The 2nd International Conference on

Sustainability in Hydropower 2023
–Ecological mitigation, best practices and governance
Trondheim, Norway, 13-15 June 2023

Overview of mitigation measures implemented in France to reduce ecological impacts of hydropower

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CONTEXT

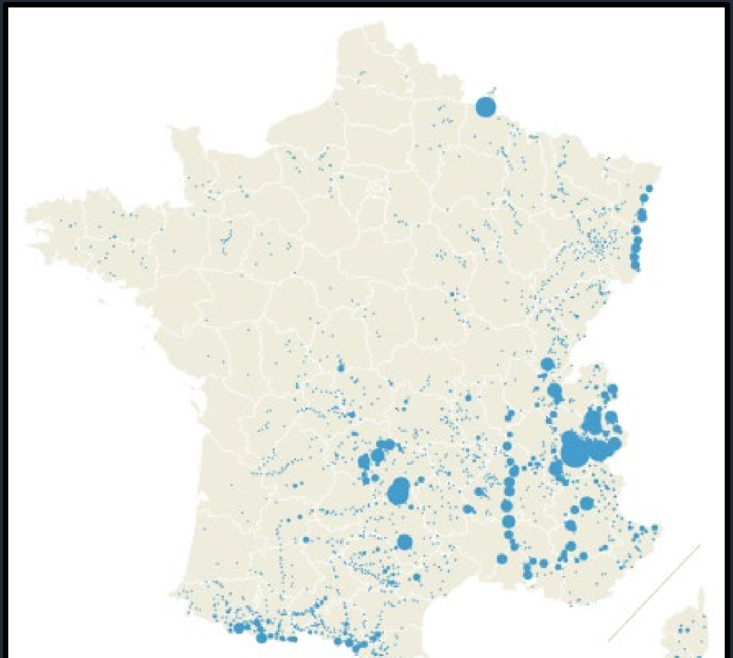
Climate change

↗ CO_2

↘ water ressources

↗ temperature

Biodiversity decline



Hydropower installed capacity

↗ Electricity demand

↗ Wind and solar power

↗ need for flexibility in hydroelectric generation

Multi-uses of water

Challenge: Implement mitigation measures which allow to reduce ecological impacts in a context of scarcity of water resources , biodiversity decline and increasing needs of electricity

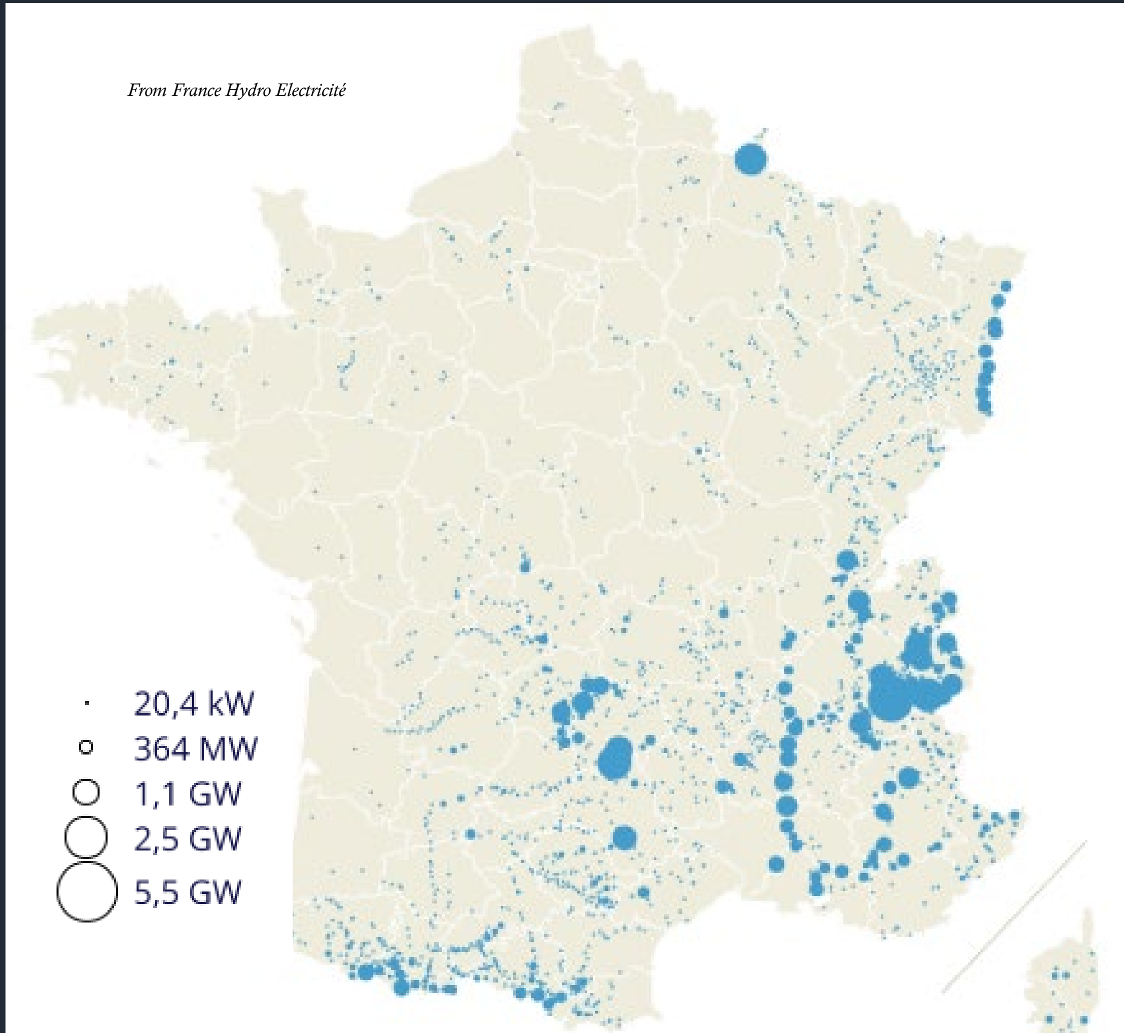
Overview of hydropower plants (HPP) in France

