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# Anatomy of a scientific paper



# Anatomy of a scientific paper: Descriptive metadata – what about?

Science of the Total Environment 675 (2019) 542–559

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Review  
**paper title**  
**Ecosystem shifts in Alpine streams under glacier retreat and rock glacier thaw: A review**

Stefano Brighenti<sup>a,b</sup>, Monica Tolotti<sup>b</sup>, Maria Cristina Bruno<sup>b,\*</sup>, Geraldene Wharton<sup>c</sup>, Martin T. Pusch<sup>d</sup>, Walter Bertoldi<sup>d</sup>

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**HIGHLIGHTS**

- We outline the changes in climate, glacier and permafrost occurring in the Alps.
- We detail the effects of glacier retreat and rock glacier thaw on stream habitats.
- We summarize the shifts in biotic communities and food webs in Alpine streams.
- A conceptual model of the diverse effects of deglaciation on such streams is given.
- Knowledge gaps and research priorities are examined, namely on rock glacier streams.

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**abstract**

This review provides a detailed synthesis of the effects of glacier retreat and permafrost thaw on stream ecosystems in the European Alps. As a working framework, we present a conceptual model developed from an integration of current knowledge and understanding of the habitat and ecological shifts in Alpine streams caused by deglaciation. In our work, we depict how climate change and the loss of cryosphere trigger complex cascading effects on Alpine hydrology, as the main water source, glaciers to rock glaciers, groundwater, and precipitation. The associated changes in stream habitat stability, turbidity, temperature, nutrient loadings, and concentrations of legacy pollutants and trace elements are identified. These changes are followed by complex ecological shifts in the stream communities (microbial community, primary producers, invertebrates) and food webs, with a predicted loss of biotic diversity. Corresponding increases in taxa abundances, biomass, functional diversity, and in the complexity of food webs, are predicted to occur in the upper reaches of Alpine catchments in response to ameliorating climatic and habitat conditions. Finally, current knowledge gaps are highlighted as a basis for framing future research agendas. In particular, we call for an improved understanding of permafrost influence on Alpine headwaters, including the ecology of rock-glacier fed streams, as these streams are likely to become increasingly important for water supply in many glacier-free Alpine valleys in the near future.

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than uncovered glaciers (Scherler et al., 2011), at least in the initial phases of glacial shrinkage (Banerjee, 2017). Although the present volume of the Alpine permanent cryosphere is difficult to quantify, Boeckli et al. (2012) estimated that permafrost has a larger extent (ca. 2000–11,600 km<sup>2</sup>) with respect to glaciers (ca. 2000 km<sup>2</sup>), and the shrinkage rates of the permafrost ice are estimated to be roughly 10–100-times lower than melting rates of the surface glacier ice (Hoegh et al., 2016). As a result, the remaining ice and residual ice will increase during the 21<sup>st</sup> century with a shift from glacial/periglacial to paraglacial/periglacial dominated processes, and here we summarize the significant effects anticipated on the hydrology, water quality and biodegradation of Alpine freshwaters.

### 3. Deglaciation and shifting stream habitat conditions

In this section we discuss the observed and predicted shifts in hydrology, geomorphology, habitat type, and water quality of Alpine streams as a consequence of deglaciation.

#### 3.1. Hydrology

Glaciers and snow currently represent major drivers of the Alpine hydrology, as their seasonal melting is strongly related with surface and groundwater flows. Driven by thawing-freezing cycles, discharge can be highly variable, with seasonal maxima during summer and minima during winter, and large diel fluctuations in summer (e.g. Malard et al., 1999; Ward et al., 1995; Smith et al., 2001; Jansson et al., 2013). Mountain rock glaciers store large amounts of water, trapped in the form of ice, which makes them significant water reservoirs in arid regions (Rangecroft et al., 2015; Jones et al., 2018). However, rock glaciers currently contribute only little to water flow in Alpine stream networks (Geiger et al., 2014; Krainer et al., 2007). For example, Krainer et al. (2011) found that only 1.4% of the annual outflow from the Laxau rock glacier watershed to have a permafrost ice origin, and that rock glaciers contribute only marginally (0.13%) to total runoff in the north Italian province of South Tyrol.

