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# Response of whitefish embryos to thermal stress diverges between perialpine populations

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## Background and objectives

- Populations evolving in different environments should develop adaptations to local conditions
- Analyzing the response of individual populations to temperature is important to predict their fate in a warming climate
- Here we provide quantitative data on development rates and survival response to two realistic local temperature treatments of embryos of *Coregonus spp.* from three perialpine lakes, at the southern edge of distribution of the genus.
- We expect southern lakes population to perform better to high temperature as temperature in those latter is naturally higher.

## Method

- Common garden experiment
- 4 populations from 3 lakes
- Intra-population crossings using wild fish
- Blocked full factorial design (table 1)
- Embryos incubated at 7 and 9°C in 24-well microplates in climate chambers in Thonon
- Traits of interest: survival from eyed stage to hatching, timing of hatching
- Effects analyzed using GLMM

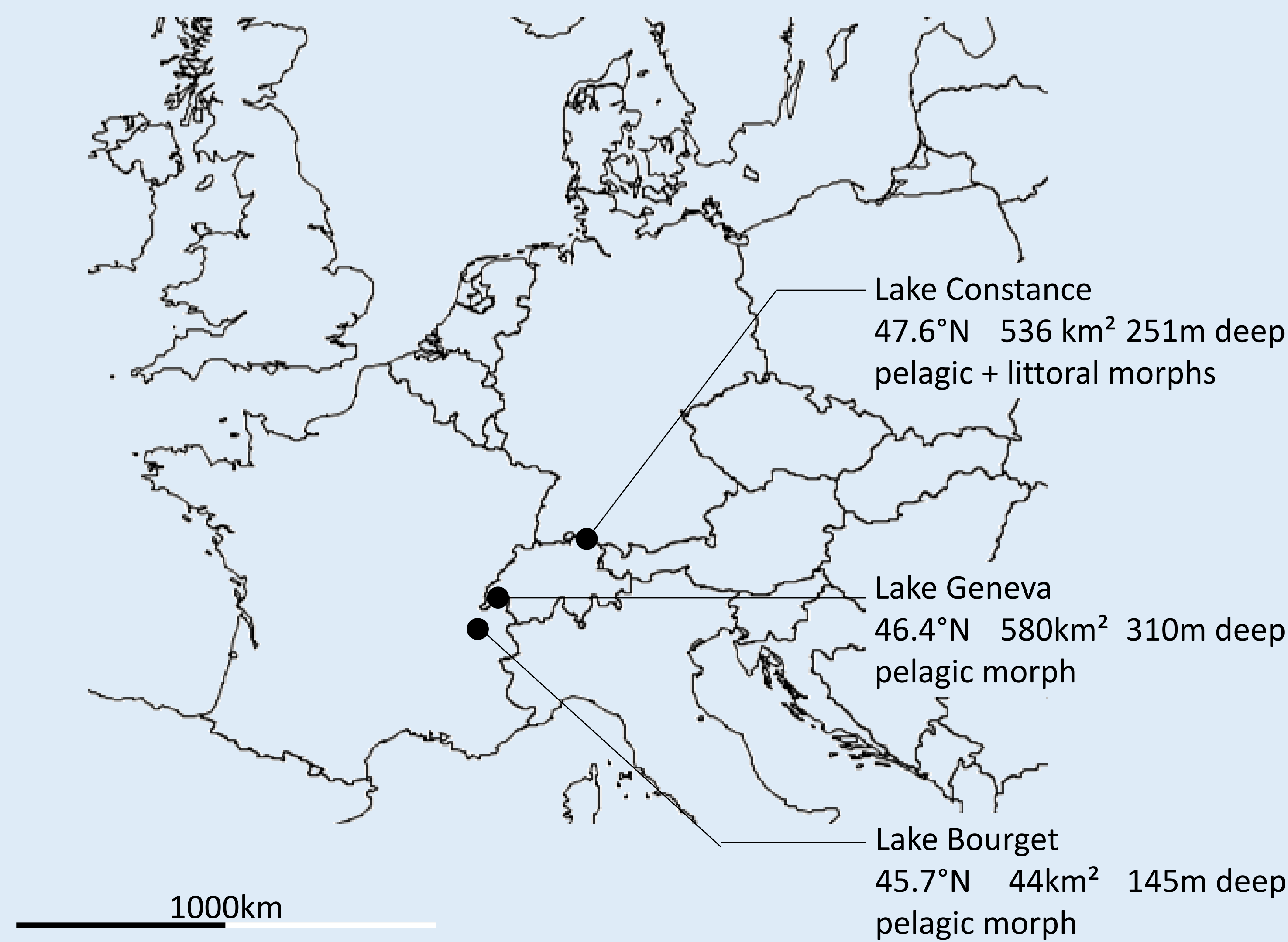


Figure 1- Characteristics of the study sites and morph of whitefish used in the experiment

Table 1- Artificial crossings realized for the common garden experiment (dam x sire).

Population	Morph	Block 1	Block 2	Block 3	families
L. Constance	pelagic	4x3	4x3	4x3	36
L. Constance	littoral	4x3			12
L. Geneva	pelagic	4x3	4x3	4x3	36
L. Bourget	pelagic	4x3	4x3	4x3	36