French hydroelectric fleet

2500 hydropower plants / 250 000 km

10-14% total output

25 GW installed capacity



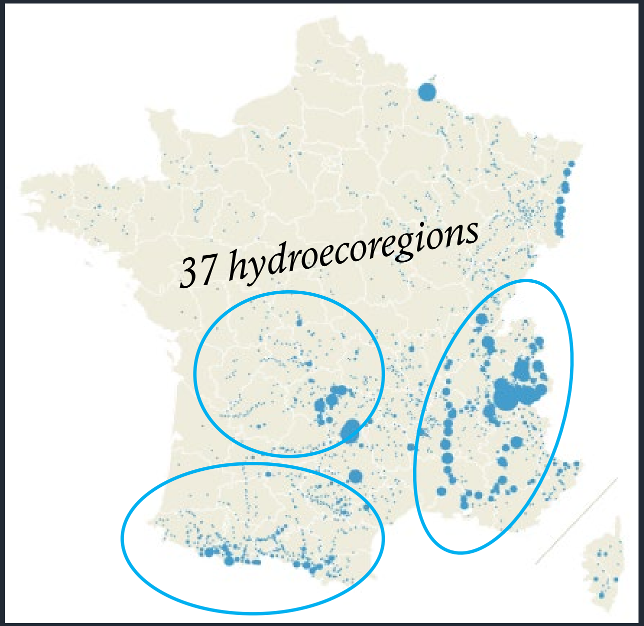
Hydropower installed capacity

Third largest European producer of hydroelectricity

75 % reservoirs for electricity generation

A diversity of ecological impacts due to …

A diversity of environmental conditions



HPP with very ≠ characteristics

- A very wide range of power
- A large range of head
- Small HPP in the headwaters with inter-basin water diversion
- Large HPP more widely distributed
- ≠ types of HPP

Power generation
- *Run-of-river 26%*
- *Hydropeaking 16%*
- *Storage 40%*
- *Pumped-storage: 18%*

