Small-scale hydropower plants in Alpine streams – studying ecological effects across different scales

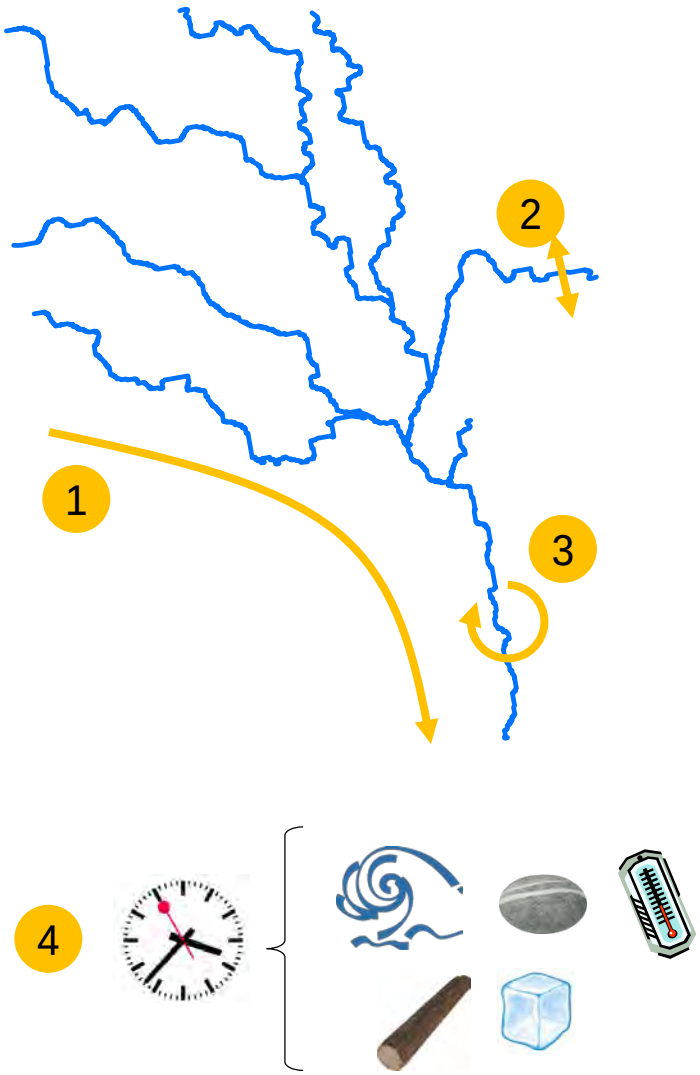
Christine Weber, Isabelle Ambord, Lisa Wilmsmeier, Katharina Lange, Eawag

Background

Heraclitus, 500 BC

Background

Rivers and streams around the world are …



- tightly connected to their surroundings (4 dimensions)
- among the most diverse ecosystems

- among the most threatened ecosystems

- intensively used for hydropower production
  - -> increasingly by means of small hydropower plants (CH: <10 MW)

What we do

Small hydropower plants: Ecological effects and their propagation?

-> We combine two approaches

1. Literature reviews

(Lange et al. 2018; Lange et al. in prep)

REVIEWS REVIEWS REVIEWS

Basin-scale effects of small hydropower on biodiversity dynamics

Katharina Lange[1,2*], Philipp Meier[1], Clemens Trautwein[1], Martin Schmid[1], Christopher T Robinson[3,4], Christine Weber[1], and Jakob Brodersen[2,5]

Construction of small hydropower plants (<10 megawatts) is booming worldwide, exacerbating ongoing habitat fragmentation and degradation, and further fueling biodiversity loss. A systematic approach for selecting small hydropower sites within river networks may help to minimize the detrimental effects of small hydropower on biodiversity. In addition, a better understanding of reach- and basin-scale impacts is key for designing planning tools. We synthesize the available information about (1) reach-scale and (2) basin-scale impacts of small hydropower plants on biodiversity and ecosystem function, and (3) interactions with other anthropogenic stressors. We then discuss state-of-the-art, spatially explicit planning tools and suggest how improved knowledge of the ecological and evolutionary impacts of hydropower can be incorporated into project development. Such tools can be used to balance the benefits of hydropower production with the maintenance of ecosystem services and biodiversity conservation. Adequate planning tools that consider basin-scale effects and interactions with other stressors, such as climate change, can maximize long-term conservation.