To assess hydrological shifts related to climate change in alpine environments, Milner et al. (2009) stress the importance of taking into account the dynamic interactions between snowmelt, ice melt, and groundwater contribution to the stream flow. In the early stages of glacier retreat, water discharge is increasing due to higher energy inputs from the atmosphere, earlier melting of reflective snow cover, and the consequent lower ice albedo (Milner et al., 2009). For instance, Finn et al. (2010) detected hydrological changes in the Roseng Valley (Switzerland) as consequence of 52 years of glacial retreat (i.e. from 1955 to 2007). Such changes include a significant increase in short-term flow variability, higher flow maxima during summer and lower minima during winter, and an earlier onset of spring runoff. In the advanced stages of glacier retreat, glacial runoff exceeds a hydrological tipping point referred to as “peak water” (Huss et al., 2017; Huss and Hock, 2018), and decreases due to prolonged glacier shrinkage and fragmentation (Stall et al., 2008). As glaciers retreat, split, and disappear, the importance of air warming (energy fueling the melting process) gradually drops, while the progressively rising snowline and the earlier onset of the seasonal snowmelt also reduces the role of the snowpack as a natural water reservoir (Stewart, 2009; Ziefel and Bugmann, 2009; Huss et al., 2017). As a result, many Alpine streams may run dry in summer in the near future, especially in warm and dry years (Ziefel and Bugmann, 2005). Moreover, the marked diel and seasonal discharge fluctuations are substituted by an increased dependency on stochastic precipitation events and on groundwater sources (Milner et al., 2009), with an increased flashiness of water regime due to the decreased buffering capacity exerted by the cryosphere (Huss et al., 2017).

The contribution of rock glaciers to Alpine water flow is anticipated to increase substantially in the future. In fact, the ice loss in rock glaciers, although slower than for typical mountain glaciers, will likely increase throughout warmer and prolonged summers. In addition, new rock glaciers may form in areas left uncovered by glaciers, through different and complex mechanisms that involve e.g. the evolution of debris-covered glaciers or the accumulation of ice and detritus under favourable slope settings (Whalley and Martin, 1992; Clark et al., 1998; Zavadni, 2007; Schoneicher et al., 2011; Anderson et al., 2018). In addition, Wagner et al. (2016) stress the potential hydrological contribution from fossil rock glaciers (i.e. with no melting activity and no residual ice) due to their water storage capacity during dry periods and buffering potential during flood events, and suggest that in the long-term, the catches rich in rock glaciers may be influenced by these landforms even when deglaciation has finished. Research on the contribution of permafrost to mountain hydrology has been mainly conducted on streams fed by rock glaciers. However, Rogger et al. (2017) considered also talus fans and Little Ice Age tills of a 5 km<sup>2</sup> catchment in the Ötztal Alps (Austria), and modelled that the complete disappearance of permafrost would reduce flood peaks by up to 19% and increase runoff by up to 17% during recession periods. This suggests that the water buffering capacity of Alpine slopes will likely change in the future not only due to snow cover and glacier loss but also due to permafrost thaw.

