UNIVERSITA' DEGLI STUDI DI MILANO BICOCCA

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THE THERMAL REGIME OF ALPINE STREAMS: NATURAL CONTROLS AND EFFECT OF HYDROELECTRIC POWER PRODUCTION

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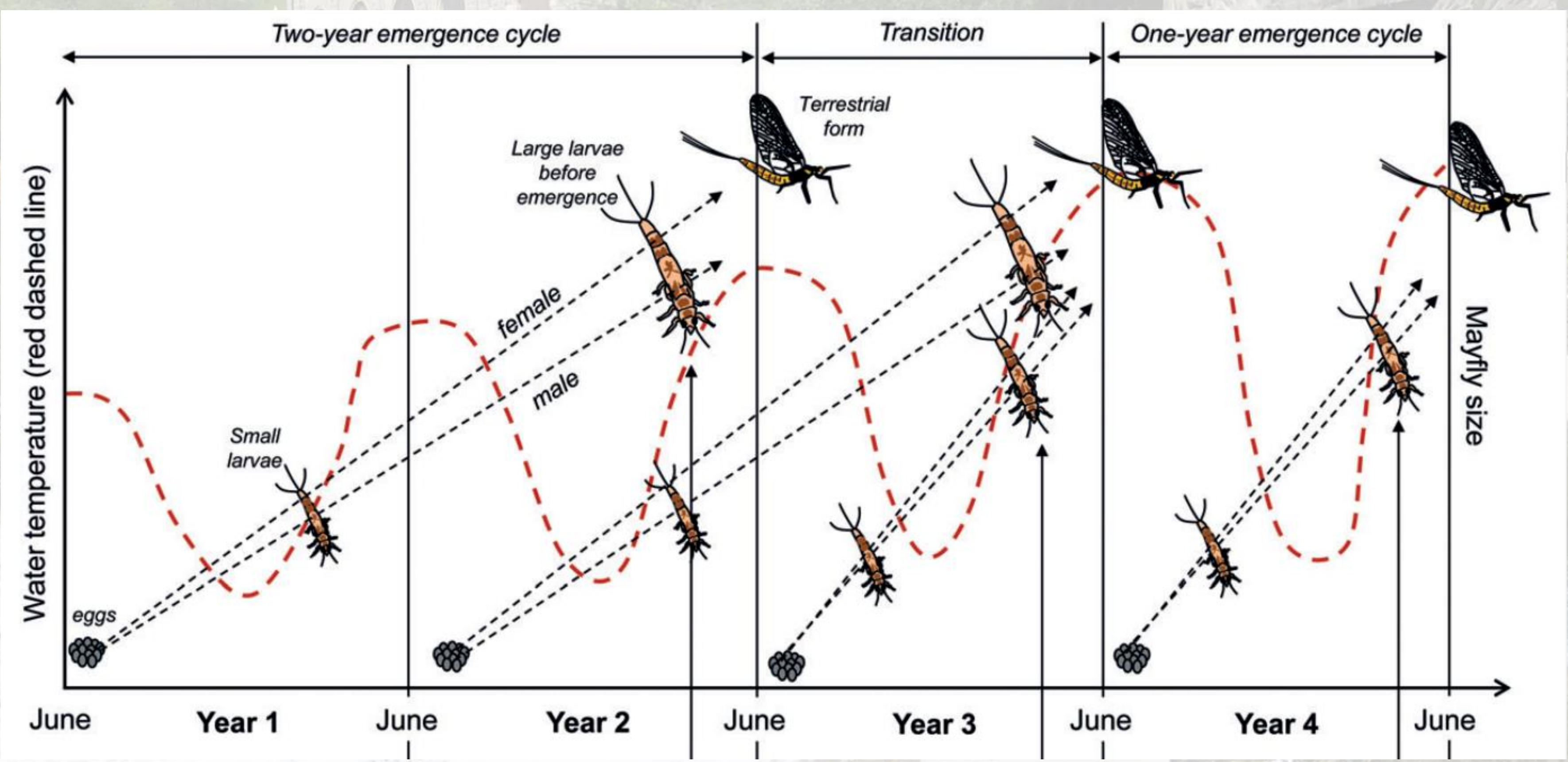
Photography encouraged

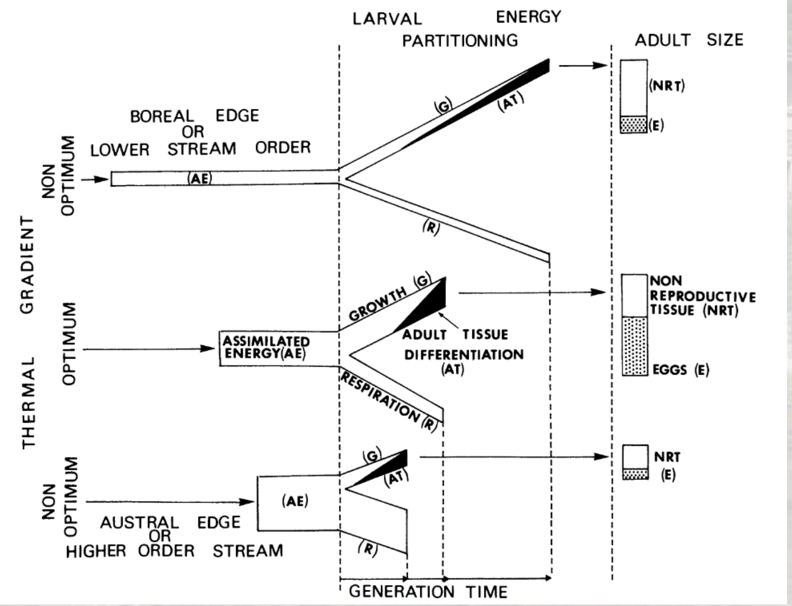
Thermal Regime

Since the earliest studies water temperature was recognized as one of the most important drivers in stream ecosystems, shaping both biodiversity and ecosystem functioning.

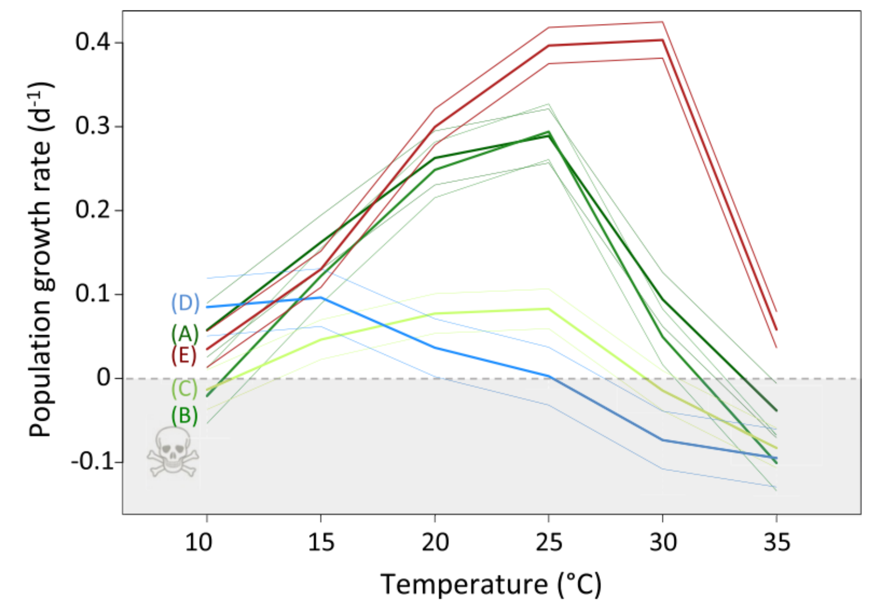


Everall N.C., Johnson M.F., Wilby R.L. & Bennett C.J. (2015) Detecting phenology change in the mayfly Ephemera danica: Responses to spatial and temporal water temperature variations. Ecological Entomology 40, 95–105.

