Identifying the influence of dams and ponds on the thermal regime at regional scale

The case of Loire catchment

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Stream (water) Temperature (ST)

- A key factor in the distribution of aquatic communities (Poole et al., 2001);
- Modified by natural processes and human activities differently (Webb, 1996);
- Exacerbated modifications due to climate change (Webb, 1996; Moatar and Gailhard, 2006; Michel et al., 2020);
- Lack of data on both upstream and downstream of anthropogenic structures (Hill et al., 2013);
- New tools required for identifying and predicting human impacts.
Objectives

- Defining thermal signatures to identify human impacts on ST
- Testing them on a large database of ST over a large French basin
- Distinguishing between natural regimes and altered ones
- Detecting the impacts of dams and cumulative effects of upstream ponds
Study area and data

Loire basin and standing surface waters

0.8% of the catchment areas with standing surface waters
73 large dams
0.3% of the catchment areas with ponds

One of the largest European catchments ($10^5 \text{ km}^2$)
Contrasting natural conditions

Loire at the entry of estuary
Coise river
Study area and data

Observed stream and air temperature

526 stations of observed ST 2008-2018 with some gap years

Air temperature from Safran reanalysis data
8~km spatial resolution and daily temporal resolution
(Quintana-Segui et al., 2008; Vidal et al., 2010)
Examples of human impacts: Large dams

Natural condition

✓ Decrease ST and delay the annual cycle
Examples of human impacts: Ponds and lakes

Natural condition

- Increase ST and impose a vertical shift in regime

With a lot of ponds in upstream
Examples of stream-air temperature relationship: dams and ponds

Using air temperature as a proxy of the heat budget (Mohseni et al., 1999, Caissie et al., 2008)

- Lower slope (TS) and $R^2$ for dams compared to ponds

Using air temperature as a proxy of the heat budget (Mohseni et al., 1999, Caissie et al., 2008)
Methodology

Step 1
Selecting stations that are sensitive to alterations

Step 2
Defining thermal signatures by comparing stream and air temperature based on seasonal regime and linear regression

Step 3
Identifying different thermal regimes through clustering based on thermal signatures

Step 4
Comparing the regimes of different clusters
Step 1: Selecting stations that are sensitive to alterations

(Caissie et al., 2006)

✓ The larger a river, the larger its volume (thermal capacity) and the less responsive it is to the alterations
Step 2: Defining thermal signatures by comparing stream and air temperature based on seasonal regime and linear regression
Step 2: Defining thermal signatures by comparing stream and air temperature based on seasonal regime and linear regression

<table>
<thead>
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<th>Notation</th>
<th>Definition</th>
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<td><strong>Dam signatures</strong></td>
<td></td>
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<tr>
<td>TS</td>
<td>slope</td>
</tr>
<tr>
<td>R²</td>
<td>coefficient of determination</td>
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<tr>
<td>Lag time</td>
<td>(\text{day}(T_{\text{w peak}}) - \text{day}(T_{\text{a peak}}))</td>
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<tr>
<td><strong>Pond signatures</strong></td>
<td></td>
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<tr>
<td>SumAbs(Tw-Ta)</td>
<td>(\sum_{\text{Mar.-Octb.}} (T_{\text{w}} - T_{\text{a}})/\text{nbdays})</td>
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</tbody>
</table>
| Mean(Tw-Ta)      | \(\sum_{
\text{Mar.-Oct.}} (T_{\text{w}} - T_{\text{a}})/\text{nbdays}\)         |
Step 3: Identifying different thermal regimes through clustering based on thermal signatures
Step 4: Comparing the regimes of different clusters

- **Dams:**
  - Delay the annual cycle by 18 days;
  - Decrease ST by 2.1°C in average over the summer

- **Cumulative effects of upstream ponds:**
  - Increase ST by 2.7°C in average over the summer
  - Exacerbate the effect in a hot year with 2°C increase in ST in average over the summer
Conclusion and Perspectives

- Dealing with spatial and temporal gaps in ST data
- Defining five thermal signatures by comparing stream and air temperature
- Distinguishing between natural regimes and altered ones
  - Dams: Delay the annual cycle by 18 days; Decrease ST by 2.1°C in average over the summer
  - Cumulative effects of ponds: increase ST by 2.7°C in average over the summer exacerbate the effect in a hot year with 2°C increase in ST in average over the summer
- Identifying highly influenced streams, and taking mitigation actions
- Designing strategic network surveys
- Using natural thermal regime for developing a reference-condition numerical model
Thank you for your attention!

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Selective References:


