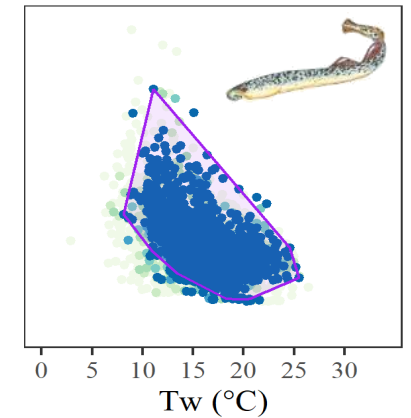
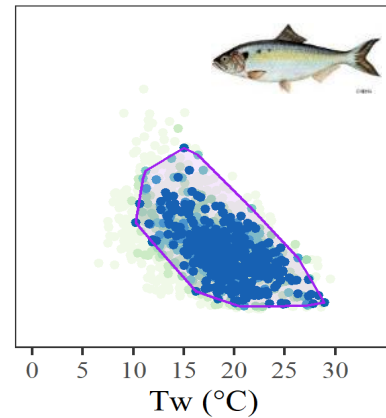
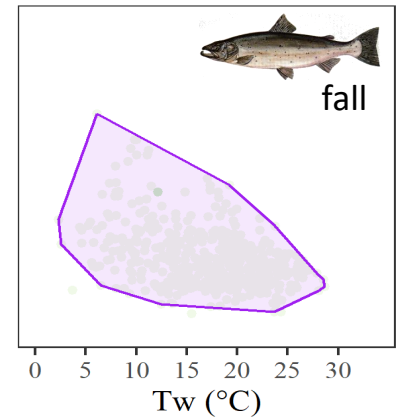
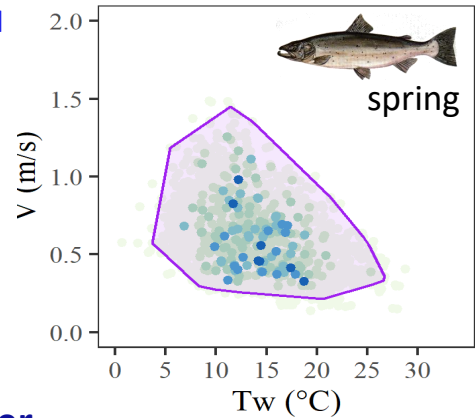
Sea lamprey
P. marinus



“Suitable conditions for migration”
= Convex hull including 90% of the days with at least one migrating individual



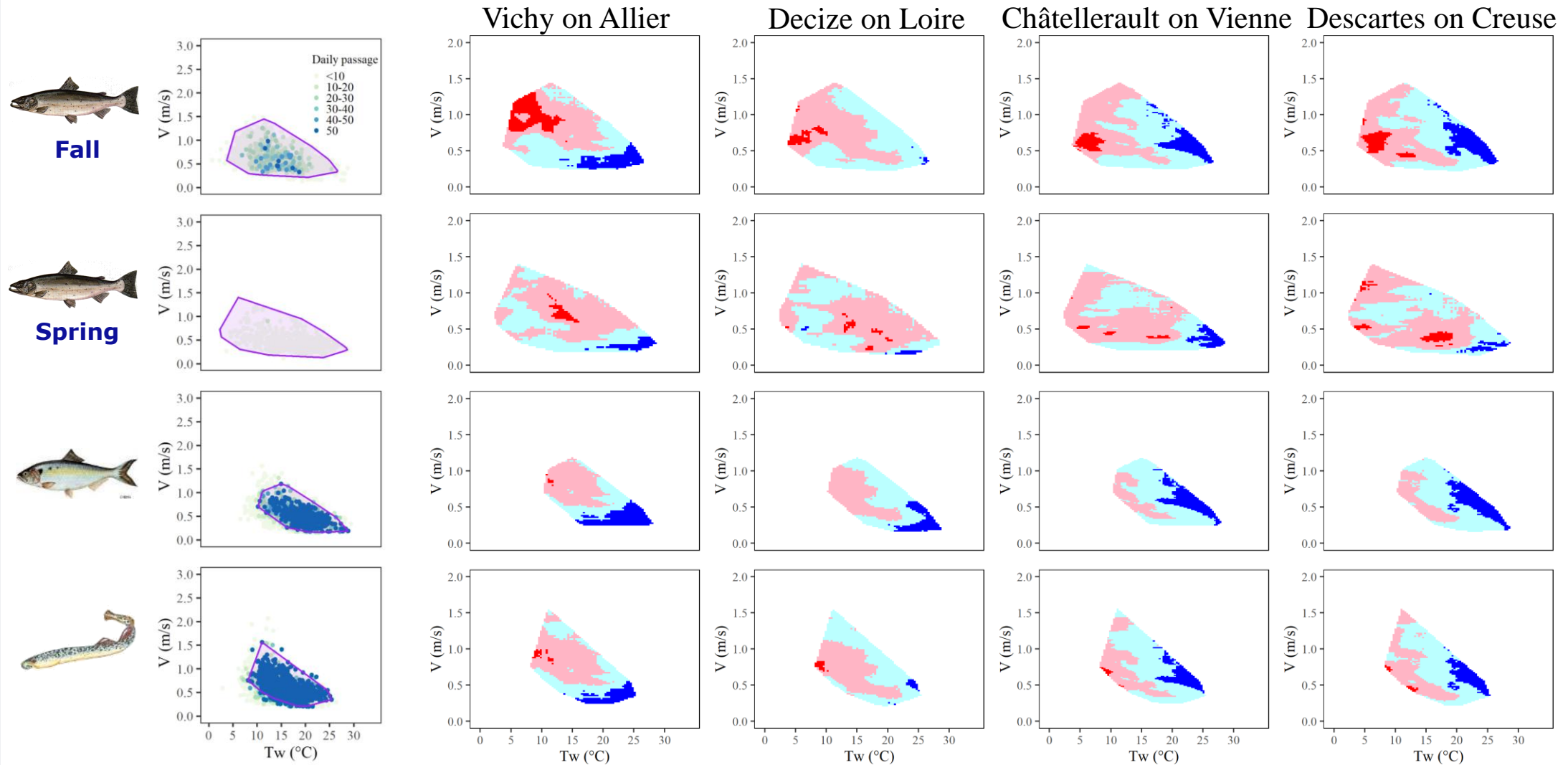
Data from Descartes on the Creuse River
Period: 2007-2019



RESULTS

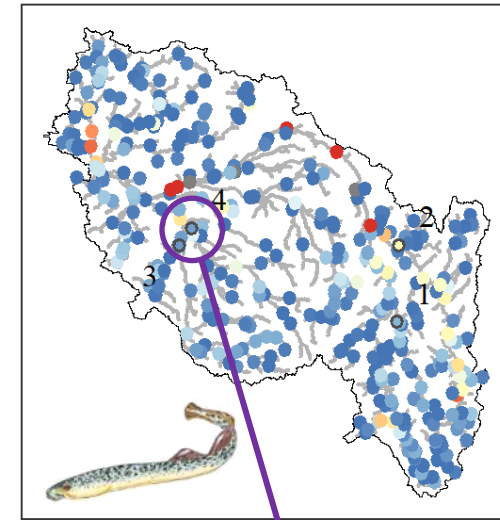
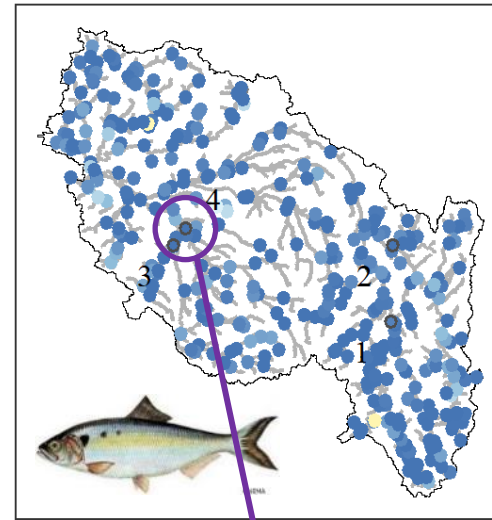
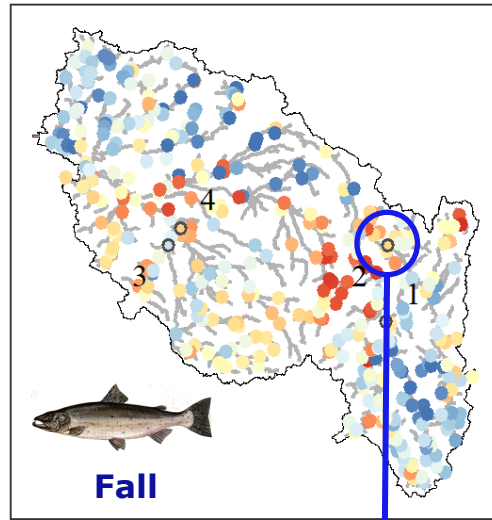
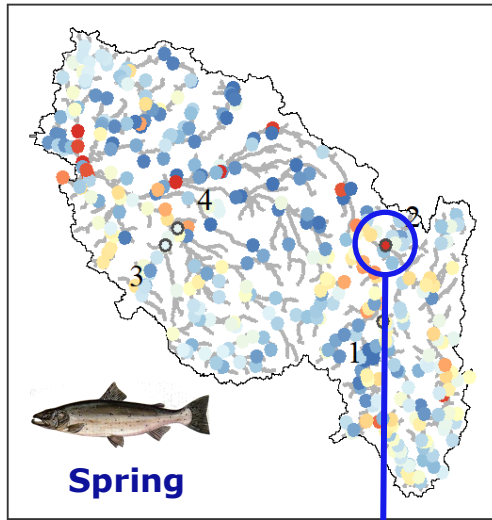
Frequency of occurrence of river temperature-current velocity associations during species' migration season