Number of HPP: Run-of-river 90%

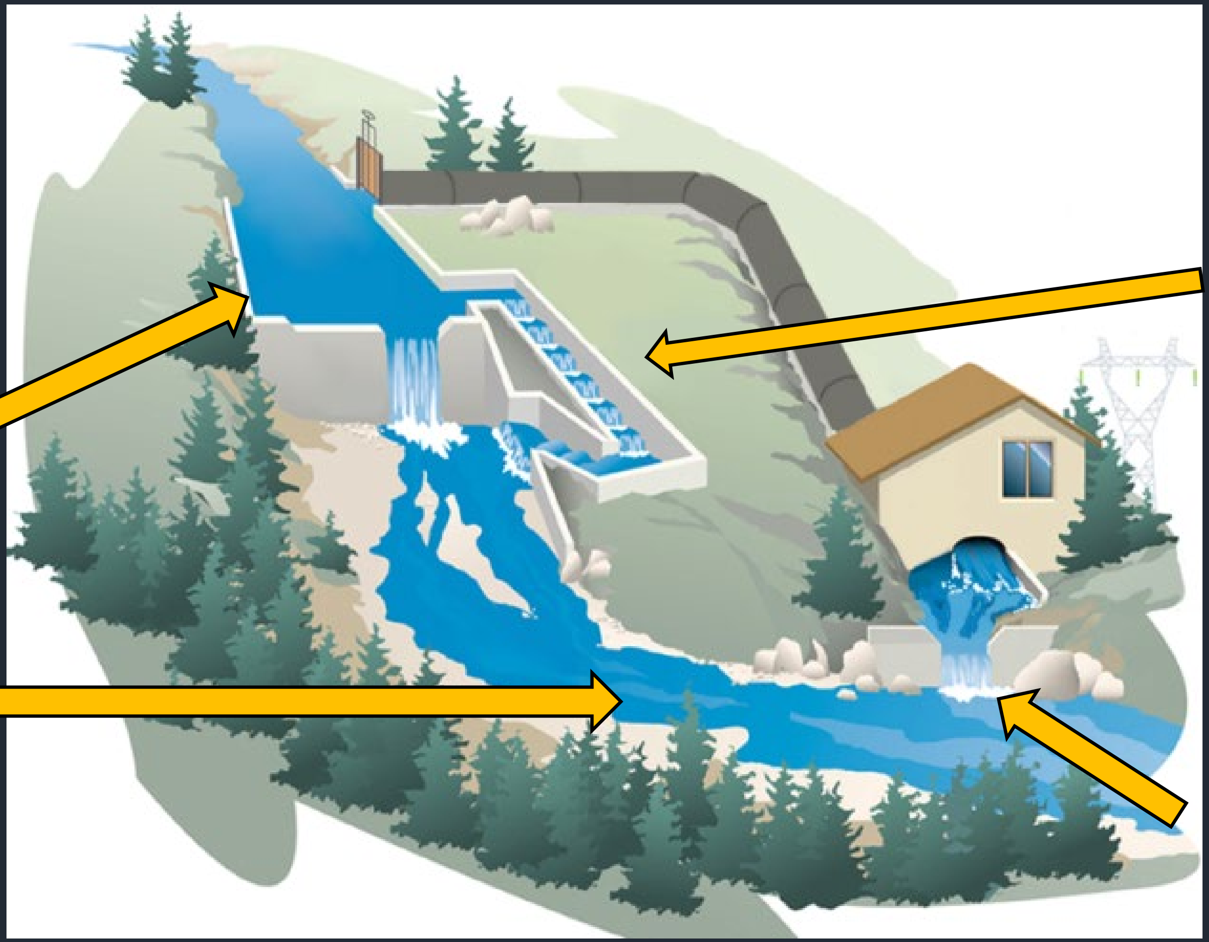
Ecological impacts

Impoundment/diversion

Water level fluctuations

Fish continuity

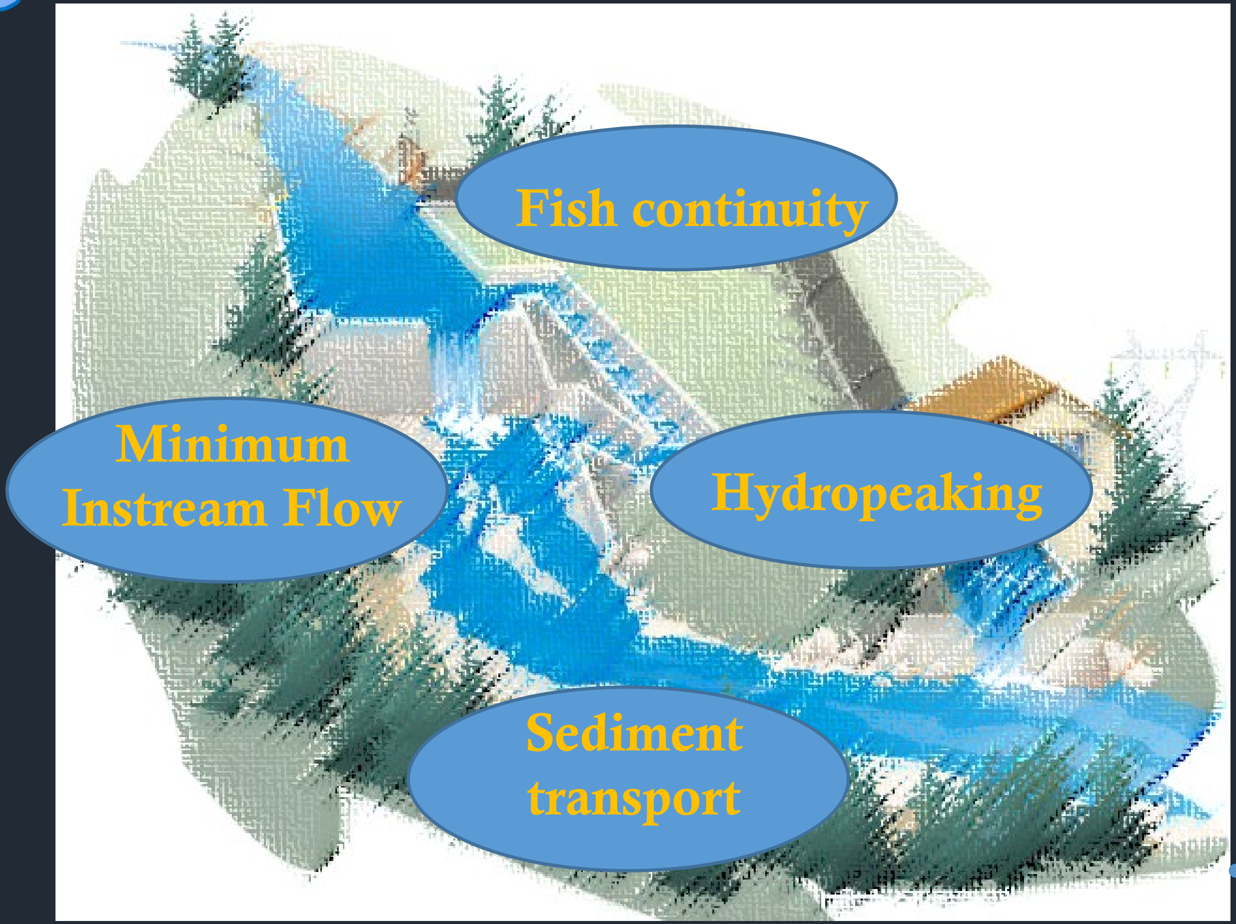
Sediment transport



Minimum Instream Flow

Hydropeaking

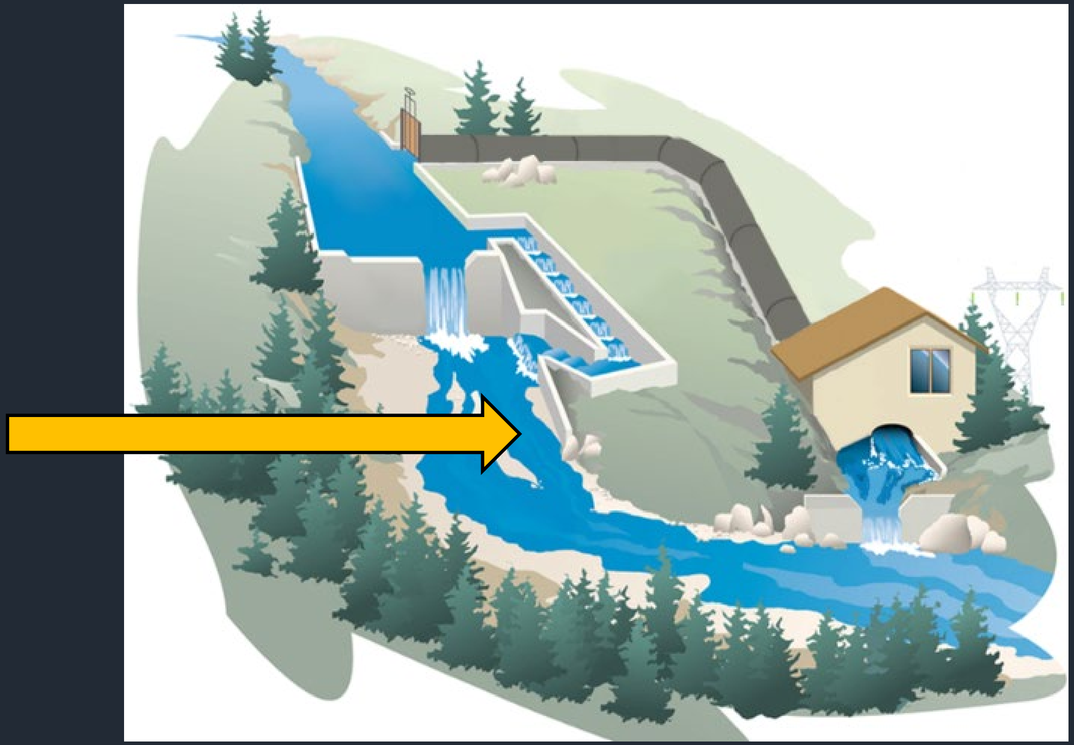
Ecological impacts



- Regulations to reduce these impacts
- Implementation of mitigation measures
- Tools and research to help their implementation
- Feedback from site experiments

Minimum Instream Flow

Minimum flow to be left in a river to guarantee the life, circulation and reproduction of the living species (fish, macro-invertebrates… etc.).



Minimum instream flow

Issue: Preserve habitat for biological communities

Current regulations:

- Minimum Flow ≥ 1/10 Mean Annual Flow (MAF) (or ≥ 1/20 MAF for 3 cases of derogation*)
- Ability to modulate minimum flow during the year

Implementation: ↗ from 1/40 to 1/10 of MAF in 2014

Tools /Research: Habitat models (HABBY platform – Royer et al., 2022 https://habby.wiki.inrae.fr/en:habby), guidelines to define ecological flows (Lamouroux et al., 2016), Long term monitoring of fish populations (Tissot et al., 2012; Cattaneo,2015), dynamic population model (Gouraud et al., 2008; Bret et al, 2017)

* if MAF > 80 $m^3.s^{-1}$, peak hydroelectricity production, reach with atypical functioning