Front Ecol Environ 2018; doi:10.1002/fee.1823

Freshwater biodiversity is declining at unprecedented rates, with habitat fragmentation and degradation among the key drivers (Dudgeon et al. 2006). ...

this pressure on freshwater biodiversity. The trend toward greater reliance on hydropower is projected to continue until at least 2050, with small- to medium-sized hydropower plants accounting for more than 75% of the 3700 hydropower plants planned or under construction worldwide as of 2014 (Zarfl et al. 2015). Small hydropower plants (installed capacity <10 megawatts [MW]; Table 1) are often constructed in high-gradient alpine streams ...

In a nutshell:

2. Field study

(in eight stream pairs)

What we do

Two types of reviews

A narrative review

(Lange et al. 2018)

A meta-analysis

(Lange et al. in prep.)

Findings/ Content:

- Large-scale and cumulative effects often ignored
- sHPP effects can interact with other anthropogenic stressors
- Value of spatially explicit planning tools

- Quantify effects of different types of sHPPs
- Look for general patterns, e.g. across organism groups
- Account for reach- to catchment-scale context -> mechanistic links

What we do

Small hydropower plants: Ecological effects and their propagation?

-> We combine two approaches

1. Literature reviews

(Lange et al. 2018; Lange et al. in prep)

REVIEWS REVIEWS REVIEWS

Basin-scale effects of small hydropower on biodiversity dynamics

Katharina Lange[1,2], Philipp Meier[1], Clemens Trautwein[1], Marvin Schmid[1], Christopher T Robinson[3,4], Christine Weber[1], and Jakob Brodersen[1,5]

Construction of small hydropower plants (<10 megawatts) is booming worldwide, exacerbating ongoing habitat fragmentation and degradation, and further fueling biodiversity loss. A systematic approach for selecting hydropower sites within river networks may help to minimize the detrimental effects of small hydropower on biodiversity. In addition, a better understanding of reach- and basin-scale impacts is key for designing planning tools. We synthesize the available information about (1) reach-scale and (2) basin-scale impacts of small hydropower plants on biodiversity and ecosystem function, and (3) interactions with other anthropogenic stressors. We then discuss state-of-the-art, spatially explicit planning tools and suggest how improved knowledge of the ecological and evolutionary impacts of hydropower can be incorporated into project development. Such tools can be used to balance the benefits of hydropower production with the maintenance of ecosystem services and biodiversity conservation. Adequate planning tools that consider basin-scale effects and interactions with other stressors, such as climate change, can maximize long-term conservation.

Front Ecol Environ 2018; doi:10.1002/fee.1823

Freshwater biodiversity is declining at unprecedented rates, with habitat fragmentation and degradation among the key drivers (Dudgeon et al. 2006). Biodiversity, and genetic diversity in particular, may be one of our greatest assets to combat the impacts of climate change and ensure long-term ecosystem stability and provisioning of ecosystem services. The global boom in hydropower development – fueled in large part by changes in public perception following the disaster at the Fukushima Daiichi nuclear power plant in Japan in 2011 and the need to reduce atmospheric greenhouse-gas emissions – exacerbates this pressure on freshwater biodiversity. The trend toward greater reliance on hydropower is projected to continue until at least 2050, with small- to medium-sized hydropower plants accounting for more than 75% of the 3700 hydropower plants planned or under construction worldwide as of 2014 (Zarfl et al. 2015). Small hydropower plants (installed capacity <10 megawatts [MW]; Table 1) are often constructed in high-gradient alpine streams (Zarfl et al. 2015), ecosystems that typically support a unique fauna and flora adapted to fast-flowing, dynamic habitats.