↓ Significant decrease ↓ Non-significant decrease ↑ Non-significant increase ↑ Significant increase

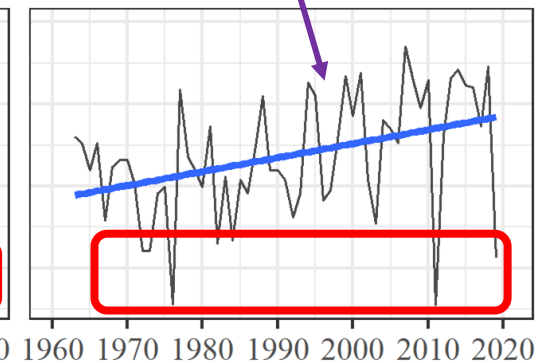
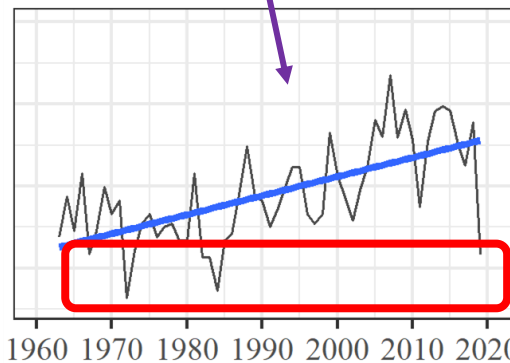
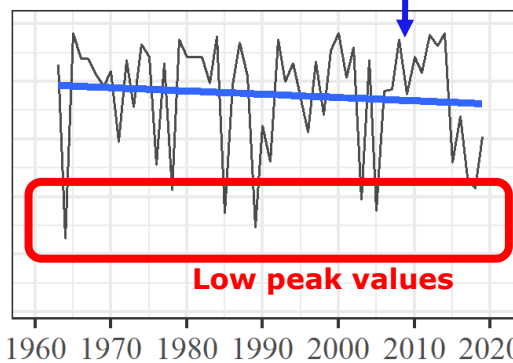
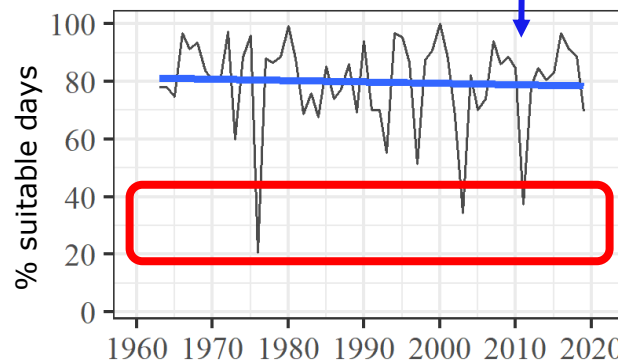