Feedback of mitigation measures for minimum instream flow

Mountain rivers

↗ min flow

17 sites
5 rivers
12 years

Sabaton et al, 2008

↗ + Δ min flow

Durance river
188 m^3.s^{-1}

Cattaneo et al., 2015

Durance + Verdon rivers

↗ + Δ min flow
+ unclogging releases

Beche et al, 2018

↗ min flow
+ morphological restauration

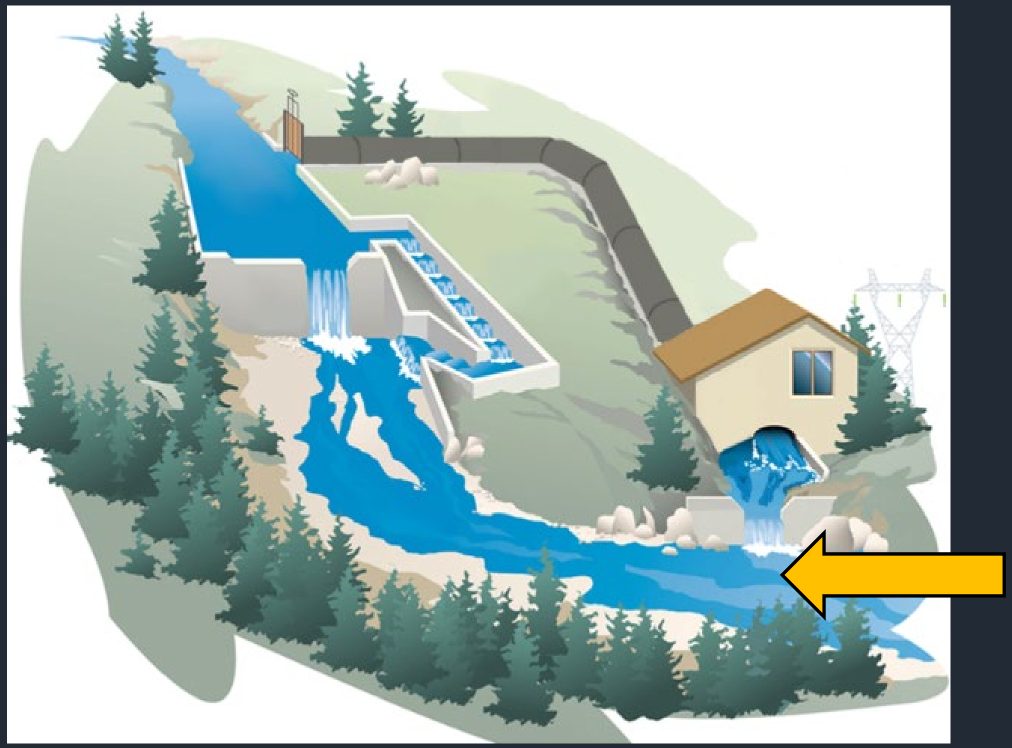
Rhône river

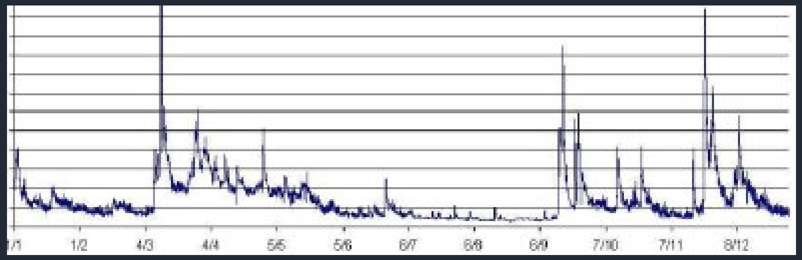
Lamouroux et al, 2015

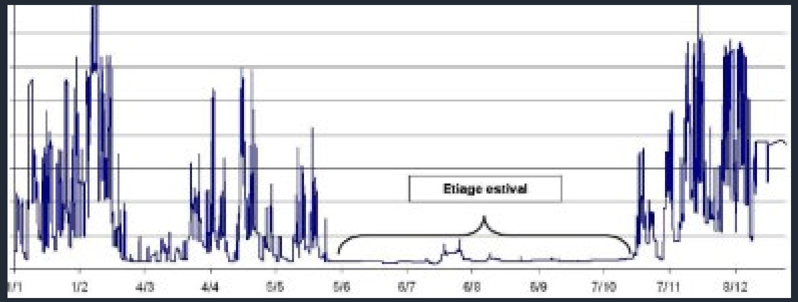
- **↗ min flow or Δ min flow ⇒ ↗ habitat at ≠ degrees - Habitat models = a good tool to assess gains**
- **Mixing hydrological, sedimentary and morphological measures ↗ chances of success**
- **Gains for biological communities difficult to disentangle from floods effects and other pressures**

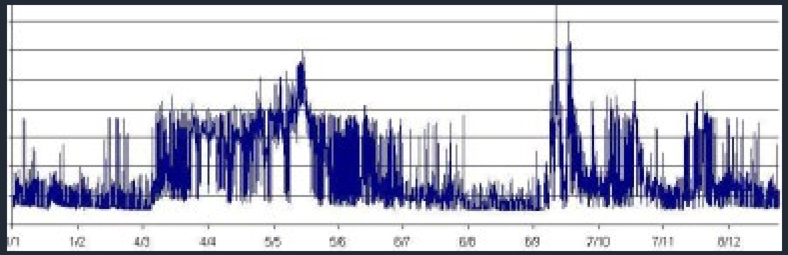
Hydropeaking

Releasing pulses of water to increase hydroelectric power production at hydro dams to meet peak
daily electricity demand









Hydropeaking

<u>Issue:</u> Reduce drift, stranding of aquatic organisms, loss of habitat due to rapid increase and decrease of flow

<u>Regulation</u>: case-by-case definition of hydropeaking operating rules / River Basin Management Plans