In a nutshell:

- Small hydropower planning often neglects large-scale ecological and evolutionary processes, as well as the cumulative effects of multiple hydropower plants
- Fragmentation by small hydropower impedes organism dispersal and migration, which can lead to reduced genetic diversity, diminishing the potential to adapt to changing environmental conditions and increasing local extinction risk
- Interactions between small hydropower and other anthropogenic stressors, such as climate change, need to be considered when assessing environmental impacts
- Spatially explicit planning tools that consider multiple objectives can substantially contribute to balancing restrictive trade-offs with long-term biodiversity conservation

The increase in small hydropower plants, as opposed to large hydropower schemes, is mainly a consequence of the hydropower potential of larger rivers already being exploited in most developed countries (eg in Austria; Wagner et al. 2015). Many governments are subsidizing the construction of small hydropower plants because these are perceived to have fewer adverse ecological impacts than large hydropower schemes (Kibler and Tullos 2013). Impacts of large hydropower plants on flow, sediments, and temperature regimes, affecting habitat properties and organisms, have been reasonably well studied (Ellis and Jones 2013); in contrast, local- and basin-scale impacts of small hydropower plants have only rarely been examined (Jager et al. 2015). This gap is surprising given that the ecological footprint of small hydropower plants per megawatt of power produced may be disproportionally higher than that of large hydropower plants (Zarfl et al. 2012; Kibler and Tullos 2013). The promotion of smaller over larger hydropower plants also means that many additional new hydropower plants will have to be built to achieve the same level of power production (Figure 1), and river basins will therefore often harbor multiple small hydropower plants. The cumulative impacts of such plants must be considered when planning

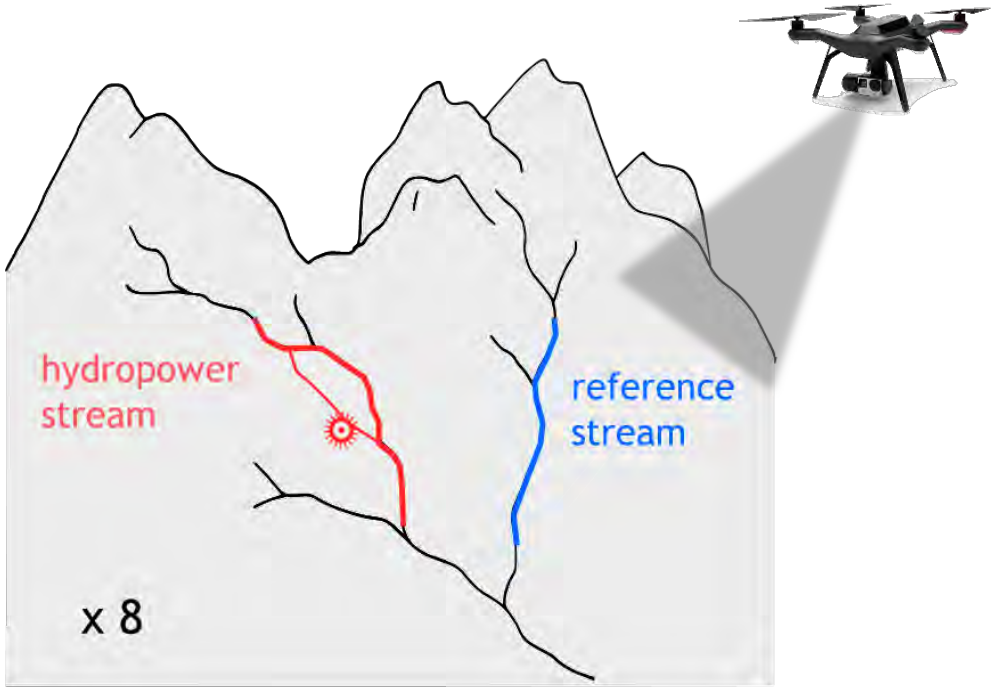
[1]Eawag (Swiss Federal Institute of Aquatic Science and Technology), Department of Surface Waters and Biogeochemistry, Kastanienbaum, Switzerland; [2]Eawag, Department of Fish Ecology and Evolution, Kastanienbaum, Switzerland; [3]Author Lange@eawag.ch; [4]Eawag, Department of Aquatic Ecology, Dübendorf, Switzerland; [5]Institute of Integrative Biology, ETH Zürich, Zürich, Switzerland; [6]University of Bern, Institute of Ecology and Evolution, Division of Aquatic Ecology & Evolution, Bern, Switzerland

