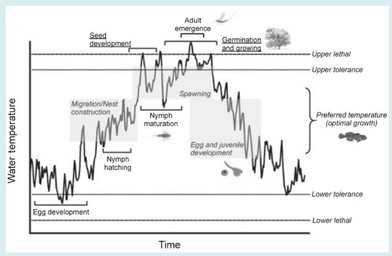
Temperature alterations due to hydropeaking

CONTEXT

Temperature

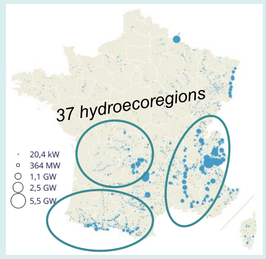


A key factor of ecosystem

Hydropeaking

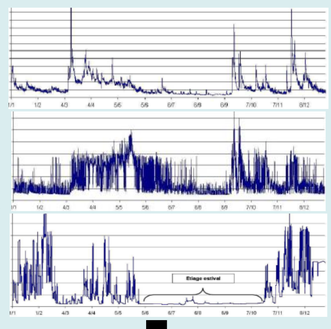
Induce artificial flow △ and may also generate temperature △ = thermopeaking

A diversity of environmental conditions



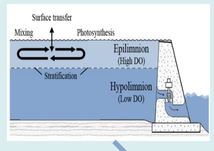
+

HPP with very ≠ characteristics



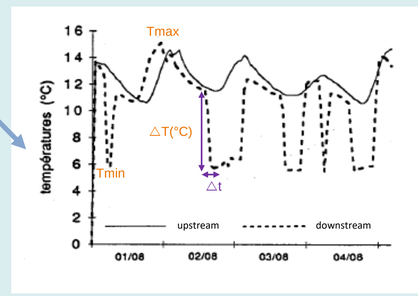
A DIVERSITY OF THERMOPEAKING?

DEFINITION & KEY POINTS



Artificial changes in temperature during nychthemeral cycle due to hydropeaking [1]

Releases from high-elevation reservoirs[2] or hypolimnetic layer[3]

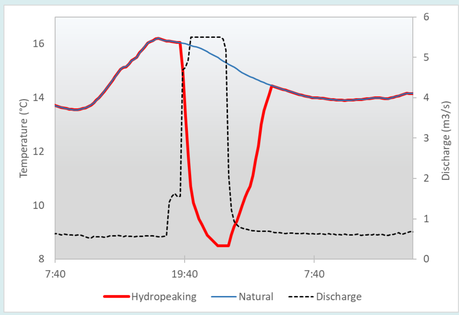


sharp and sudden T△ [6]

rapid and frequent T△ [1]

strong T△ at sub-daily scales [9]

ramping rate, ranges, frequency, seasonal values[4] > natural metrics[5]

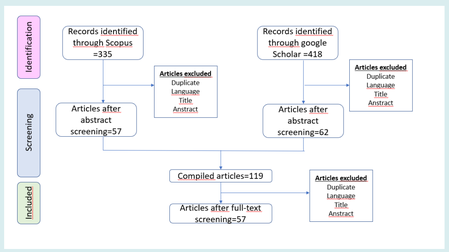


1. Distinguish the thermal alterations caused by the hydropower releases from the diurnal cycle
2. Compare with a reference thermal regime[1]
3. Describe time lag in thermopeaking (↗ with distance)

OBJECTIVES AND METHODOLOGY

Review on the Scopus database with search string 'TITLE-ABS-KEY'

"thermopeaking" Scopus n=18
("hydropeaking" OR "pulsed flow") AND ("temperature alteration" OR "thermopeaking") Scopus n=16
("hydropower") AND ("temperature alteration" OR "thermopeaking") Scopus n=20
("hydropeaking" OR "pulsed flow" OR "rapid flow alteration") AND ("temperature alteration" OR "thermopeaking" OR "therm*" OR "temperature") Scopus n=281



57 articles

- 27 articles on thermal alterations
- 30 articles on ecological impacts of thermal alterations

- What knowledge is available to describe thermopeaking? What are the thermal repercussions on aquatic organisms?

  ⇨ **Literature review**

- What is the variability of thermopeaking according to facilities and configurations?