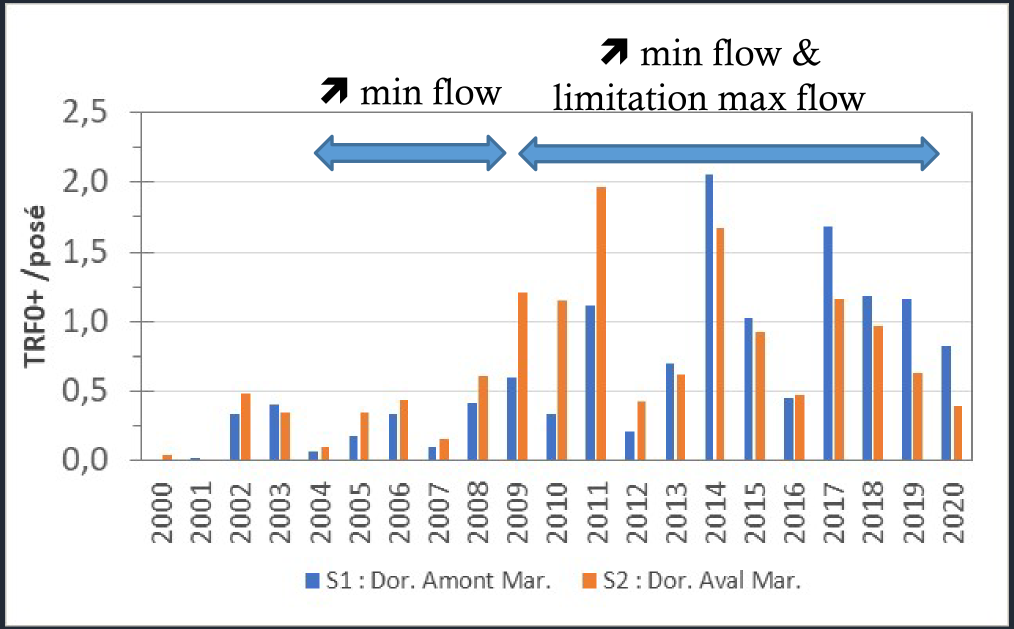
<u>Implementation:</u> ➚ base flow, ➘ up/down-ramping rate, ➘ amplitude, ➘ frequency, ➘ timing but no new balancing reservoir

<u>Tools /Research :</u>

Hydropeaking indicators (Courret, 2021), Risk assessment (Terrier & Baran, 2022), hydraulic models, guidelines, reference metrics (OFEV, 2017), long term fish monitoring (Gouraud et al., 2016; Judes et al., 2021), microhabitat selection (Judes et al., 2023)