RESULTS

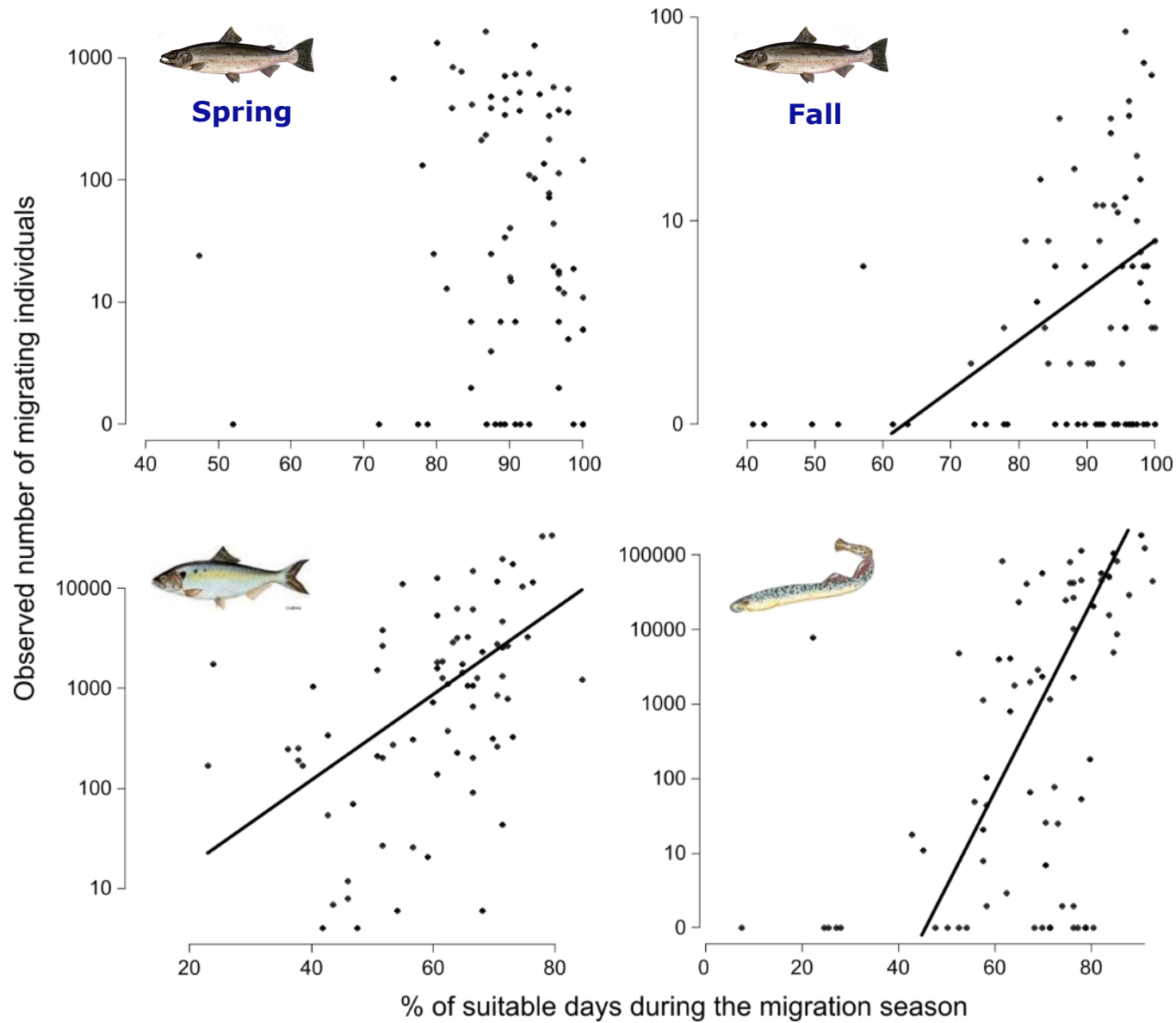
Frequency of occurrence of days with suitable conditions during the migration season