  ⇨ **Analysis of 3 representative cases of the main configurations encountered**

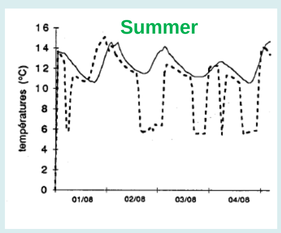
Could we classify the ≠ types of impact? Which elements will be needed?

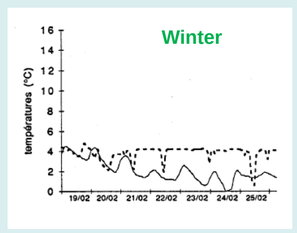
RESULTS

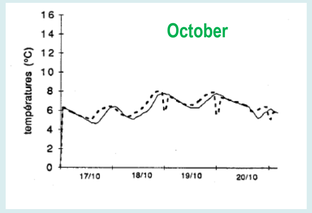
Variability of thermopeaking

↘ [3 to 6°C] in summer & ↗ [2 to 5°C] in winter in Alpine[9], Norvegian[10], Pyrenean[11], Korean rivers[12]

△T <[Preferendum]





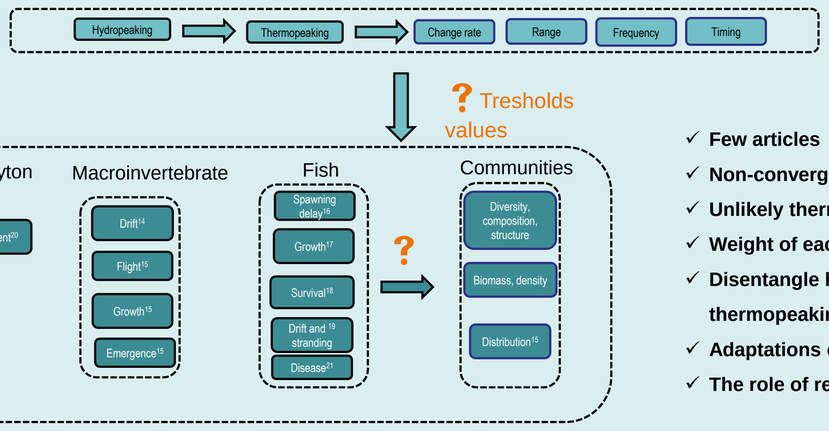


Not all hydropeaking produce significant T△[10]:
- Sites without thermopeaking[11]
- Month without thermopeaking[11]

Higher frequency than reference[13] *(but very variable)*

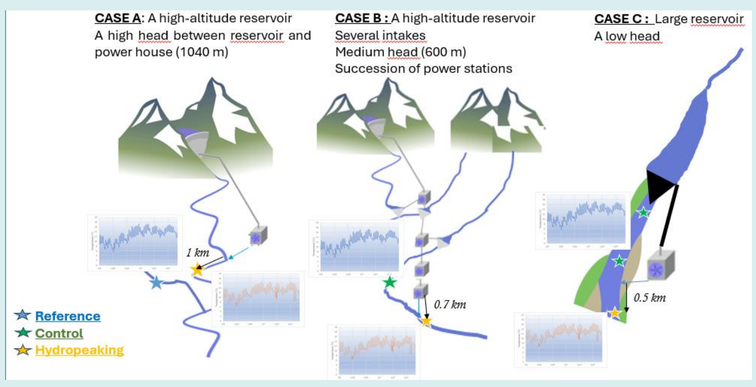
T ramping rate △?

Ecological impact of thermopeaking



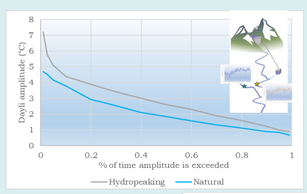
- ✓ **Few articles**
- ✓ **Non-convergent results**
- ✓ **Unlikely thermal shocks**
- ✓ **Weight of each phenomena?**
- ✓ **Disentangle hydropeaking from thermopeaking**
- ✓ **Adaptations of fish or invertebrate?**
- ✓ **The role of refuge and connectivity?**