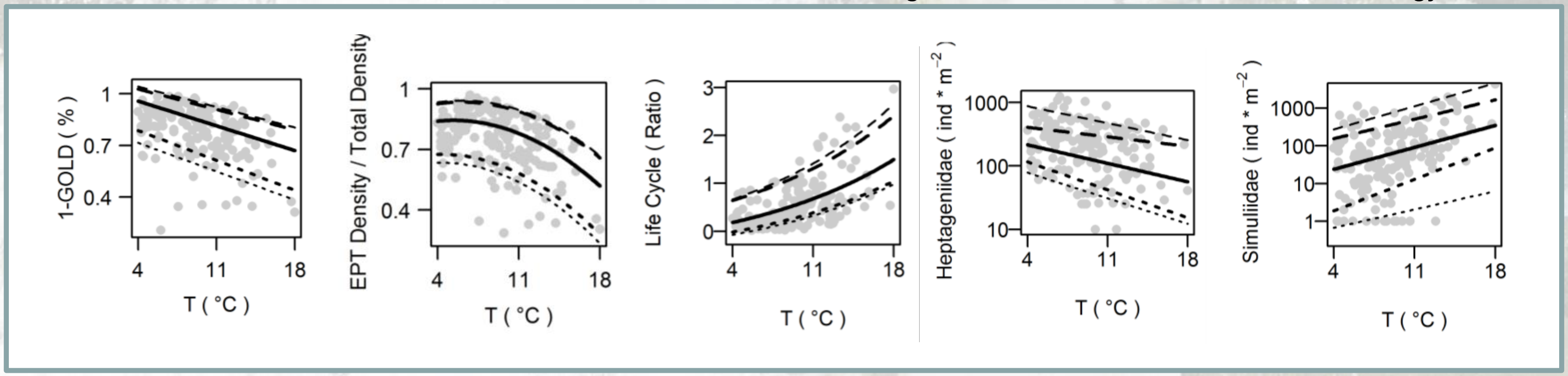
Ecological Significance



Vannote R.L. & Sweeney B.W. (1980) Geographic Analysis of Thermal Equilibria : A Conceptual Model for Evaluating the Effect of Natural and Modified Thermal Regimes on Aquatic Insect Communities. The American Naturalist 115, 667–695.



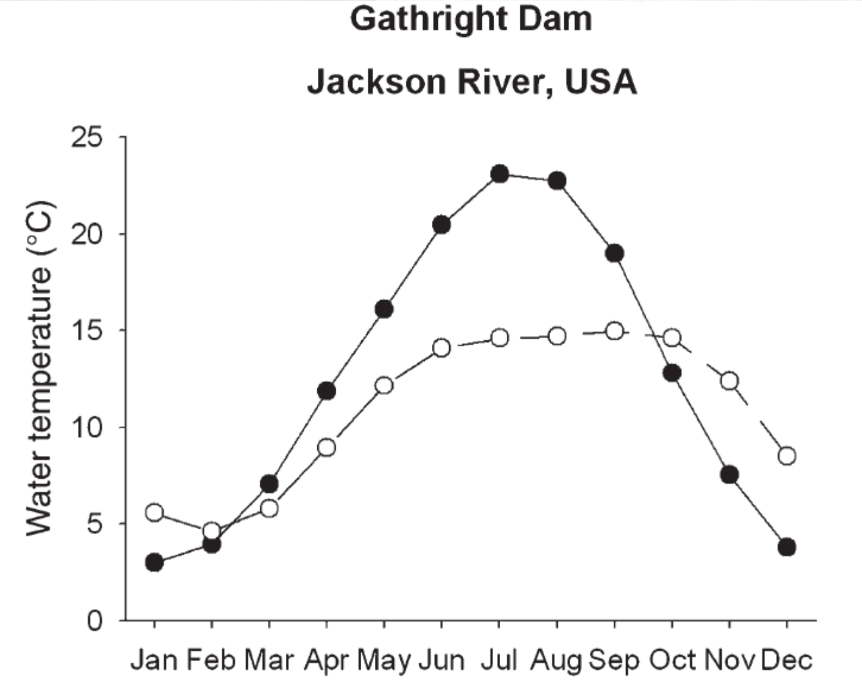
Majdi N., Traunspurger W., Fueser H., Gansfort B., Laffaille P. & Maire A. (2019) Effects of a broad range of experimental temperatures on the population growth and body-size of five species of free-living nematodes. Journal of Thermal Biology 80, 21–36.



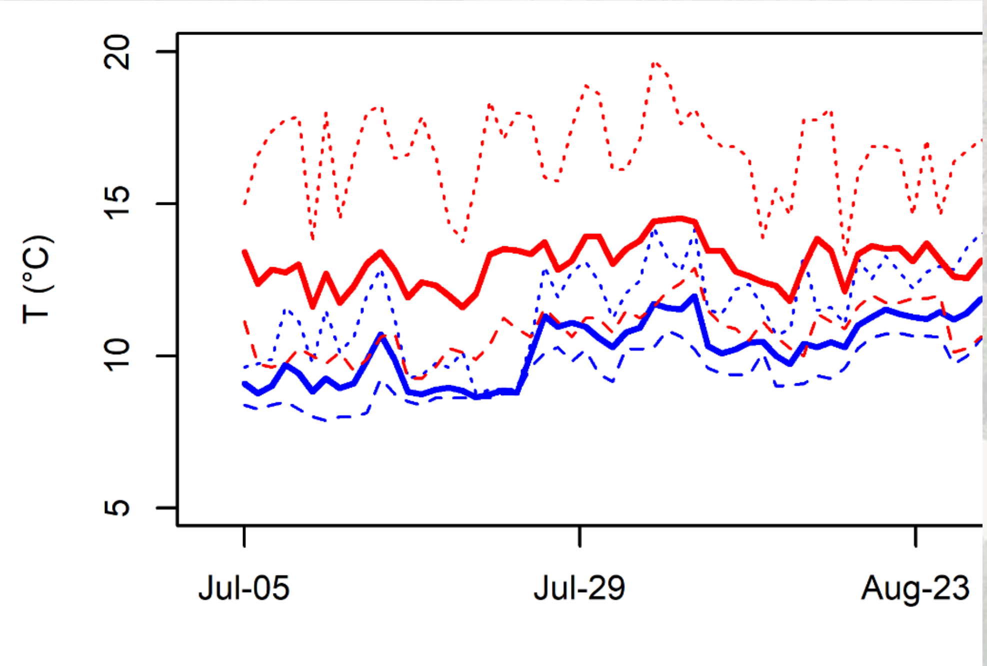
Fornaroli R., Calabrese S., Marazzi F., Zaupa S. & Mezzanotte V. (2019) The influence of multiple controls on structural and functional characteristics of macroinvertebrate community in a regulated Alpine river. Ecohydrology, 1–12.