#### 3.2. Geomorphology

Glacier-fed streams represent an important source of sediments for the river basin below, with a significant proportion transported as bedload (Gurnell et al., 2000; Mao et al., 2019). The formation and reworking of glacial deposits left uncovered after glacier retreat promotes the formation of actively braiding proglacial reaches (Church and Ryder, 1972) with high width-depth ratios (Milner and Petts, 1994). Meltwater outburst events can be a key geomorphic driver for fluvio-glacial deposits (Gurnell et al., 2000). In addition, new lakes can form in the glacial forelands, with an increased likelihood of glacier outburst floods and related hazards (e.g. Emmer et al., 2015; Haeblerli et al., 2016; Carrivick and Tweed, 2016; Otto, 2019). Though rare in high mountain environments, thermokarst (i.e. ice-thaw formed) lakes can occur in permafrost conditions, as reported by Källä and Haeblerli (2003) on a rock glacier in the Swiss Alps. As deglaciation proceeds and glaciers shrink, fragment, and ultimately disappear, sediment transport gradually decreases, giving way to a period of incision of previously accumulated sediments (Church and Ryder, 1972; Fleming and Clarke, 2005) and a shift to more stable forms such as single-thread channels with higher sinuosity (Milner and Petts, 1994; McGregor et al., 1995; Gurnell et al., 2000). As the rapid uplift of the vegetational belts occurring in the Alps (Rogora et al., 2018) suggests, riparian vegetation may exert an increasing hydrogeomorphological role in stabilizing the channels in the late phases of glacier retreat. However, in glacier forelands, the succession rate from pioneer and herbaceous stages to shrubs is very slow, as it usually spans over more than a century (Gurnell et al., 2000; Eichel, 2019). Furthermore, preliminary findings from the Rocky Mountains (USA) suggest that the homogenisation of alpine vegetation will favour riparian herbaceous species at high elevations (McKernan et al., 2018), where shrubs may not act as hydrogeomorphological drivers as they do in lower reaches.

#### 3.3. Alpine stream habitat types

Water origin is considered the main driver of the habitat conditions in alpine streams, so that three major stream types were originally identified and described (see Ward, 1994): krenal (glacier-fed), krenal (groundwater-fed) and rhithral (snowmelt/precipitation-fed), each type characterized by different water temperature, channel form and stability, discharge patterns, turbidity, electrical conductivity and hydrochemistry (for a detailed description see Brown et al., 2003; Milner et al., 2010). Since the contribution of the different water sources to stream discharge shows high spatial heterogeneity and pronounced seasonality, a classification of stream types based on a longitudinal

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urgently needed for several key reasons. First, these freshwater habitats may serve as ecological refugia for cold-stenothermala biota and gain increasing conservation value. Secondly, permafrost thaw alters the physical and chemical properties of streams, causing water contamination and related problems for drinking waters (Sapetza, 2015). Thirdly, the so far limited studies in the Alps, supported by a few findings from outside Europe, show that streams fed by active rock glaciers are characterized by peculiar habitat conditions, which differ from those of other alpine stream types recognized so far. As a consequence, the role of rock glaciers in driving and modulating Alpine stream ecology is likely to become even more important in the near future.

Based on the review of existing knowledge on ecosystem shifts in alpine streams under glacier retreat and rock glacier thaw, we identify several key research priorities, and provide suggestions on how knowledge gaps may be addressed:

1. We advocate the need for an understanding of the interactions between the autotrophic and the heterotrophic components of biofilms, and on their relative importance and role in nutrient cycling. This will provide important insights into the food quality for primary consumers and allow predictions of future situations. In particular, there is the need for a deeper understanding of the ecological role of fungi and bacteria in alpine stream food webs.
2. Further investigations on community composition of primary producers in different stream types, and an understanding of the drivers and limiting factors for algal accrual during windows of opportunity, will lead to better predictions of future shifts in abundance and biomass increase and timing. Little is known about aquatic mosses diversity in alpine streams, and about their importance as hydromorphological drivers and detritus traps.
3. Invertebrate meio/microfauna, such as Copepoda, Ostracoda, Nematoda, Rotifera and Tardigrada, remain understudied in Alpine streams. Further work is particularly needed on species distribution, their autecology, and their sensitivity to deglaciation, which helps in recognizing their functional and ecological role in Alpine stream ecosystems.
4. For macroinvertebrates, interest in the intraspecific diversity loss linked to climate change has been increasing in recent years (e.g. Finn et al., 2013, 2014). Despite a recent study on benthic alpinist diversity (Leys et al., 2016), no specific research has been published so far on the loss of cryptic species related to deglaciation in the Alps. In addition, the phenotypic plasticity of organisms, and their physiological responses to environmental changes deserve further investigation (e.g. Lenanton et al., 2013).
5. For future food web studies, we call for better knowledge about the trophic and functional role of species in Alpine contexts, also based on molecular fingerprinting combined with stable isotope analysis and Bayesian mixing modelling (Niederist and Füreder, 2018). Considering small invertebrates in food web studies, when possible, will also give a more comprehensive picture on the ecological role of hypoxenes. Studies of the effects of POPs pollution and nutrient (P, N, OC) loads from glaciers into the food web are also limited. To the best of our knowledge, the ecological effects (e.g. uptake, biomagnification) of metals in both rock glacier- and glacier-fed streams have not been investigated so far.