2. Field study

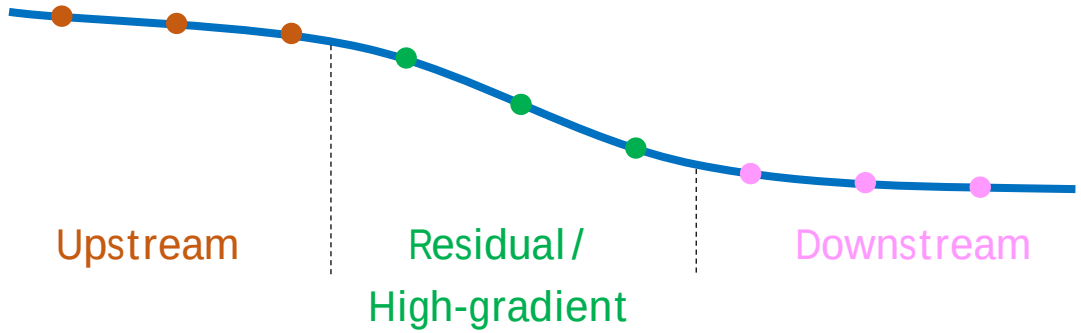
(in eight stream pairs)

What we do:

General design of the field study

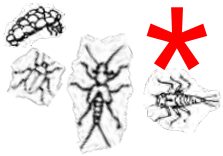


Stuart Lane, Jonathan Molina (UNIL)