Thermal Alterations

COLD-WATER POLLUTION



WARM-WATER POLLUTION



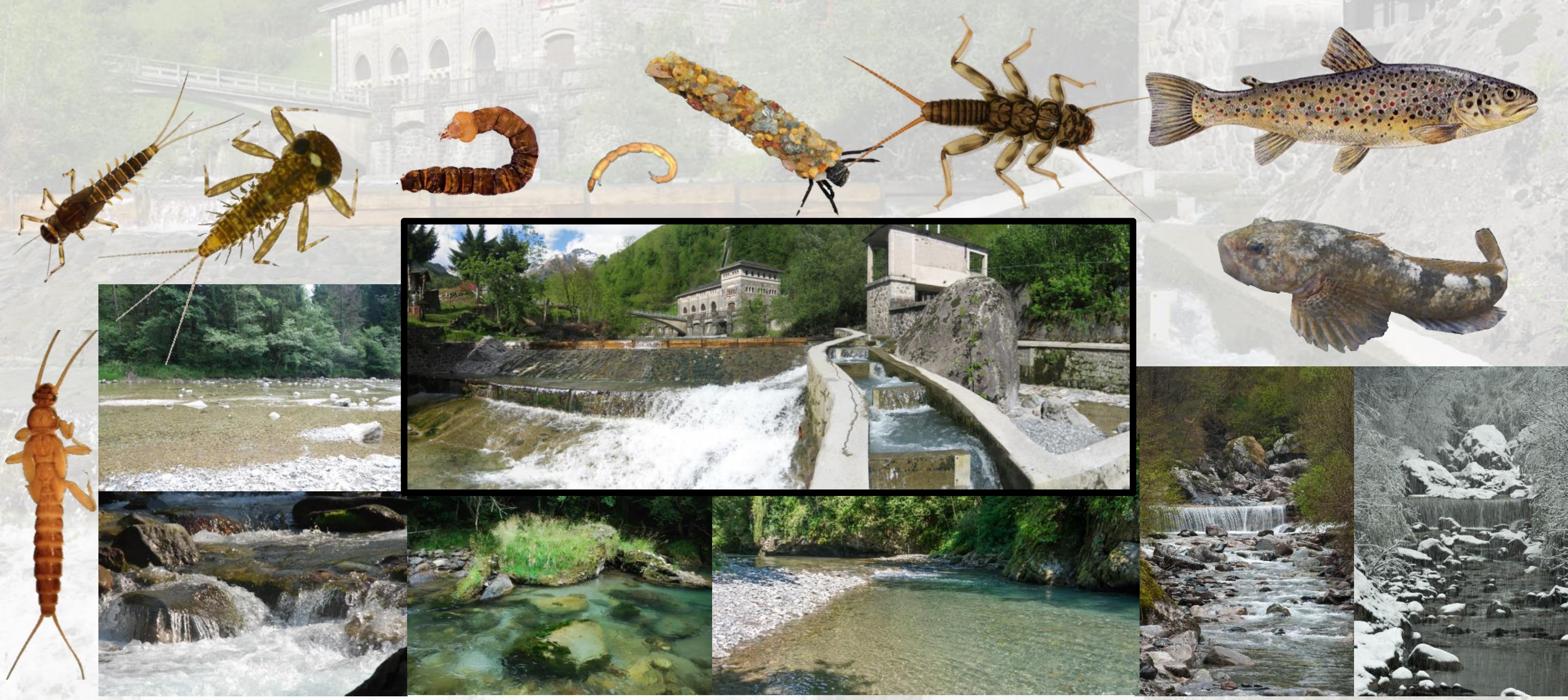
The correct definition of ecosystem needs is essential in order to guide policy and management strategies to optimize the use of water.

Olden J.D. & Naiman R.J. (2010) Incorporating thermal regimes into environmental flows assessments: Modifying dam operations to restore freshwater ecosystem integrity. *Freshwater Biology* **55**, 86–107.

Comte L. & Olden J.D. (2017) Climatic vulnerability of the world's freshwater and marine fishes. *Nature Climate Change* 7, 718–722.

Aims of the study

To predict the impacts on the thermal regime caused by the installation of new hydroelectric power plants or by a different management of the existing ones.



To develop quantitative models to be used for management and decision-making processes.

Study Area

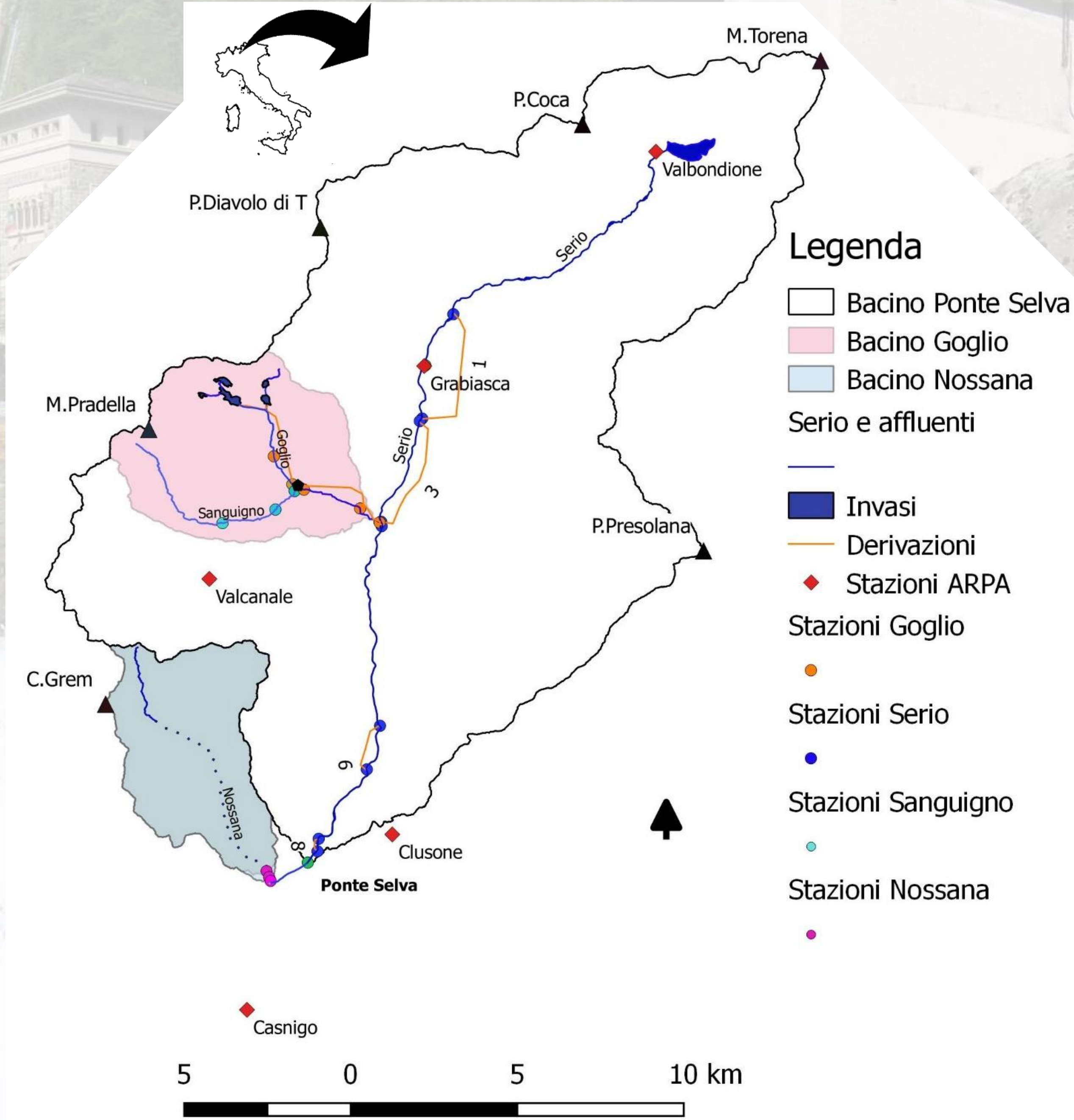
The alpine valley of the Serio River

-SERIO
High altitude reservoir
Run-Of-The river plants
Snow-melt/storm-water

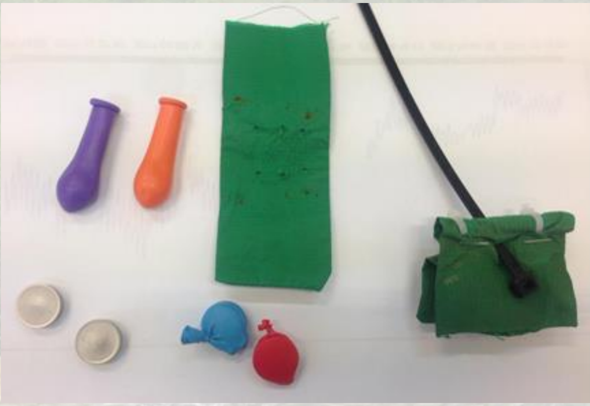
GOGLIO
High altitude reservoir
Run-Of-The river plants
Snow-melt/storm-water

