RESPONSES TO COMBINED TEMPERATURE AND IMMUNE STRESSORS IN WILD GUDGEON

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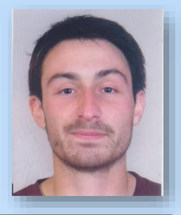


CONTEXT

- ✓ Aquatic ecosystems are increasingly exposed to multiple stressors because of climate change and emerging pathogens, but their combined effects on fish are elusive.
- ✓ Physiological and behavioral responses to temperature and immune challenges caused by pathogens could potentially interact
- ✓ Different populations exposed to contrasted environments could differ in their sensitivity to stressors

QUESTIONS

- ✓ **Are there interactions between temperature and immune stressors across levels of biological organization ?**
- ✓ **Is there a variability of response between populations ?**

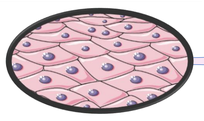
MODEL SPECIES

Gobio occitaniae, Kottelat & Persat, 2005

- ✓ The gudgeon *Gobio occitaniae.*
- ✓ Sedentary and ubiquitous.
- ✓ Exposed to contrasted temperatures and pathogens around Toulouse, France
- ✓ Optimal temperature around 17°C

MEASURED TRAITS

Cellular level



- ✓ **Inflammatory response :** local skin swelling at injection
- ✓ **Energy reserves in muscles:**
  - ❑ Carbohydrates
  - ❑ Lipids
  - ❑ Proteins

  } Available energy-AE (kJ.g tissue^{-1})
  - ❑ Electron transport system

  } Energy consumption-EC (kJ.g tissue.h^{-1})

  ➔ **Cellular Energy Allocation (CEA) = AE/EC** (h^{-1})

Organ level

- ✓ **Global condition index**
  - ❑ Daily mass change (%g.day^{-1})
  - ❑ Hepatosomatic index (HSI)
  - ❑ Gonadosomatic index (GSI)
  - ❑ Splenosomatic index (SSI)

Individual level

- ✓ **Behaviour**
  - ❑ **General activity (PCA Axis 1) :** - Time swimming, in central area , water column, latency to forage, foraging events
  - ❑ **Sociability (PCA Axis 2):** - Encounter numbers, Average Nearest Neighbour Distance (ANND)

POPULATIONS

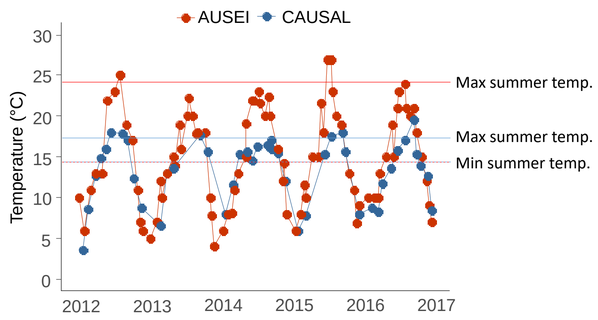


Fig. 1. *Thermal regimes on CAUSAL (blue) and AUSEI (red)*

- ✓ 2 populations with contrasted thermal regimes :
  - ➔ (AUSEI & CAUSAL)

EXPERIMENTAL DESIGN

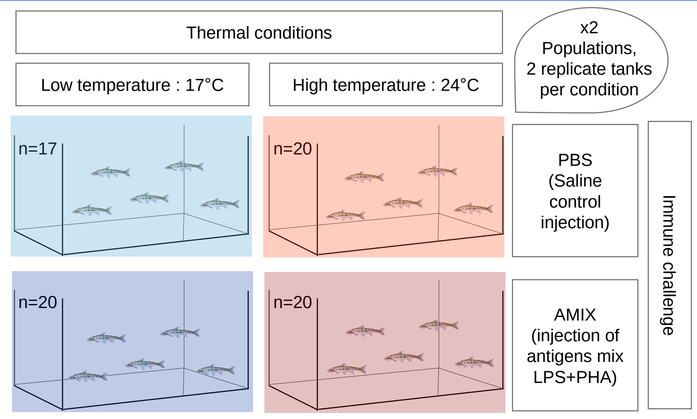


Fig. 2. *Full factorial design (7 days exposure). Low temperature 17°C = optimal temperature and 24°C = maximum average summer temperature recorded in the warmest site. AMIX = antigen mixture of LPS lipopolysaccharide and PHA phytohemagglutinin mimicking a pathogen attack.*

MULTIPLE STRESSORS EFFECTS

Statistics: Linear Mixed Model (lmer) with treatment and/or population as fixed effects and replicate tank as random effect.