What we do

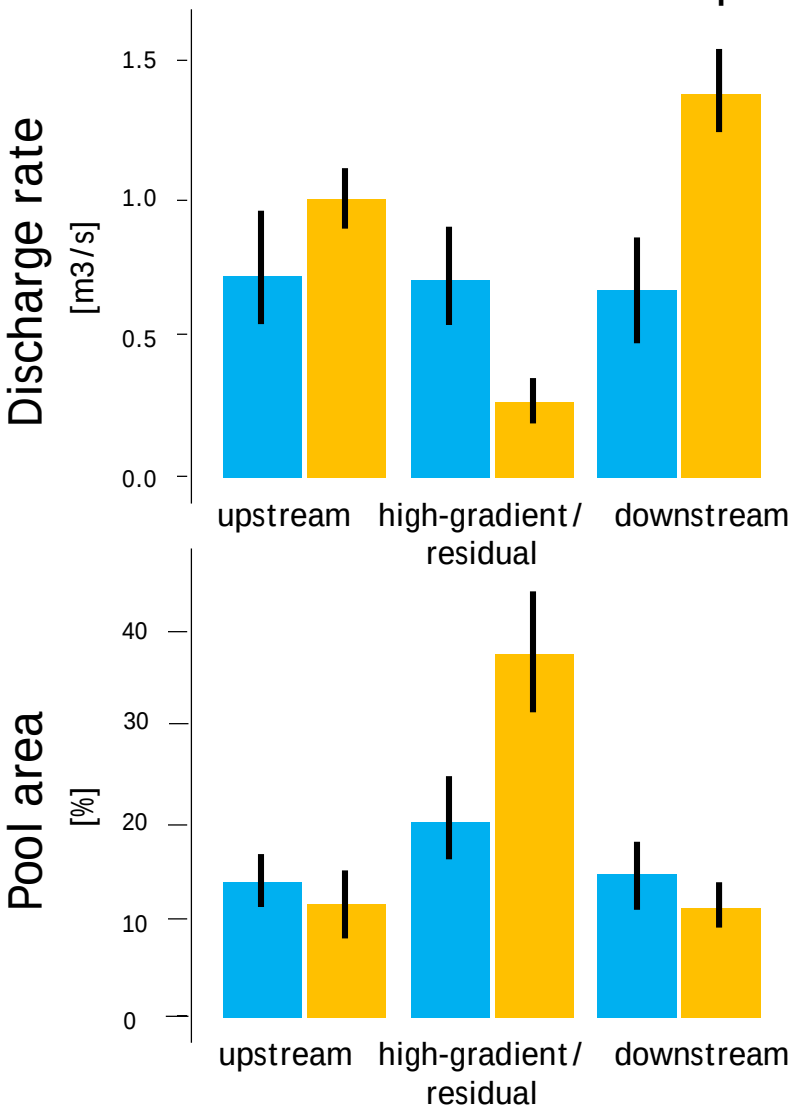
Specific measurements

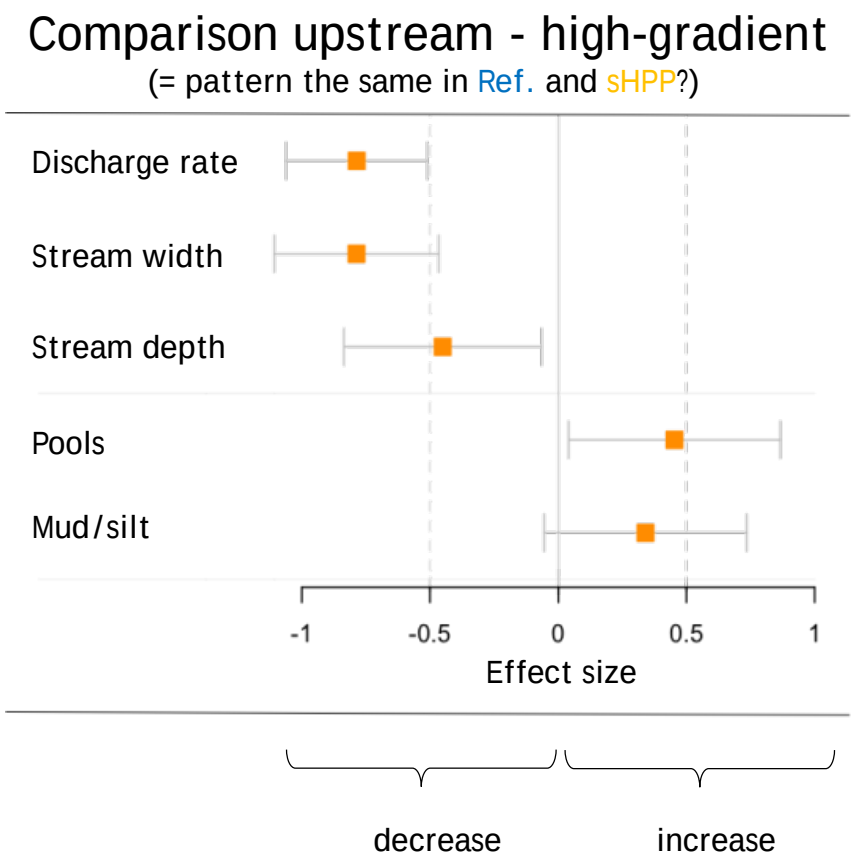


What we measured… (examples)	• Water level • Temperature • Substrate	• Organic matter • Algal biomass	• Aquatic inverts (e.g. insect larvae) -> How many? Who?	• Terr. spiders: -> Body form and composition
… and what it tells us:	• Dynamics • Habitat diversity • Connectivity (longitudinal)	• Productivity • Resource availability	• Diversity • Functional complexity (e.g. resource use) • Food resources	• Connectivity (lateral) • Adaptation