Feedback of mitigation measures for hydropeaking

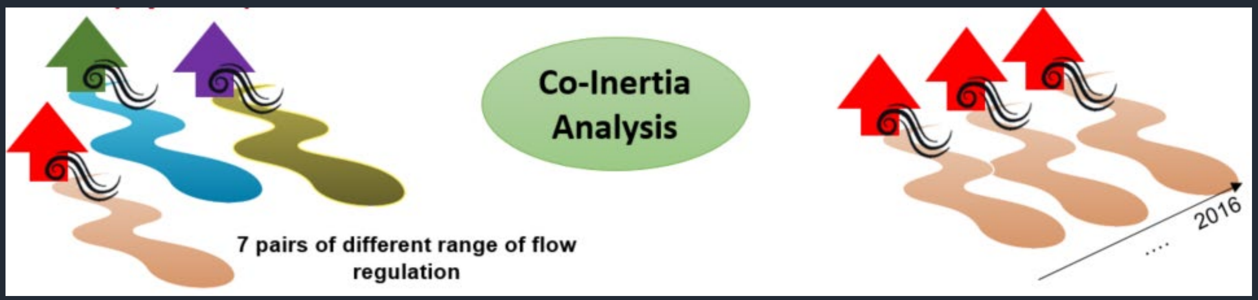
Dordogne river



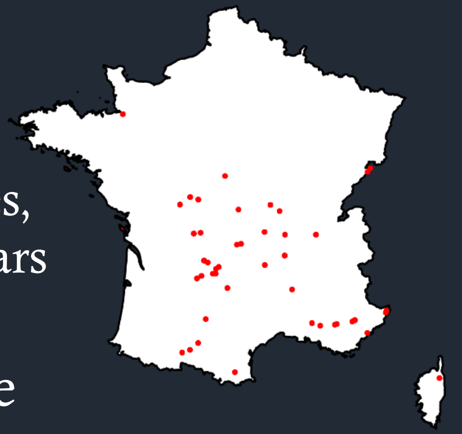
Ladoux et al, 2016

Gains for trout recruitment

27 rivers



Judes et al, 2020

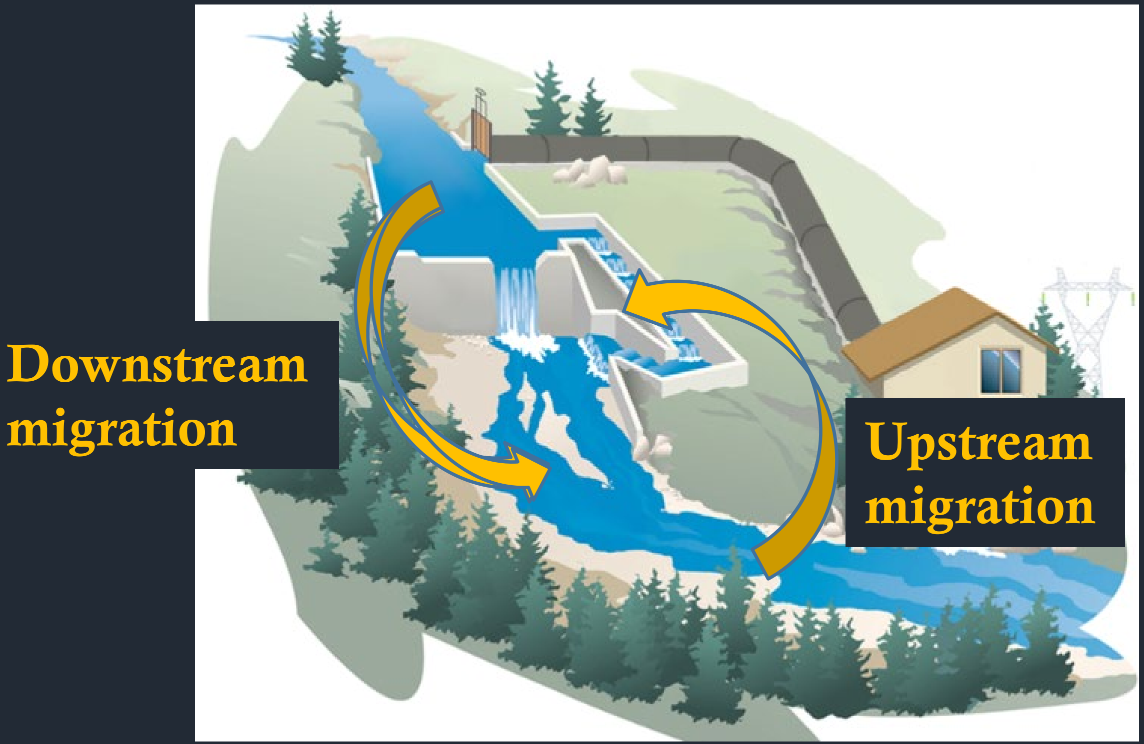


45 reaches,
3 to 17 years

Consistent but secondary influence

Long-term monitoring needs to identify measures effects, Secondary effect of hydropeaking on fish populations / floods, ≠ sensitivities of species, specific impacts according to site characteristics (ex: stranding of individuals for river with secondary channels, gravel bars, drift for channeled river….)

Fish continuity



Fish continuity

Issue: Enable fish migration, particularly diadromous species (eels, salmon, shad…)

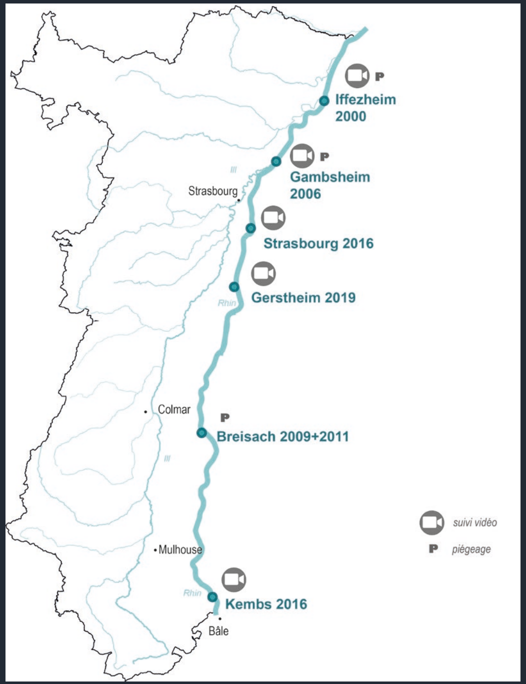
Regulation: Classification of rivers: List 1 = no new obstacle; List 2 = restoration of ecological continuity (fish migration and sediment transport)

Implementation: Construction of fishways in 1980, downstream passage devices in 2000 => 267 fish passage systems (upstream and downstream) / 543 obstacles

Tools/Research: Guidelines for fishways (Larinier et al., 1994, 2002; Groux et al., 2015), Guidelines for fish downstream passage solutions (Courret&Larinier 2008), fish behavioral monitoring and models

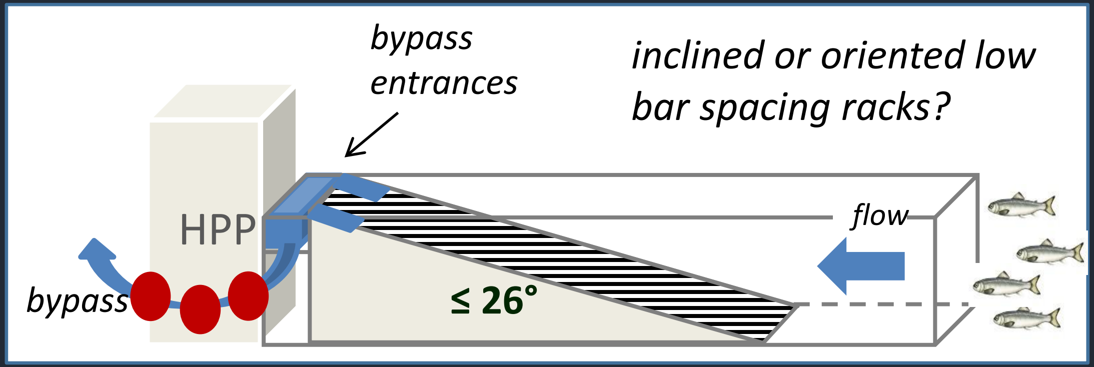
Feedback of mitigation measures for fish continuity

Efficiency of fishways on the Rhine using 10 years of monitoring (RFID telemetry, video)



Roy et al, 2022

Test of downstream passage solutions on 9 sites



Tomanova et al, 2021

Test of targeted turbine shutdowns, harmless turbines, addition of repellent effects like light, floating fishways

- **More knowledge for upstream migration than for downstream migration = major challenge**
- **Efficiency at the scale of the dam but lack at the scale of the reach, the watershed basin and populations**
- **Effect of other drivers reduce the success of mitigation measures**