In conclusion, our current understanding of the impacts of deglaciation on alpine stream ecology is largely based on fragmented data. A combination of high frequency logging and remote sensing would provide datasets with increased spatial and temporal resolution and the potential to derive valuable insights into the processes underpinning habitat and stream ecosystem changes in response to deglaciation. Advances in the analysis of such large datasets are currently creating collaborative opportunities for interdisciplinary and international research groups working on permafrost (International Permafrost Association, <https://iparcportal.org/>). Such innovative scientific networks





# Anatomy of a scientific paper: Descriptive metadata - Identifier

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**GRAPHICAL ABSTRACT**

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This review provides a detailed synthesis of the effects of glacier retreat and permafrost thaw on stream ecosystems in the European Alps. As a working framework, we present a conceptual model developed from an integration of current knowledge and understanding of the habitat and ecological shifts in Alpine streams caused by deglaciation. In our work, we depict how climate change and the loss of cryosphere trigger cascading effects on Alpine hydrology, as the main water sources shift from snow and glaciers to rock glaciers, groundwater, and precipitation. The associated changes in habitat conditions, such as channel stability, turbidity, temperature, nutrient loadings, and concentrations of legacy pollutants and trace elements are identified. These changes are followed by complex ecological shifts in the stream communities (microbial community, primary producers, invertebrates) and food webs, with a predicted loss of biotic diversity. Corresponding increases in taxa abundances, biomass, functional diversity, and in the complexity of food webs, are predicted to occur in the upper reaches of the Alps. Alpine catchments in response to ameliorating climatic and habitat conditions. Finally, current knowledge gaps are highlighted as a basis for framing future research agendas. In particular, we call for an improved understanding of permafrost influence on Alpine headwaters, including the ecology of rock-glacier fed streams, as these streams are likely to become increasingly important for water supply in many glacier-free Alpine valleys in the near future.

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### 3. Deglaciation and shifting stream habitat conditions