Percentage of days with suitable conditions during the migration season



RESULTS



Annual values for the four fish monitoring stations considered together

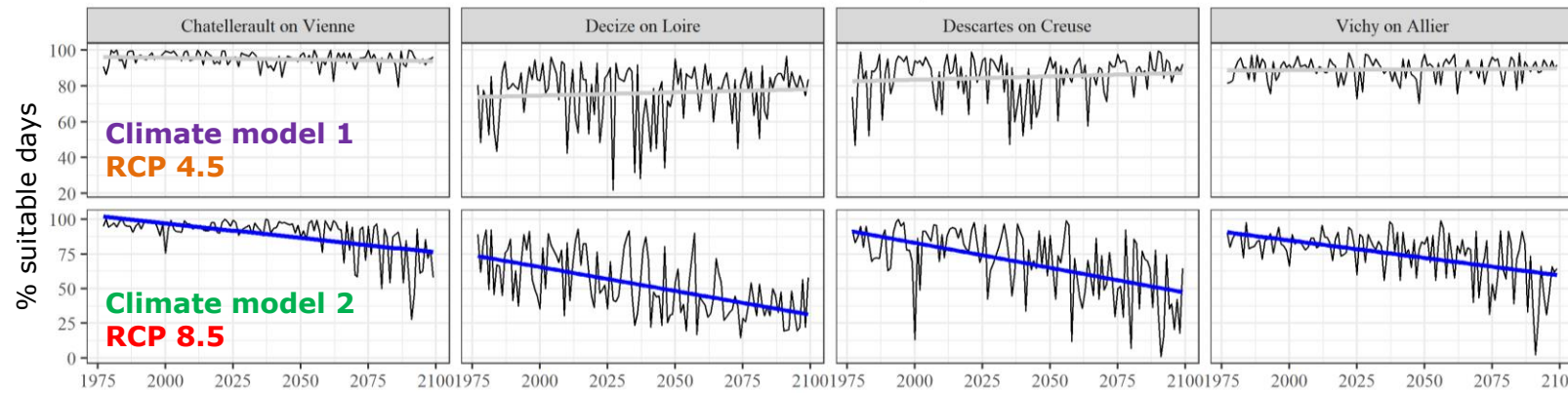
CONCLUSION & PERSPECTIVES

➤ Effects of global change on river thermal and hydrological conditions during upstream migration

- **Allis shad and sea lamprey**: do not seem responsible for the observed population declines
- **Atlantic salmon**: alarming, especially for fall salmons, despite spatial disparities

➤ In the coming months: **quantification and comparison of past, present and future suitability** of the tributaries of the Loire River for the migration of the 3 species

- Use of projected Tw and V daily data under different climate models and IPCC scenarios until 2100



Fall

➤ Species **physiological and behavioural adaptations**

- Not accounted for to define future suitable conditions
- Conservative approach

THANK YOU

For details / More to come

Arevalo E., Lassalle G., Tétard S., Maire A., Sauquet E., Lambert P., Paumier A., Villeneuve B., Drouineau H. (2020) An innovative bivariate approach to detect joint temporal trends in environmental conditions: application to large French rivers and diadromous fish. *Science of The Total Environment*, 748, 141260.

Arevalo E., Drouineau H., Tétard S., Durif C., Diserud O.H., Poole R., Maire A. (2021a) Joint temporal trends in river thermal and hydrological conditions can threaten the downstream migration of the critically endangered European eel. *Scientific Reports*, 11, 16927.

Arevalo E., Maire A., Tétard S., Prévost E., Lange F., Marchand F., Josset Q., Drouineau H. (2021b) Does global change increase the risk of maladaptation of Atlantic salmon migration through joint modifications of river temperature and discharge? *Proceedings of the Royal Society B: Biological Sciences*, 288, 20211882.

Drouineau H., Arevalo E., Lassalle G., Tétard S., Maire A. (2021) chocR package - Exploring the temporal CHange of OCcurrence of events in multivariate time series - version 1.0.0. <https://github.com/Irstea/chocR>

Syedhashemi H., Vidal J.-P., Diamond J.S., Thiéry D., Monteil C., Hendrickx F., Maire A., Moatar F. (2022) Regional, multi-decadal analysis reveals that stream temperature increases faster than air temperature. *Hydrology and Earth System Sciences*, 26, 2583–2603.

Syedhashemi H., Moatar F., Vidal J.-P., Thiéry D. (2023) Past and future discharge and stream temperature at high spatial resolution in a large European basin (Loire basin, France). *Earth System Science Data*, in press.

Syedhashemi H., Drouineau H., Arevalo E., Legrand M., Moatar F. & Maire A. (in prep.) Heterogeneous joint temporal trends in river temperature and current velocity in a large European basin: implications for anadromous fish.

Contact : anthony.maire@edf.fr | hanieh.seyedhashemi@inrae.fr