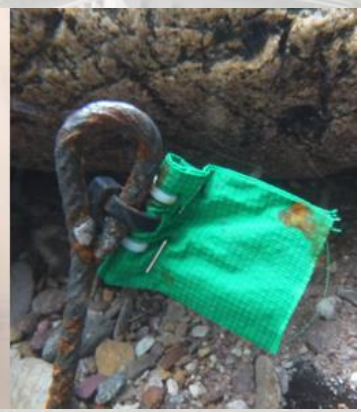
SANGUIGNO
Natural
Snow-melt/storm-water

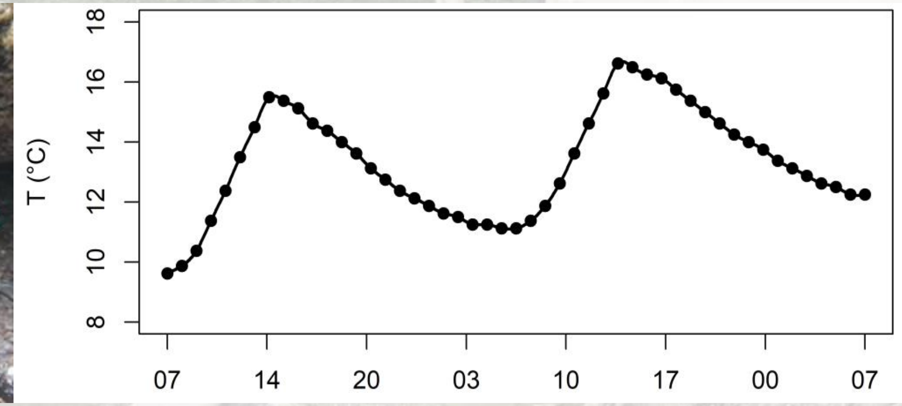
NOSSANA
Water diversions for potable uses
Karst spring

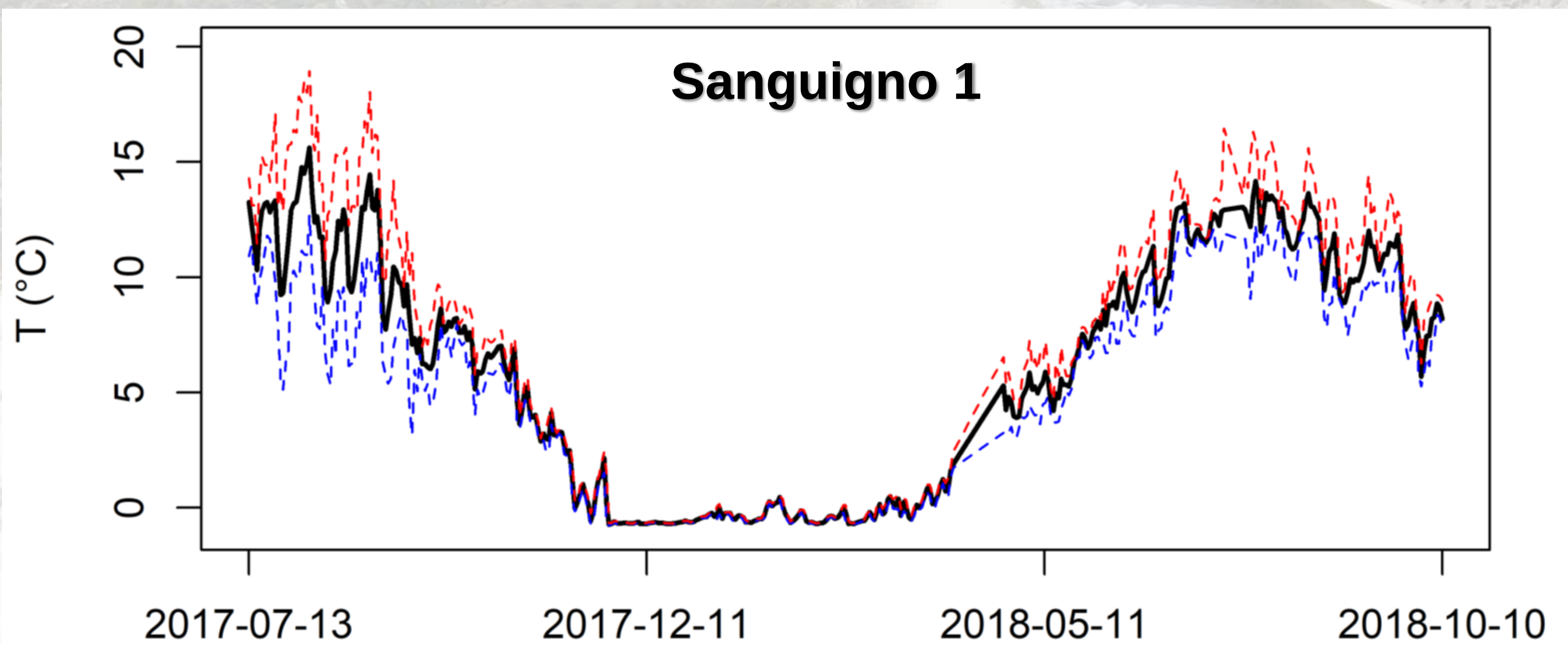


Temperature Monitoring



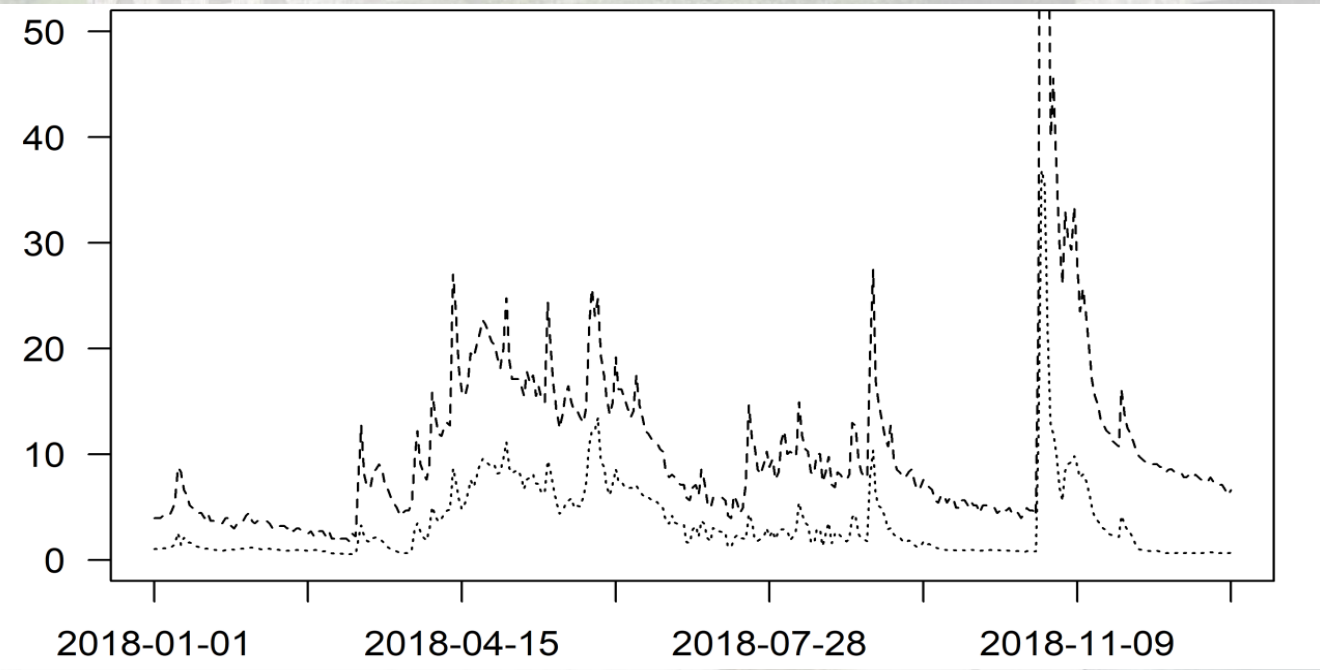






Flow Monitoring

Two water level recorders were located in the study area: the first one was located between the two upper sampling sites and the second one about 500m downstream site 7 along the Serio River.