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#### 3.1. Hydrology

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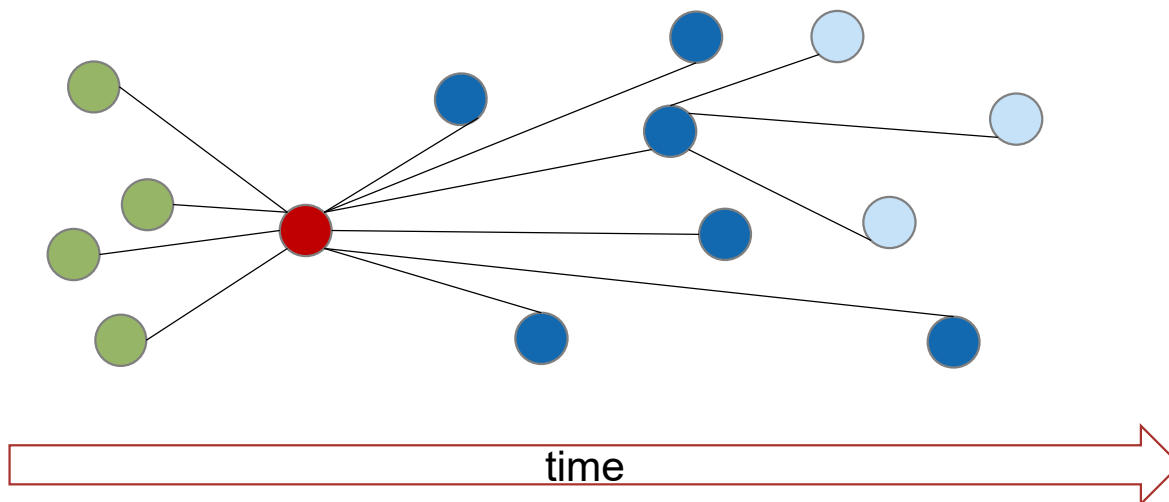
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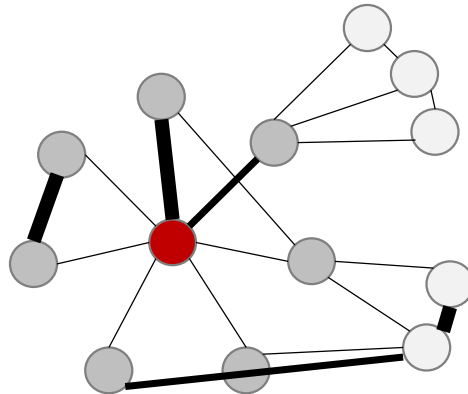
# Networks

# Scientific papers form networks: 1.) Citation network (terms used)

- **Paper** = article = journal article = work
- **Seed paper, source paper, origine paper** = *important paper – in my subjective view* ●
  - has **references** = cites **earlier works** = cites **prior works** ●
  - is **cited by** = is cited by **later works** = has **citations** ●



## Scientific papers form networks: 2.) Collaboration networks



- Researcher A
- Direct collaborators
- Collaborators of collaborators
- # of publications together