☆ indicates significant variability between population

Cellular level

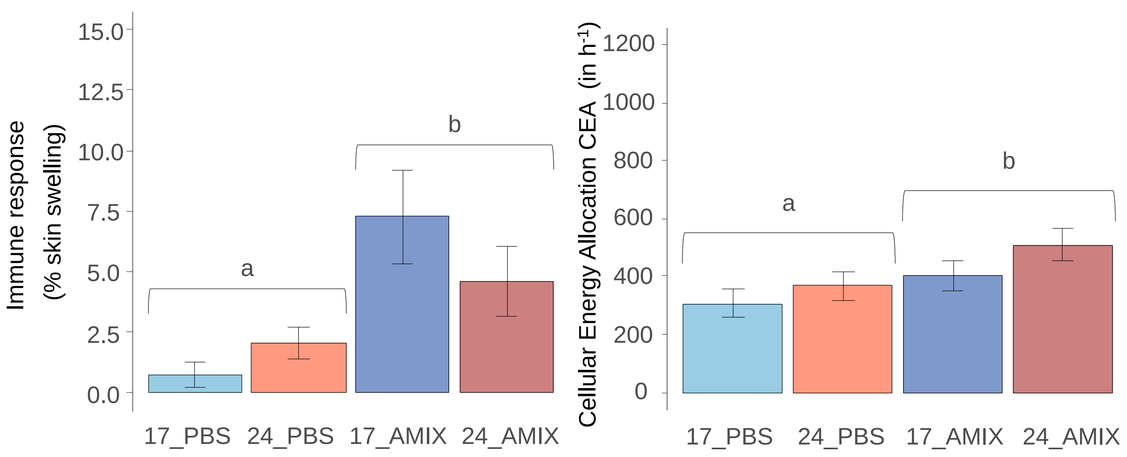


Fig 3: *Effects of treatments on fish immunity*

Fig 4: *Effects of treatments on Cellular Energy Allocation of fish*

Conclusion

Immunity	AMIX	Temp	AMIX x Temp
Results	↗	NS	NS

- ✓ Antigen injection only increased inflammatory response as expected. No interaction.

Conclusion

CEA	AMIX	Temp	AMIX x Temp
Results	↗	NS	NS

- ✓ Immune challenge only increased cellular energy allocation. No interaction.

Organ level

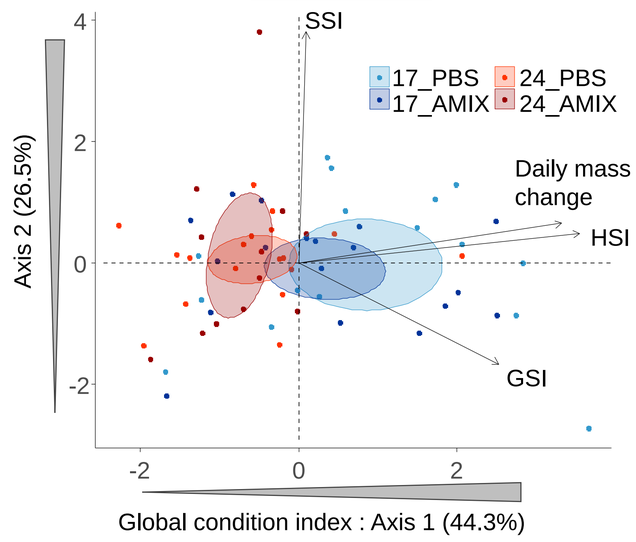


Fig 5: *Effects of treatments on global condition index of fish*

Conclusion

Global condition	AMIX	Temp	AMIX x Temp
Results	NS	↘	NS

- ✓ Temperature only decreased body condition. No interaction.