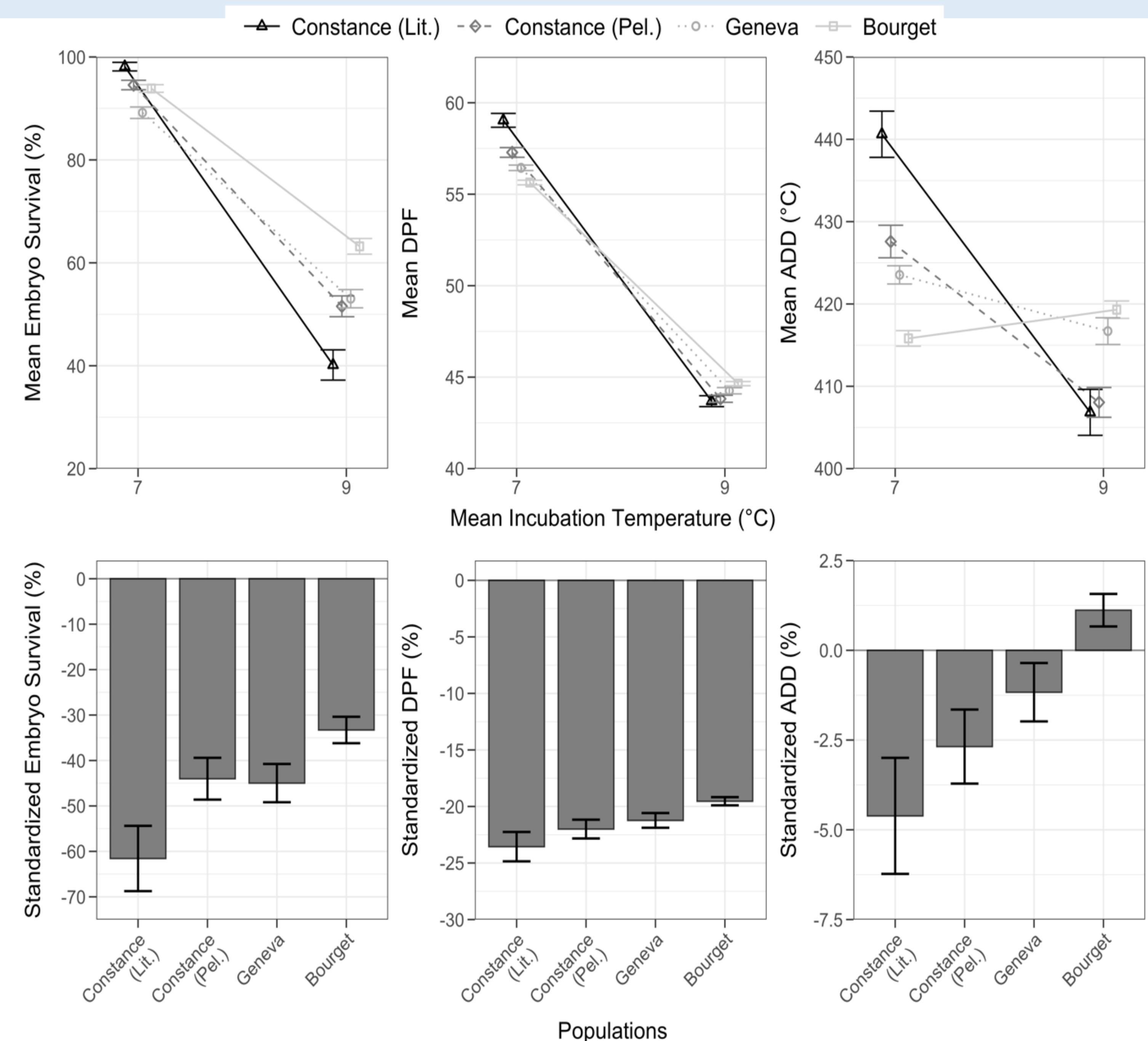
## Results

Table 2- Percentage of embryos reaching the eye-up stage.

Incubation temp. (°C)	Eyed embryos (%)			
	L. Constance (littoral)	L. Constance (pelagic)	L. Geneva	L. Bourget
7.0	61.8	46.8	59.9	80.7
9.0	64.6	47.3	61.2	77.2

Table 3- Likelihood ratio test output for each model selected for embryo survival and accumulated degree days (°C; ADD) from European whitefish (*Coregonus spp.*) in lakes Constance (littoral and pelagic forms), Geneva, and Bourget. The full model that was selected is bolded for each trait and species. t indicates temperature, pop indicates population. Statistics for DPF not presented here very similar to ADD,

Trait	Model	Effect Tested	df	χ <sup>2</sup>	p-value
Embryo Survival	<b>t + pop + t:pop + female:male + female + block + plate</b>				
	pop + female:male + female + block + plate	t	1	377.56	< 0.001
	t + female:male + female + block + plate	pop	3	4.14	0.246
	<b>t + pop + female:male + female + block + plate</b>	t:pop	3	39.79	< 0.001
	t + pop + t:pop + female + block + plate	female:male	1	14.35	< 0.001
	t + pop + t:pop + female:male + block + plate	female	1	10.39	0.001
	t + pop + t:pop + female:male + female + plate	block	1	27.27	< 0.001
t + pop + t:pop + female:male + female + block	plate	1	51.31	< 0.001	
Incubation Period (ADD)	<b>t + pop + t:pop + female:male + female + male + block + plate</b>				
	pop + female:male + female + male + block + plate	t	1	33.21	< 0.001
	t + female:male + female + male + block + plate	pop	3	1.49	0.686
