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Habitat use and tolerance levels of macroinvertebrates concerning hydraulic stress in hydropeaking rivers – A case study at the Ziller River in Austria

P. Leitner [a,*], C. Hauer [b], W. Graf [a]

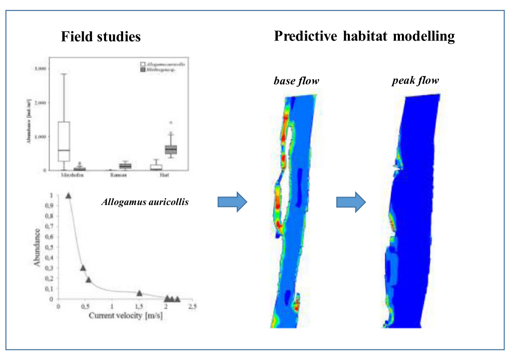
[a] Institute for Hydrobiology and Aquatic Ecosystem Management, Department for Water – Atmosphere – Environment, BOKU - University of Natural Resources and Life Sciences Vienna, Max Emanuel Str. 17, 1180 Vienna, Austria

[b] Institute for Water Management, Hydrology and Hydraulic Engineering, Department for Water – Atmosphere – Environment, BOKU - University of Natural Resources and Life Sciences Vienna, Muthgasse 107, 1190 Vienna, Austria

HIGHLIGHTS

- Habitats of stagnophilic macroinvertebrate taxa are significantly minimized in channelized stretches affected by hydropeaking.
- The WFD compliant national Austrian assessment method fails to detect impacts of hydropeaking on macroinvertebrates.
- The development of a stressor-specific sampling design is required as the MHS largely ignores vulnerable habitats.
- The hydraulic stress analysis provides expertise on the resistance of certain taxa in terms of hydropeaking.

GRAPHICAL ABSTRACT



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ABSTRACT

Artificial flow fluctuations due to the operation of hydropower plants, frequently described as hydropeaking, result in a constant decrease of biomass of specific macrozoobenthos (MZB) taxa. For the presented case study, we assessed three reaches in the Ziller River catchment. At each sampling reach we performed the Multi-Habitat-Sampling (MHS) method with a Water Framework Directive (WFD) compliant AQEM/MHS net according to the Austrian guideline. Additionally, a hydraulic-specific sampling was conducted with a modified Box (Surber) sampler. As a basis for predictive habitat modelling of the MZB fauna, we measured abiotic parameters like mean (v_{40}) and bottom-near (v_{bottom}) flow rate or water depth respectively, for each box sample. In addition, the choriotope type, representing grain size classes, was determined. One of the main results is, that the national status assessment was not capable to reflect the impact of pulse release at the investigated river stretches on the basis of status classes. Moreover, we figured out that 1) habitats of stagnophilic macroinvertebrate taxa are minimized in channelized stretches affected by hydropeaking, leading to heavy quantitative losses for populations, becoming apparent in significant decreases in total individual numbers and biomass for many taxa. 2) The minor respond of the ecological status class in affected stretches by applying the WFD compliant national assessment method for macroinvertebrates owes to the tolerance of rheobiont or rheophilic taxa commonly classified

* Corresponding author.
E-mail address: patrick.leitner@boku.ac.at (P. Leitner).

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as indicators for good conditions regarding saprobity or degradation score. 3) A development of a stressor-specific sampling design is required as the MHS method largely ignores vulnerable habitats. 4) The habitat suitability of selected species provides efficient expertise for impact assessment and mitigation measure design in terms of predictive habitat modelling.

1. Introduction

Artificial flow fluctuations due to the operation of hydropower plants, frequently described as hydropeaking (Moog, 1993; Saltveit et al., 2001), lead to an increase of physiological stress (Valentin et al., 1995), accelerating macroinvertebrate's (MZB) drift rate (e.g. Meile et al., 2005; Limnex, 2009) resulting in a constant decrease of biomass of specific taxa (Schweizer et al., 2009). In addition, changes in substrate composition and sediment quality are associated with hydropeaking (Anselmetti et al., 2007; Hauer et al., 2014) and reservoir operation in general (Poff and Hart, 2002; Wohl and Cenderelli, 2010). According to Wood and Armitage (1997) fine sediment deposition additionally impairs the MZB fauna by changing the substrate composition (Richards and Bacon, 1994), generally resulting in a reduction of abundance and diversity (e.g. Culp et al., 1985). Hence, both hydraulic stress and changes in substrate composition are crucial drivers of macroinvertebrate population in rivers with hydropeaking impacts.