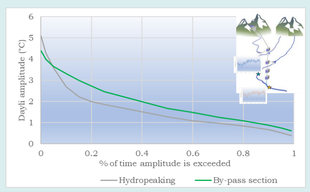
3 ≠ types of storage hydropower plants

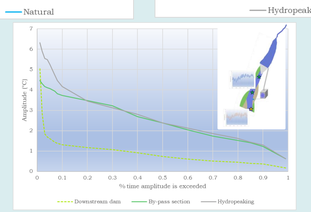


Analysis at sub-daily scale

Daily amplitude of temperature (>4.5°C) even up to 7°C, but this concerns only a small percentage of hydropeak (<8%)

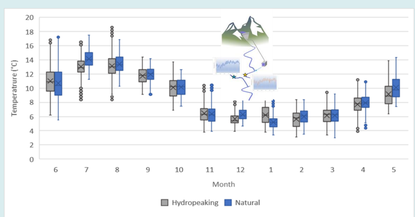


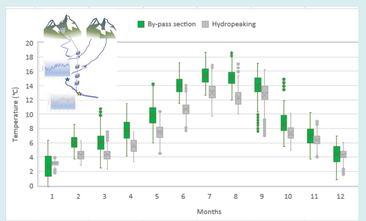


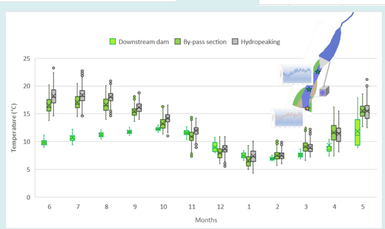


Analysis at annual & monthly scale

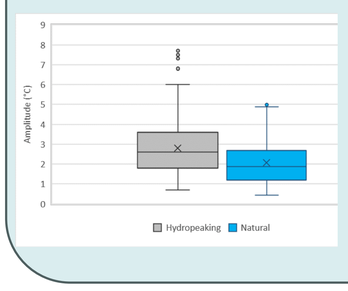
Changes in monthly temperature patterns are highly dependent on site configuration

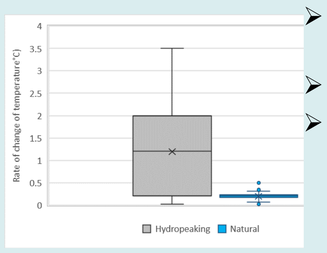






CONCLUSION





- ➢ Changes in temperature regimes as a result of hydropeaking are highly dependent on site configuration
- ➢ Hydropeaking does not systematically lead to thermopeaking
- ➢ The most significant changes occur in summer, with an increase in :
  - ✓ amplitudes but this generally concerns less than 10% of annual hydropeaking regime
  - ✓ ramping rate

PERSPECTIVES

- ➢ Better characterize the diversity of situations in terms of temperature regimes downstream of hydropeaking schemes
- ➢ Better understanding of the effects of amplitude and ramping rate increases on biology
  - Consequences at individual level
  - But also at the level of populations or communities?
- ➢ Gain or loss of cold releases with climate change?

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References
[1]Ward and Stanford 1979; King 2012; [2] Toffolon et al., 2010 ; [3] Bruno et Siviglia, 2012; [4]Webb et Walling, 1996 ; Steel et Lange, 2007 ; Zolezzi et al., 2011; Frutiger, 2004; [5]Higgens, 1996; Hunter, 1992; [6] Toffolon et al., 2010; Bruno et Siviglia, 2012; Schaefli, 2015; [7]Bakken et al., 2016; [8]Feng et al., 2018; [9]Zolezzi, 2011; Feng et al., 2018 [10]King, 2012; Bakken et al., 2016; [11] Lauters, 1995; Cereghino et Lavandier 1997 [12] Choi&Choi; [13] Vanzo 2015; [14]Carolli et al., 2012; Bruno et al., 2013; Schülting et al. 2016; [15]Céréghino and Lavandier (1997, 1998); [16] Wang et al., 2013; [17] Floodmark et al., 2004 ; [18] Horne et al., 2004; [19] Greimel et al; Bradford (1997), Kaiser 2016, Auer 2023; Mameri 2023; Führer et al., 2024 . [20] Bondar-Kunze et al., 2021; [21]Casas Mulet