	<b>t + pop + female:male + female + male + block + plate</b>	t:pop	3	51.28	< 0.001
	t + pop + t:pop + female + male + block + plate	female:male	1	59.13	< 0.001
	t + pop + t:pop + female:male + male + block + plate	female	1	4.30	0.038
	t + pop + t:pop + female:male + female + block + plate	male	1	8.15	0.004
	t + pop + t:pop + female:male + female + male + plate	block	1	17.53	< 0.001
	t + pop + t:pop + female:male + female + male + block	plate	1	199.59	< 0.001



## Synthesis and discussion

- Populations have contrasted response to temperature for all traits suggesting genetic divergence.
- The four studied populations showed high survival at 7°C and increased mortality at 9°C, L. Bourget having the best survival and L. Constance littoral the poorest
- All populations except L. Bourget population had a precocious hatching at 9°C suggesting they are stressed.
- All populations performed better compared to L. Konnesevi (FI) whitefish in the North of distribution area (Stewart et al. 2021).

- Put together, these results and those of Stewart et al. (2021) suggest that southernmost studied populations are better adapted to warm temperatures
- Population management, including supportive breeding or translocation, should consider genetic divergences of populations to maintain/increase adaptive potential.

Reference: Stewart, T.R., Mäkinen, M., Goulon, C., Guillard, J., Marjomäki, T.J., Lasne, E., et al. 2021. Influence of warming temperatures on coregonine embryogenesis within and among species. *Hydrobiologia* **848**: 4363–4385.