Preliminary results

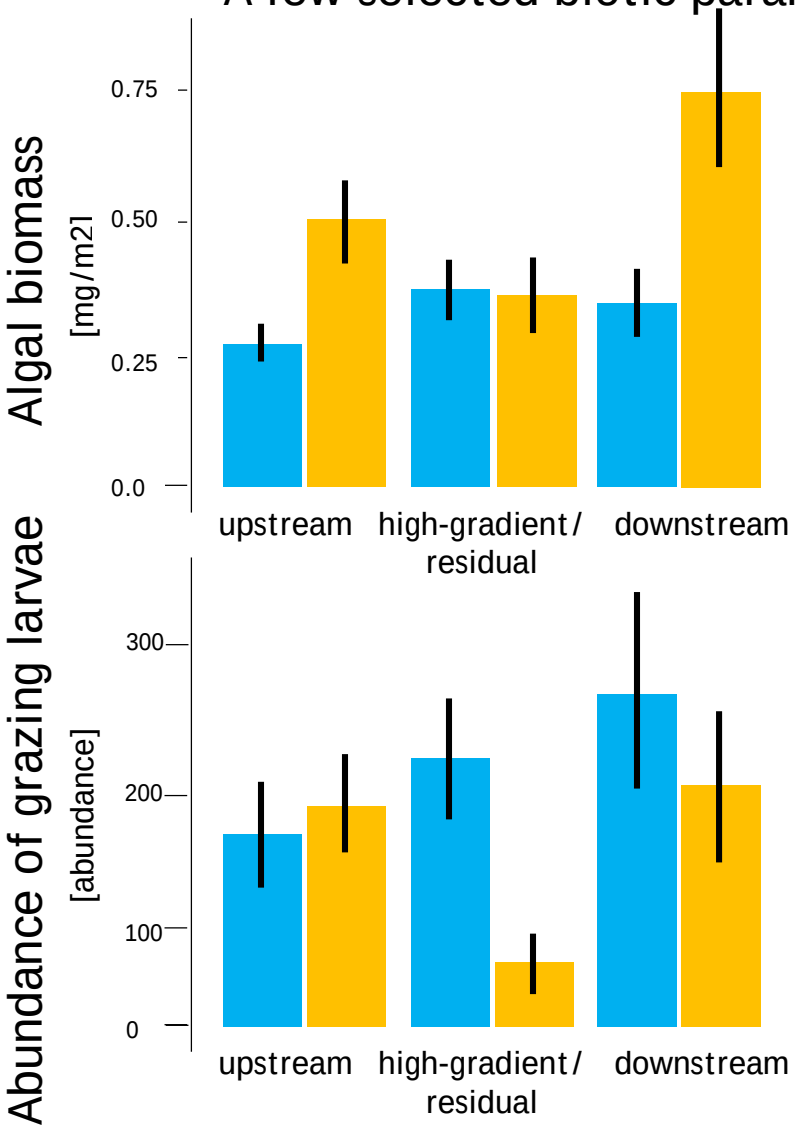
A few selected abiotic parameters

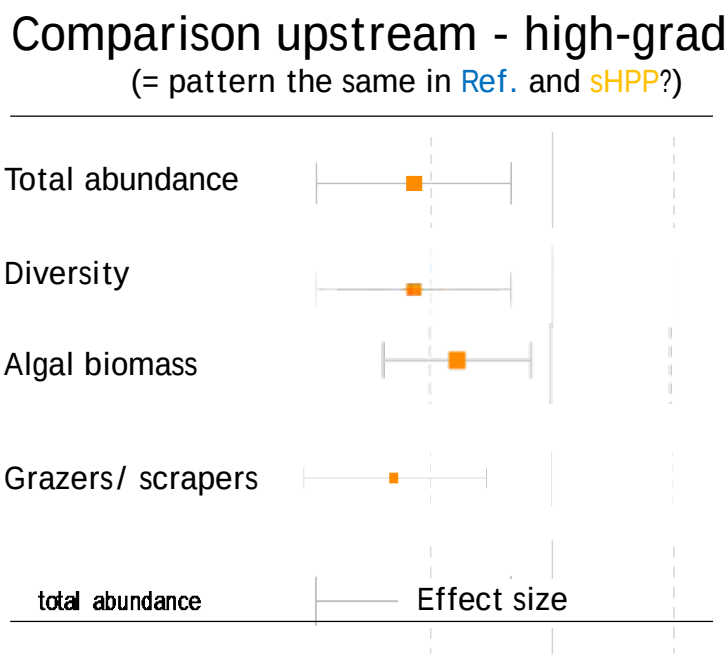




Preliminary results

A few selected biotic parameters





Conclusions so far


Basin-scale effects of small hydropower on biodiversity dynamics

- Basin-scale perspective important:
  - interplay between multiple plants
  - Interaction with other anthropogenic pressures

- First results indicate complex effects and interactions, both biotic and abiotic
- Full data set under processing/ analysis
- Propagation of effects need to be taken into account (longitudinally, laterally)

For comments, questions, ideas:

Christine Weber, PhD
Research Group River Restoration/ Swiss Rivers Program
Eawag, Seestrasse 79, 6047 Kastanienbaum
Phone: +41 (0)58 765 22 14; Email: christine.weber@eawag.ch