Concerning the aims of the European Water Framework Directive (to achieve and preserve the good ecological status) the two aspects (i) sampling design and (ii) management tools turned out to be important and adapted for the analysis and the management of artificial flow fluctuation by hydropower on macroinvertebrates. The Water Framework Directive (WFD) compliant method for assessing the ecological status of rivers, concerning the Biological Quality Element macroinvertebrates, is exclusively based on the principle of the Multi-Habitat-Sampling (MHS) providing two assessment modules, Organic Pollution (saprobity) and General Degradation (multi-metric index) in Austria (Ofenböck et al., 2010). Previous studies (e.g. Graf et al., 2013) dealing with the effects of hydropeaking on benthic invertebrates already indicated that existing methods do not always lead to convincing results as abundance of populations is excluded from the analyses. Alpine rivers in Central Europe, with a few exceptions, are uniformly straightened and channelized, showing a general increase of flow velocity and hydraulic stress. Considering the hypothesis that lentic species inhabiting bank structures or habitats along the shoreline are worst affected by the additive stressor hydropeaking, we designed and applied an individual sampling design for this qualitative and quantitative survey.

For the required management and the need to implement predictive tools into the analysis of impacted rivers, habitat modelling turned out as a successful tool for a quantitative determination of (artificial) flow fluctuations (e.g. Tharme, 2003). Univariate functions, representing the habitat use related to a specific environmental variable (e.g. flow-velocity) were frequently applied in e-flow assessments based on habitat modelling (Ahmadi-Nedushan et al., 2006; Paredes-Arquiola et al., 2011). Univariate (suitability) functions for macroinvertebrates have been derived on hemisphere measurements (Bockelmann et al., 2004; Lancaster and Hildrew, 1993) representing near-bottom hydraulics (e.g. bottom shear stress), flow-velocity measurements (Shearer et al., 2015; Kelly et al., 2015), and Froude-number (Brooks et al., 2005; Jowett, 1993). However, studies about the habitat use of macroinvertebrates in terms of hydropeaking are missing. There is a lack of knowledge, which physical conditions are suitable under the restriction of artificial fluctuations in flow and consequently in altering hydraulics (e.g. flow velocities, bottom shear stress).

Thus, the aim of the present short communication is (i) to evaluate the national standard of macroinvertebrate sampling in terms of hydropeaking and (ii) to derive functional relationships between the abiotic environment (under the restriction of hydropeaking) and habitat use (suitability) of selected macroinvertebrate species. The derivation of suitability curves for *Rhithrogena* sp. and *Allogamus auricollis* is referred to on-site flow velocity measurements of depth-averaged flow velocities (ms^{-1}) and water depth (m). The hydropeaking impact was investigated on the basis of a calibrated depth-averaged hydrodynamic numerical model.

2. Study reach

For the present case study, we selected three reaches in the Ziller River catchment. The stream is a right tributary of the river Inn with a length of 55.7 km and a total catchment of 1135 km^2. The spring area is located at an altitude of 2270 m·a.s.l., the altitude at the confluence with the river Inn in Strass is at 517 m·a.s.l. According to Illies (1978) the river belongs to the ecoregion “Alps”, with its source in the bioregion “glaciated Crystalline Alps”, the investigated reaches are, however, located in the bioregion “non-glaciated Crystalline Alps” (Moog et al., 2001). Hence, the Ziller River has a nivo-glacial regime with a runoff maximum in July (Mader et al., 1996). According to Wimmer (1994), the stream order at the confluence is 6.

The first reach in the river continuum (Mayrhofen) was surveyed as a non-impacted reference site (global coordinates: 47.32886 N, 11.87256 E) and the stretches Ramsau (global coordinates: 47.20524 N, 11.86927 E) and Hart (global coordinates: 47.32928 N, 11.86657 E) were examined for hydropeaking impacts on macroinvertebrates due to the operations of hydropower-plant (HPP) Mayrhofen and HHP Gerlos (Fig. 1). The Ziller River exhibits significant morphological changes resulting from flood protection measures during the 1960's. Hence, only straight and/or plane-bed morphology was present, with average bed slopes of 0.0043 and 0.0054 for the hydropeaking stretches (Table 1). However, we recorded local sedimentological deposits (initial bar formations) within groin fields (Hauer et al., 2014).

3. Methods

At each sampling reach ($n = 3$) the MHS method was performed with a WFD compliant AQEM/MHS net (AQEM Consortium, 2002) according to the Austrian guideline (Ofenböck et al., 2010). The MHS method focuses on a multi-habitat scheme designed for sampling major habitats proportionally according to their presence (of at least 5% coverage) within a sampling reach, providing 20 sub-samples pooled to a total sample. Additionally, a hydraulics-specific sampling was performed with a modified Box (Surber) sampler. In total we took 18 box samples per investigation-site separately in different distances from the shoreline to cover the hydraulic gradient. Both methods were performed during base-flow to characterize and compare the benthic invertebrate fauna of an unaffected (reference) stretch and two downstream stretches of the Ziller River impaired by consistently pulse release. Per sample all benthic invertebrates were sorted and counted, determined to the highest possible level (for MHS) or to the mixed ‘screening level’ (for box samples) according to Ofenböck et al. (2010). Biomass was ascertained only for box samples.

As a basis for the modelling of the hydraulic impact on the MZB fauna, abiotic parameters like mean (v_{40}) and bottom-near (v_{bottom}) flow rate (using FloMate Marsh McBirney 2000) and water depth respectively, were measured for each box sample. In addition, we determined the choriotope type (according to Moog et al., 1999), representing different grain size classes (Bunte and Abt, 2001). Due to