Individual level

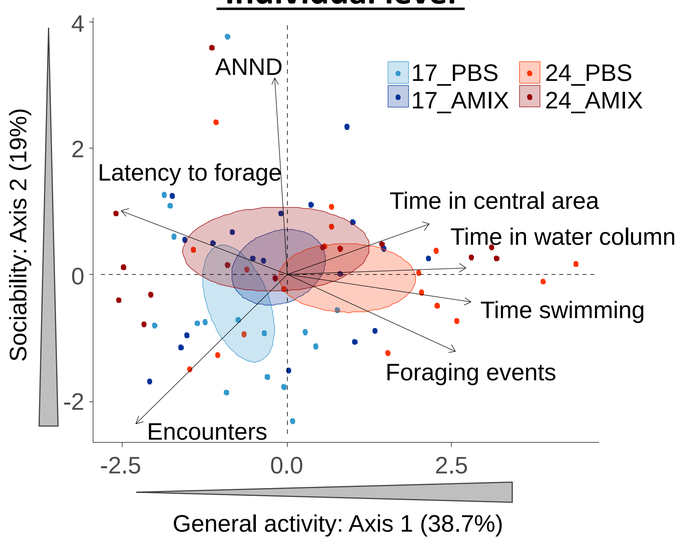


Fig 6: *Effects of treatments on behavior of fish*

Conclusion

		AMIX	Temp	AMIX x Temp
General Activity	Results	☆ ↘	↗	Antagonistic
Sociability	Results	☆ ↘	NS	NS

- ✓ Temperature increased general activity while Immune challenge decrease it as expected. Interaction between stressors is antagonistic.

POPULATION VARIABILITY

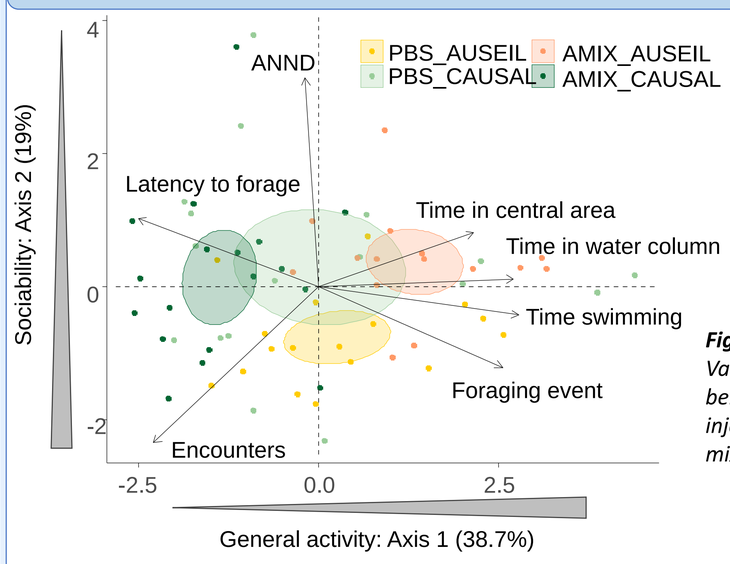


Fig 7. *Interpopulation Variability on behavior of fish injected with antigen mixture*

- ✓ Populations differed mostly in their behavioural responses to immune challenge (general activity and sociability) but not to temperature.

CONCLUSIONS/PERSPECTIVES

- ✓ **Both stressors affected fish responses but at different levels of biological organization :**
  - **Temperature :** at the organ and individual level
  - **Immune challenge :** at the cellular and individual level.

- ✓ **Interactions** between stressors occured **only at high level of organization** on behavior (antagonistic effects on activity).
- ✓ Responses (behavior) were **contrasted between populations** suggesting **different sensitivity to stressors.**
- ✓ However, responses to temperature did not differ between populations**,** suggesting strong effects of other environmental factors such as pathogens. Further work on a higher number of replicate populations is now needed.

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