Sediment transport

Coarse sediment

Fine sediment

Feedback of mitigation measures for sediment

Issue: Preserve habitat (coarse and geomorphological processes) and limit impact of fine sediments' releases

Regulation:

- Mitigation requirements for sediment continuity : classification of rivers (list 2: Sufficient sediment transport) or River Basin Management Plans
- Threshold standards for fine sediment discharges

Implementation: Case by case / morphological restoration, adding sediments in river, removing in reservoirs, routing sediments around reservoirs

Research/Tools: Guidelines handbook (Malavoi et al., 2011), protocol to assess sufficient sediment transport (Malavoi et Loire, 2015), ecological impact of fine sediments (TEC/PEC* fromMacDonald et al., 2000)

TEC: Threshold Effect Concentration; PEC: Probable Effects Concentration

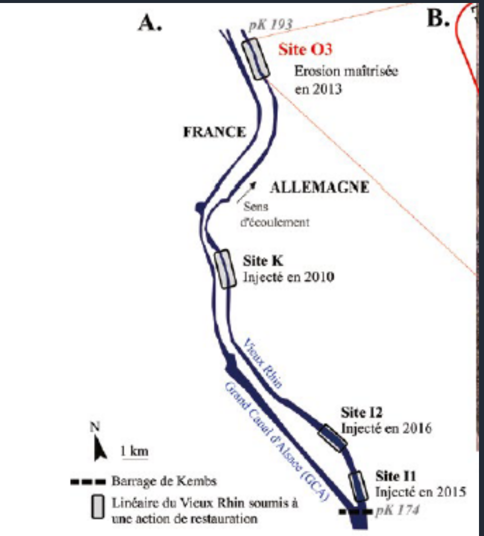
Feedback of mitigation measures for sediment continuity

Maronne river

Gravel augmentation (2013, 2014, 2017) => ➚ salmonid recruitment

EPIDOR , Lupinski et al. 2023

Rhine River Downstream Kembs Dam



Morphological Restoration through Bank Erosion (2013) and Sediment Injections (2015, 2016, 2022)

Staentzel et al. 2018

- **Durability of measures ? Necessary to find solutions to stabilize gravel refill**
- **Success of morphological restauration in terms ➚ habitat heterogeneity, recovery of riparian biocenosis but new ecological niches for invasive species**
- **➚ interest in restoration with WFD objectives but lack of standardized methods to assess effectiveness**

Conclusion and perspectives

Conclusions and perspectives

Implementation of mitigation measures

- The legal requirements relating to minimum flows and fish continuity are more precise than those relating to sediment and hydropeaking (case-by-case approach)
- The lack of knowledge and the complexity arising from the diversity of ecological impacts mean that it is often difficult to formulate precise legal requirements
- It is not always possible to apply identical thresholds
- But the use of standardized methods is necessary for defining appropriate mitigation measures
- Gaps in knowledge and the absence of proven measures need to be clarified through research or pilot studies

Conclusions and perspectives

Good practices:

- Need for a proper diagnosis to identify appropriate mitigation measures adapted to specific environmental conditions
- Carry out environmental and biological monitoring proportionate to the risk of ecological impact
- More long-term monitoring is needed to assess the effectiveness of mitigation measures

All pressures

Local scale

Basin scale

temporal variability

Climate change

Wednesday 14 June 16:15 Plenary 4: Focus on, good governance and long-term changes of the water resources systems

Laurence Tissot (EDF, FR)

Multidecadal trends in brown trout (Salmo trutta) populations in regulated and unregulated river

Perspectives

Research of future win-win solutions

- Simulate the optimization of energy production while reducing the water and biodiversity footprint

➔ ***Wednesday 14. June 12:30 Session 3 cont. - International hydropower, sustainability and the use of LCA***
Barillier A.(EDF) Biodiversity footprint of hydropower : introducing aquatic pressures into the Product Biodiversity Footprint (PBF)

- Identify mitigation measures appropriate to the changing environmental and socio-economic context

➔ ***Wednesday 14. June*** *Session 3 - International hydropower, sustainability and the use of LCA11:15*
Leah Bêche (EDF) Uncertainty and complexity in ecological and social mitigation of hydropower in developing countries

↘ water ressources

↗ Electricity demand

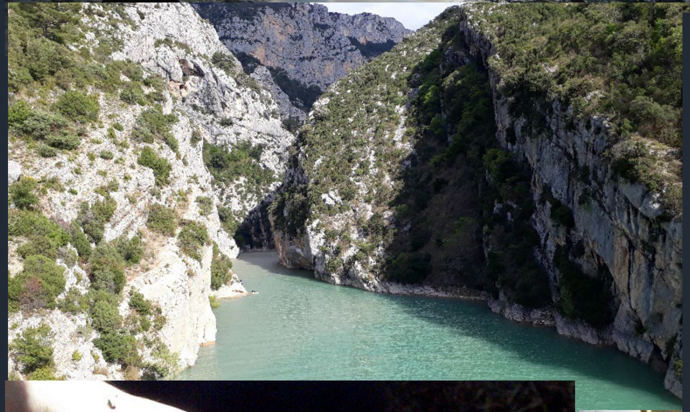
LCA

↗ temperatures

Social mitigation





Thank your attention