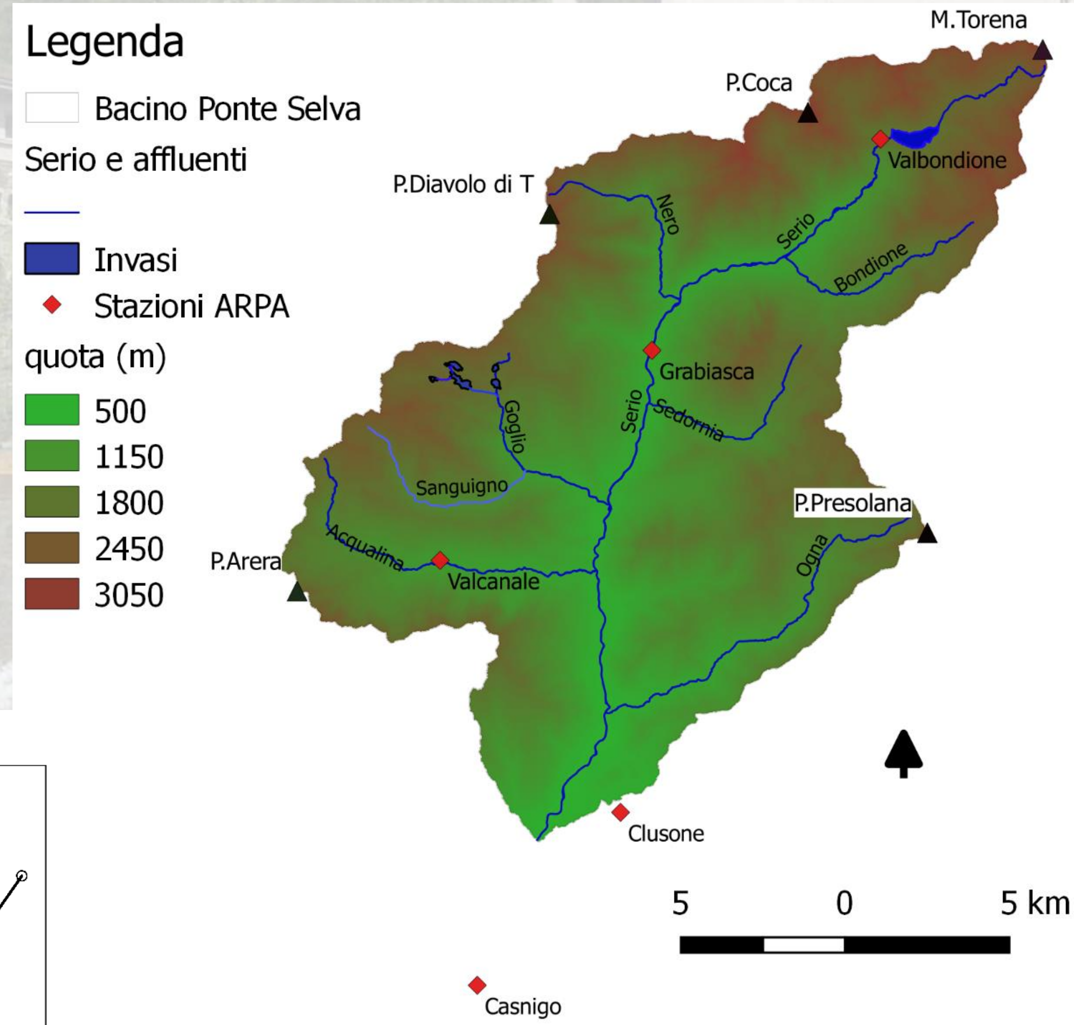


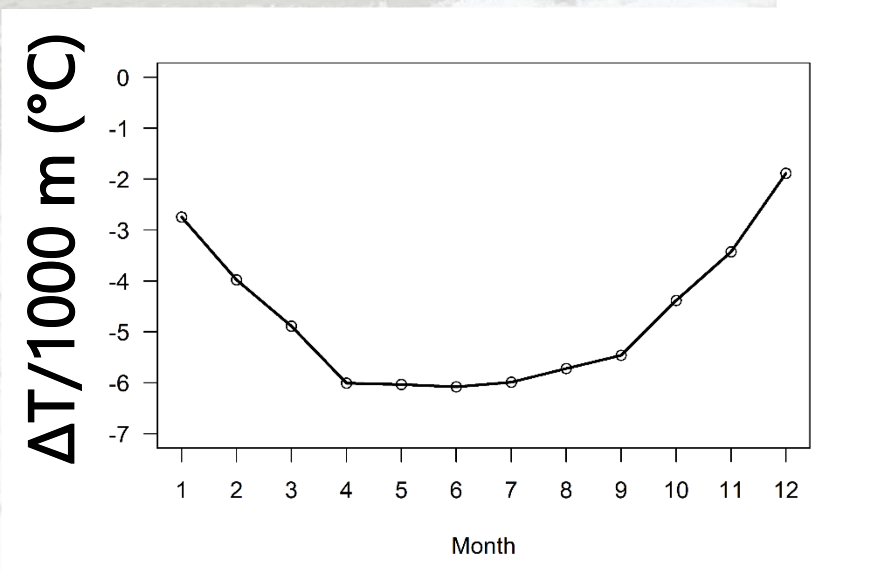
The water level data were used, together with the diversion rates of each hydroelectrical power plants, to reconstruct the mean daily discharge in each site of Serio River.

Air Temperature Interpolation

- **Monthly thermal gradients**
- **Daily interpolations**

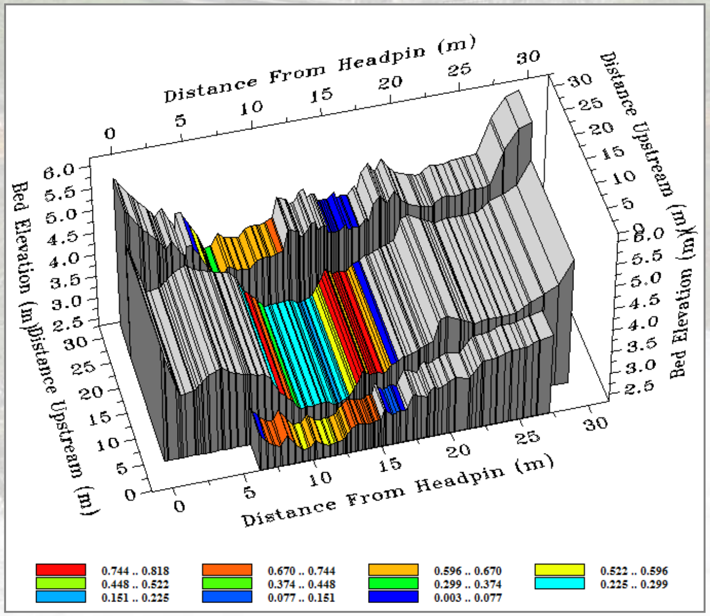
- **Daily air temperature of the relevant sites as a function of altitude**

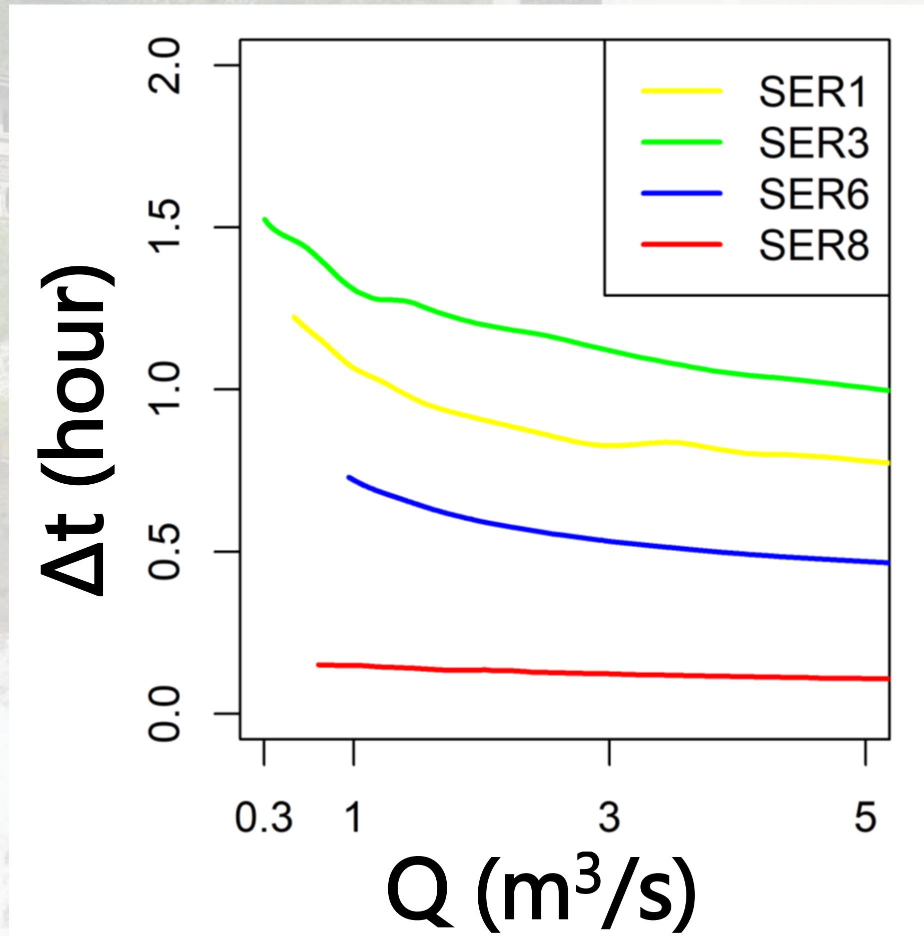




Transit Time

$$\Delta t = \frac{\Delta S}{v}$$





Strickler's formula: $v = \sqrt{i} * \sqrt[3]{R^2} * \frac{1}{n}$

i=slope *R=hydraulic radius* *n= Manning's coefficient*

Fornaroli R., Cabrini R., Sartori L., Marazzi F., Canobbio S. & Mezzanotte V. (2016) Optimal flow for brown trout: Habitat – prey optimization. Science of The Total Environment 566–567, 1568–1578.

Model Selection

Multiple Linear Regression was used to model the relationships between meteorological conditions and stream water temperature by fitting a linear equation to observed data.

THERMAL REGIME

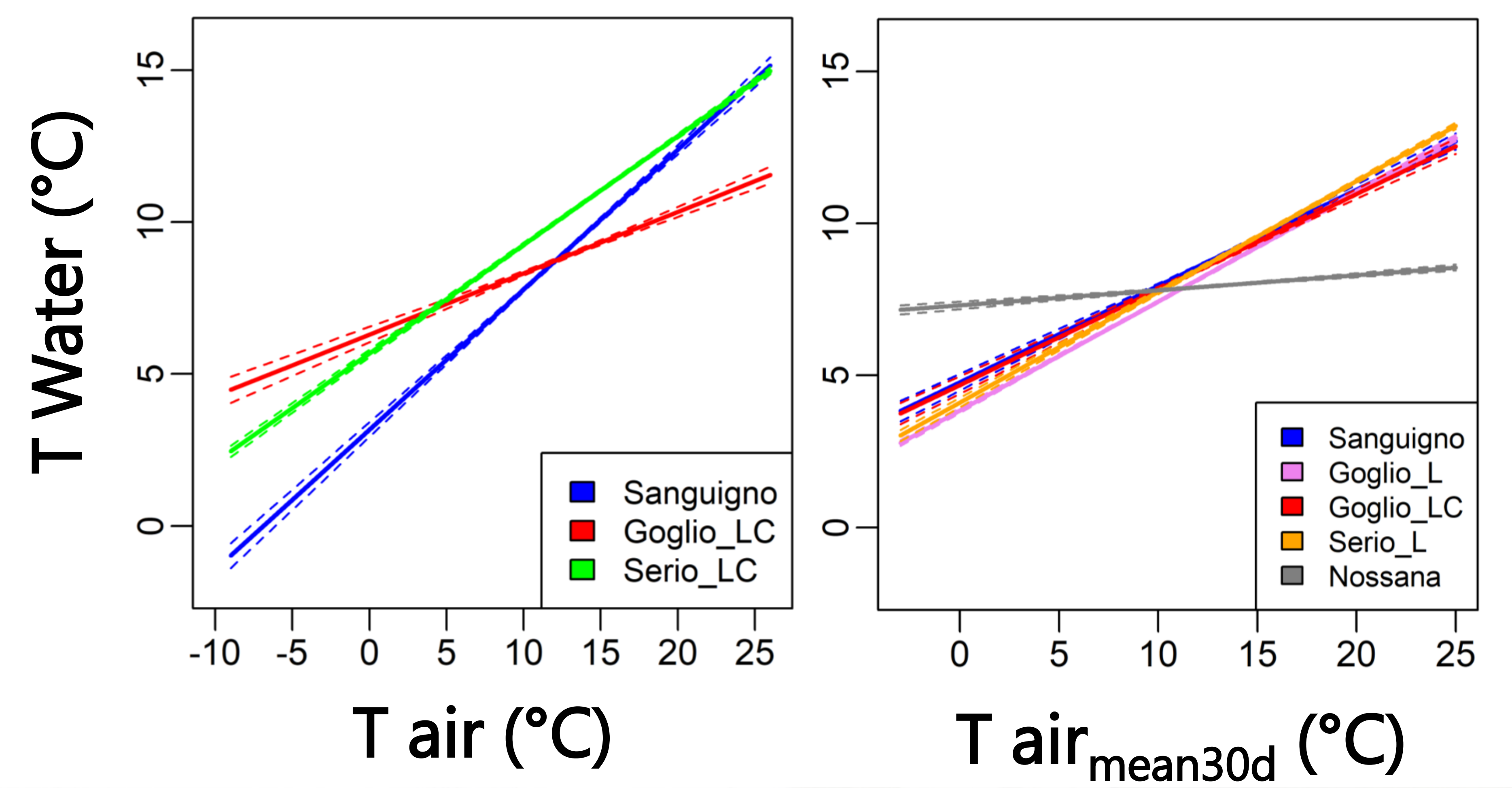
Dependent Variable	Independent Variables
Mean Daily Water T (°C)	Mean Daily Air T (°C)
	Mean 30-Days Air T (°C)
	Distance from Headwater (km)
	Elevation (m. a.s.l.)

THERMAL ALTERATIONS

Dependent Variable	Independent Variables
Mean Daily Water T Difference (°C)	Upstream Mean Daily Water T (°C)
	Mean Daily Air T (°C)
	Mean 30-Days Air T (°C)
	Corrivation Time (min)

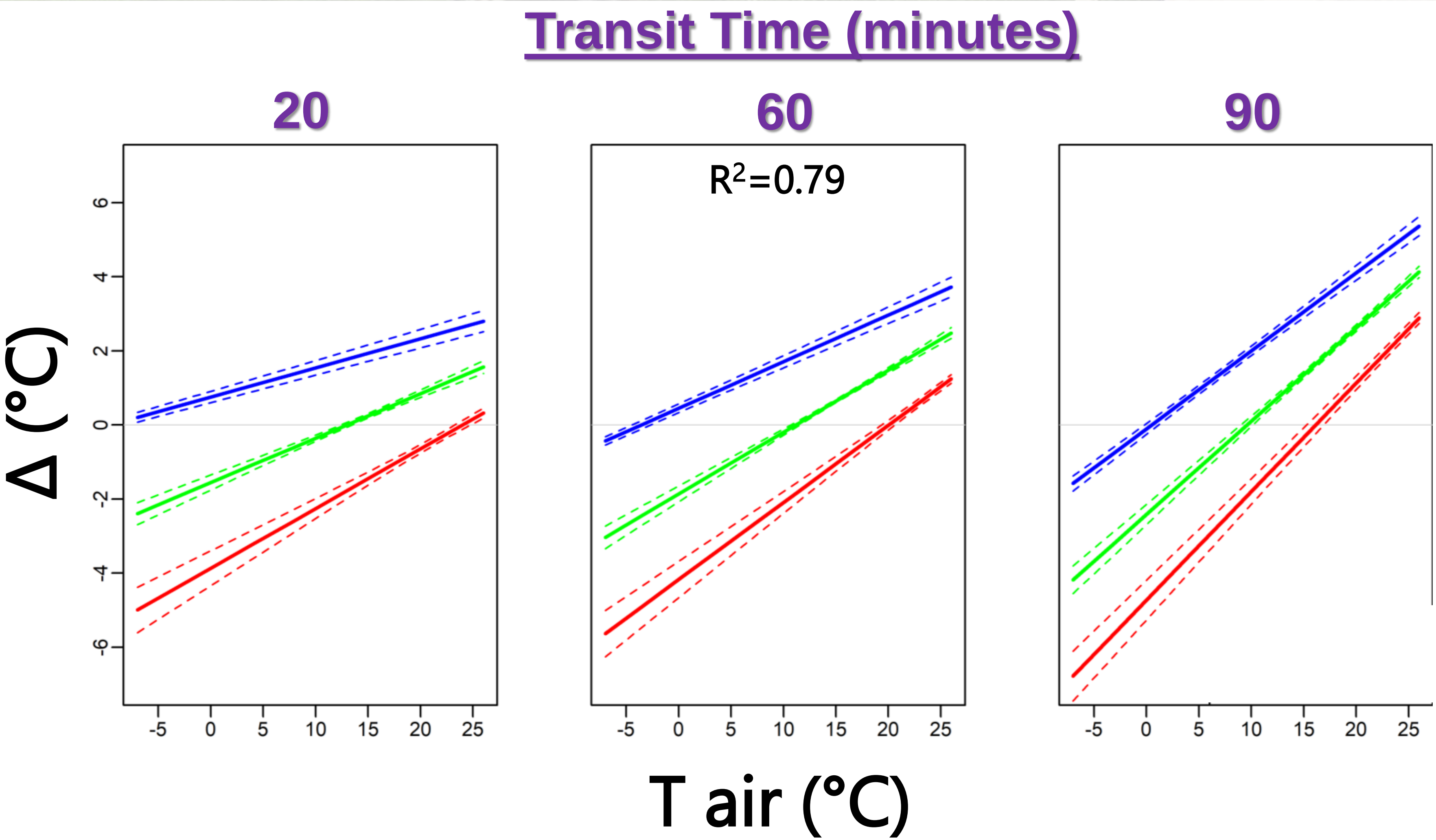
All the models were fitted using 75% of the data and the remaining 25% were used to calculate Predictive R^2. This procedure were bootstrapped 500 times. The models were simplified using a backward step-wise procedure until the identification of the optimal solution.

Thermal Regime



Daily air temperature is important only for natural snow-melt/stormwater fed streams and stream reaches subjected to flow reduction due to ROR operation.

Run-Of-The-River power plants

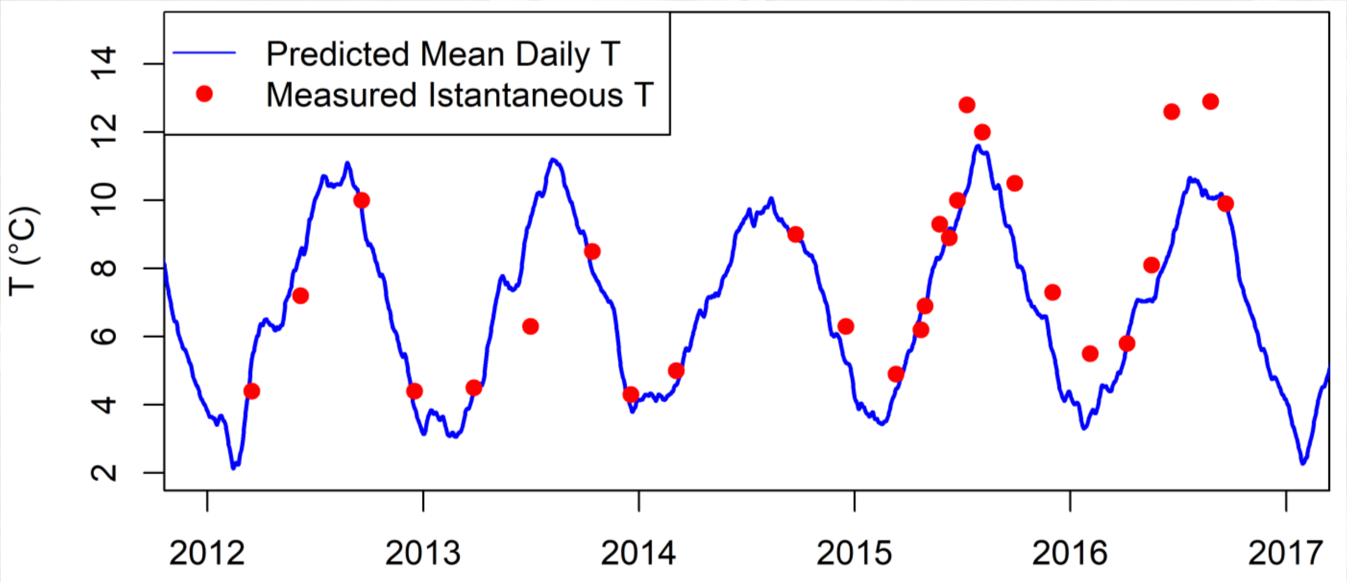


Upstream water temperature: 5 °C 10 °C 15 °C

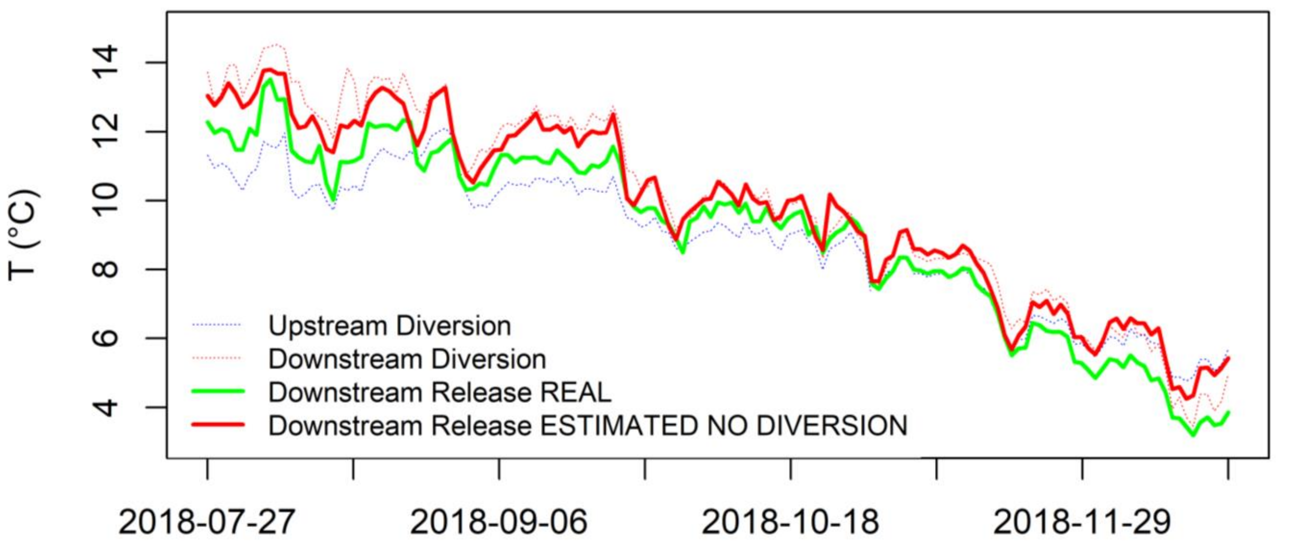
ΔT = 3.311 – 0.737*(Tran_Time) – 0.462*(Up_Water_T) + 0.113*(Air_T:Corr_Time) + 0.008*(Air_T:Up_Water_T)