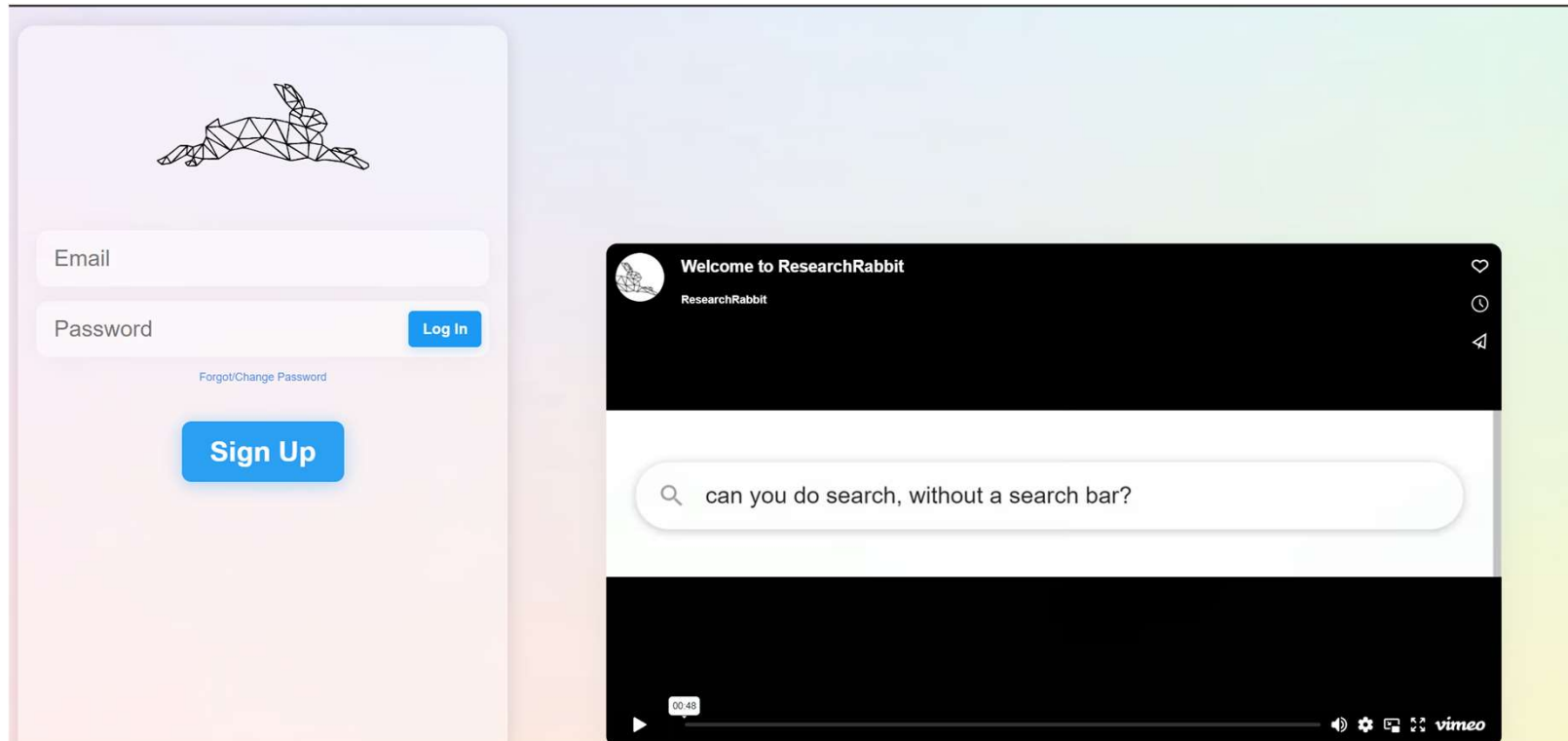
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# Research Rabbit: Procedure



1. Create new collection or select existing collection
2. Add paper(s)
3. Explore
  - earlier / later / similar works
  - authors
4. Export selected papers
  - BibTex, RIS, CSV

## **My seed paper**

Brighenti, Stefano, et al. "Ecosystem **er**:Shifts in Alpine Streams Under Glacier Retreat and Rock Glacier Thaw: A Review." *The Science of the Total Environment*, vol. 675, 2019, pp. 542–59, <https://doi.org/10.1016/j.scitotenv.2019.04.221>.

# Demo

# Limitations & Recommendations

# Recommendations

## Limitations

- What is the **data source**? ResearchRabbit uses Semantic Scholar & Pubmed. No data source covers “everything”!
- Analysis and visualization is based on a **subset of data** (= result list)
- Tools emerge and disappear – **longevity** of a tool is not guaranteed

## Recommendations

⇒ use the tools with these limitations in mind

⇒ **cannot replace searching classic databases**

⇒ **cannot replace reference management tools**

⇒ **can serve as an additional discovery path (visual approach 😊)**

# Further information

## ResearchRabbit help

- ResearchRabbit FAQ -> see help on <https://researchrabbitapp.com/home> (on the right hand side)

## Other tools with similar approach

- Connected papers <https://www.connectedpapers.com/>
- Inciteful <https://inciteful.xyz/>
- Litmaps <https://www.litmaps.com>

## ETH Library website information pages

- [Use of electronic media at ETH Zurich](#)
- Information on «classic» databases: [Dimensions Analytics](#), [Scopus](#), [Web of Science](#)
- Subject specific databases: [Media sorted by subject](#)
- [Managing references](#)



# Thanks for your attention!

Next Coffee Lecture:

Coffee Lectures will be back in June!  
Wednesdays 3.15 p.m.

See: [www.library.ethz.ch/coffee-lectures](http://www.library.ethz.ch/coffee-lectures) for program details!