Models Applications

Reconstruction of daily water temperature for selected



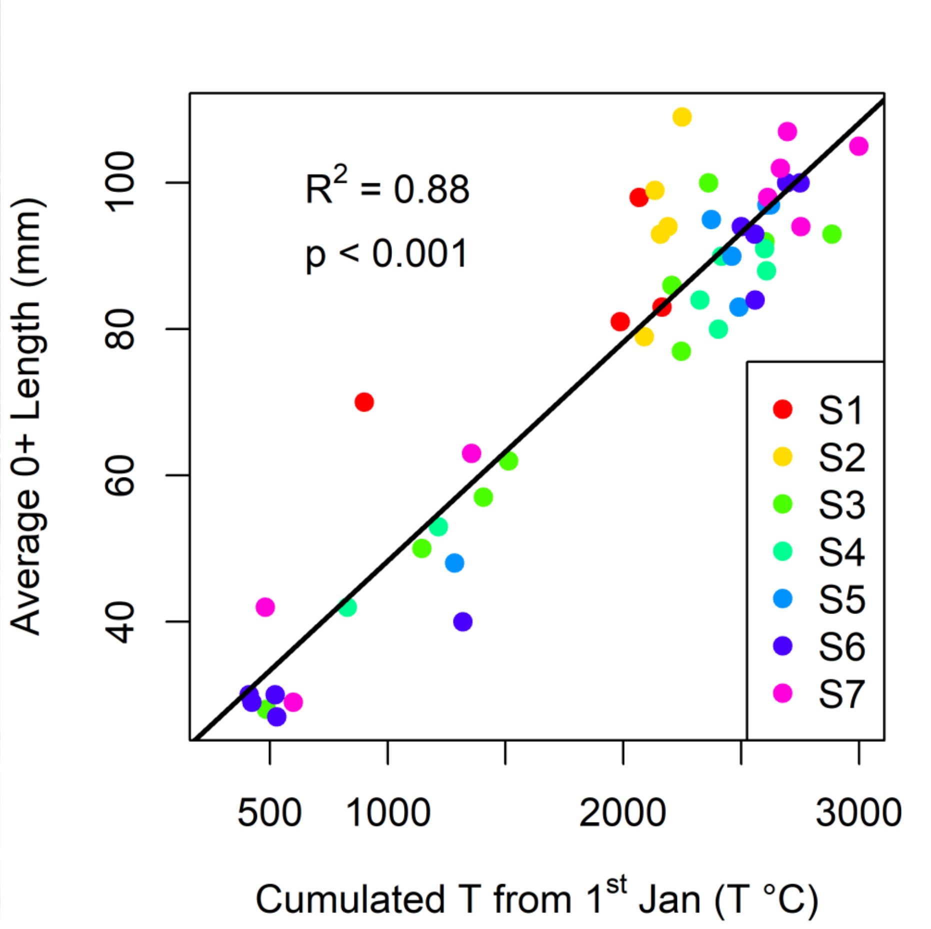
Prediction of the thermal alterations caused by different management of Run-Of-River hydroelectric power plants



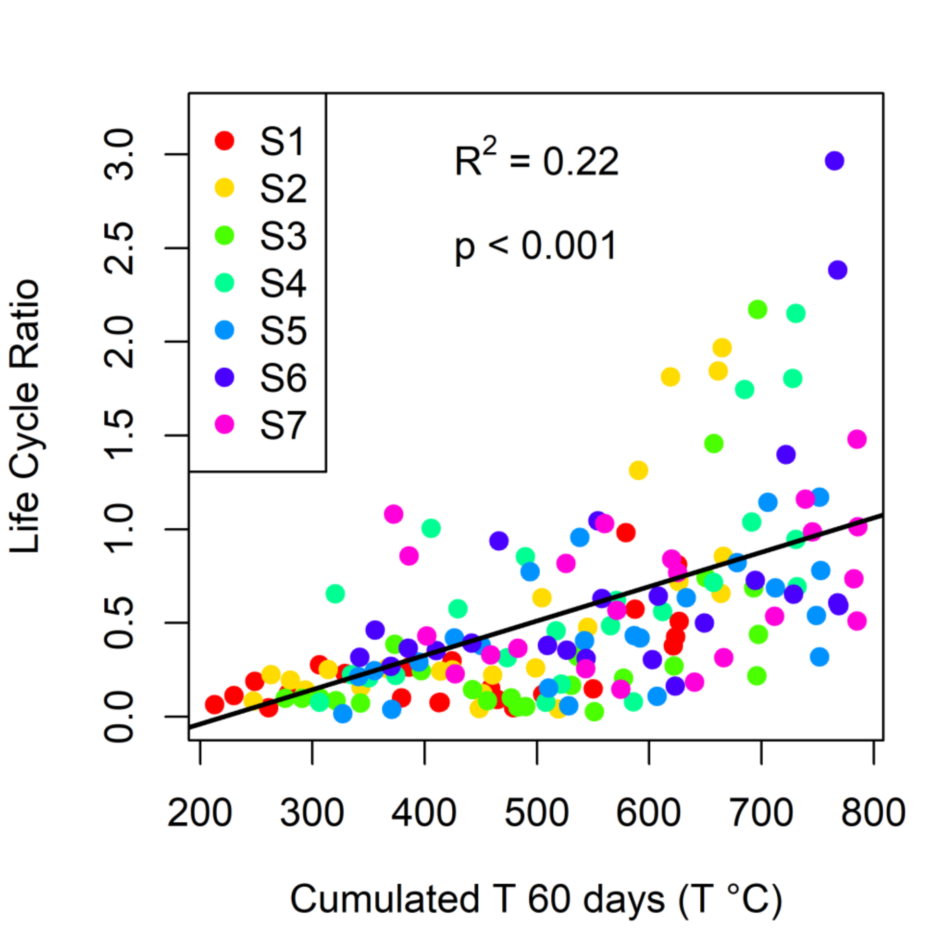
Ecological Significance

The availability of antecedent daily temperatures data, instead of instantaneous one, can improve the interpretation of biological data.

FISH



MACROINVERTEBRATES



Conclusions

<u>High altitude reservoirs profoundly alter the thermal regime of streams</u> with potential implications for the overall ecosystem dynamics.
Structural measures (e.g. multiple level outlets) can reduce the alterations to the downstream sectors while management actions (e.g. residual flow) play only a minor role.

<u>The overall impact of run-of-river hydropower plants on thermal regime is almost negligible.</u> The key drivers of thermal alterations in the diverted stretches were the distance from the diversion and the residual flow.

<u>Further researches are needed to properly describe the relationships among thermal regime and biological communities</u>, similarly to what was done in the last 10 years for the development of flow-ecology relationships.

This kind of information will allow to predict or to describe changes within the biological communities and in ecosystem functions and ultimately to <u>properly manage and conserve the Alpine stream ecosystems</u>.

Poole G.C. & Berman C.H. (2001) An ecological perspective on in-stream temperature: Natural heat dynamics and mechanisms of human-caused thermal degradation. *Environmental Management* 27, 787–802.
Carlisle D.M., Nelson S.M. & May J. (2016) Associations of stream health with altered flow and water temperature in the Sierra Nevada, California. *Ecohydrology* **9**, 930–941.

Thanks for your attention!

QUESTIONS?

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