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Evaluation of Restoration Projects with Hyperspatial Remote Sensing of Fish Habitat using an Unmanned Aerial Vehicle (UAV)

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Abstract

We developed a method to provide a relatively simple, quick and inexpensive assessment of restoration success in relation to fish fauna. Using a UAV, high-resolution orthomosaics of three restored and three channelized river sections were created under low, medium, and high flow situations. These served as the basis for remote mapping of fish habitats, focusing on riffle and shallow water areas as potential spawning and juvenile and hence key habitats for rheophilic fish species. It was found that by interpreting high-resolution orthomosaics, it was possible to map these habitats, whose actual suitability was validated with field observations. Together with an analysis of discharge time series (17 years), the mapped habitat situations were related to the probability of their occurrence. By combining morphological and hydrological analyses of the restoration projects, it was possible to assess whether the newly created habitats were usable all year round or only at certain flow situations.

Keywords: UAV, fish habitat mapping, restoration, hydropeaking.

1. INTRODUCTION

The evaluation of river restoration projects is very important (Bash and Ryan 2002) to enhance the effectiveness of future attempts. Regarding the fish fauna, there is common agreement that a rehabilitation of key habitats of the target community is necessary for long-term improvement. For rheophilic fish species in Europe, both spawning and juvenile habitats are considered key habitats (Person et al. 2014). It is thus reasonable to assume that restoration actions that restore

these key habitats are more likely to have a positive effect on the fish community than those that do not.

Traditionally, river habitat assessment is carried out in the field. However, it is more and more supplemented by methods of aerial image interpretation and other remote sensing techniques. Especially Unmanned Aerial Vehicles (UAVs) provide an easy, cost-effective alternative to traditional habitat mapping (Carbonneau and Piégay 2012).

In this work, a UAV was used to map fish habitats at three restored and three channelized river sections in Austria. One study site is located at the river Ybbs in Lower Austria, which shows a nivo-pluvial flow regime. The other two sites are located at the river Enns in Styria (moderate nival flow regime), one of which is heavily affected by hydropeaking. In addition, discharge time series were analyzed to relate the mapped habitat situations to the probability of occurrence of the documented flow situations.

2. DESCRIPTION OF THE METHOD

2.1 Habitat mapping

Aerial imagery was acquired with the UAV model DJI Phantom 4 RTK at an altitude of 60 m. The generated orthomosaics had a spatial resolution of 1.9 cm. For each restoration site, a channelized river section of equal length was chosen as comparison site. At each site, surveys were conducted at multiple flow situations, ranging from low to high flow. The mapping was done in the GIS-software QGIS. Fish habitat was digitized manually on mesohabitat-level by visual interpretation. The mapped mesohabitats consisted of riffles, shallow areas, pools and runs. Riffles and shallows were assigned the fish-ecological function as potential spawning and larval/juvenile habitats for rheophilic fish species. As ground-truth data, coloured metal discs were placed on the river bottom before the UAV survey. At each disc, water depth was measured, which later helped in the visual estimation of different water depths. Additionally, the mapped potential juvenile habitats were validated with traditional visual mapping of juvenile fish in these areas. We hereby were able to outline habitat availability both quali- and quantitatively.

2.2 Discharge analysis

To investigate the probability of the documented situations, discharge time series (2002–2018, 15 min) were obtained from the gauging stations closest to study sites. These were split into three discharge periods, respectively, according to the life cycle of the European grayling (*Thymallus thymallus*), whereas "spawning and incubation" included all data from March–May, "early juvenile" all data from May–July, and "late juvenile" all data from August–October. For these periods, flow-duration curves were calculated. These enabled to estimate the share of time the documented flow situations were exceeded, which was set as exceedance probability.

3. RESULTS AND CONCLUSION

The restoration at the Ybbs is considered a complete success, as the recreated spawning and juvenile habitats are available in high proportions at all flow situations, even at higher discharges with a rather low probability of occurrence.

The first studied restoration at the Enns led to an increase in spawning habitat. Juvenile habitat however remains a bottleneck as it is massively decreased at higher flows, which, however, are typical in the early phase of the life cycle of grayling due to the nival flow regime.

At the second studied restoration at the Enns, potential spawning and juvenile habitats have been recreated. However, because of sub-daily flow fluctuations due to hydropeaking, they are instable and hence not permanently available for fish. For example, 79% of newly created shallow water areas are dewatered in about 20% of the time and are therefore impose a high risk of stranding juvenile fish. These findings are summarized in Fig. 1.

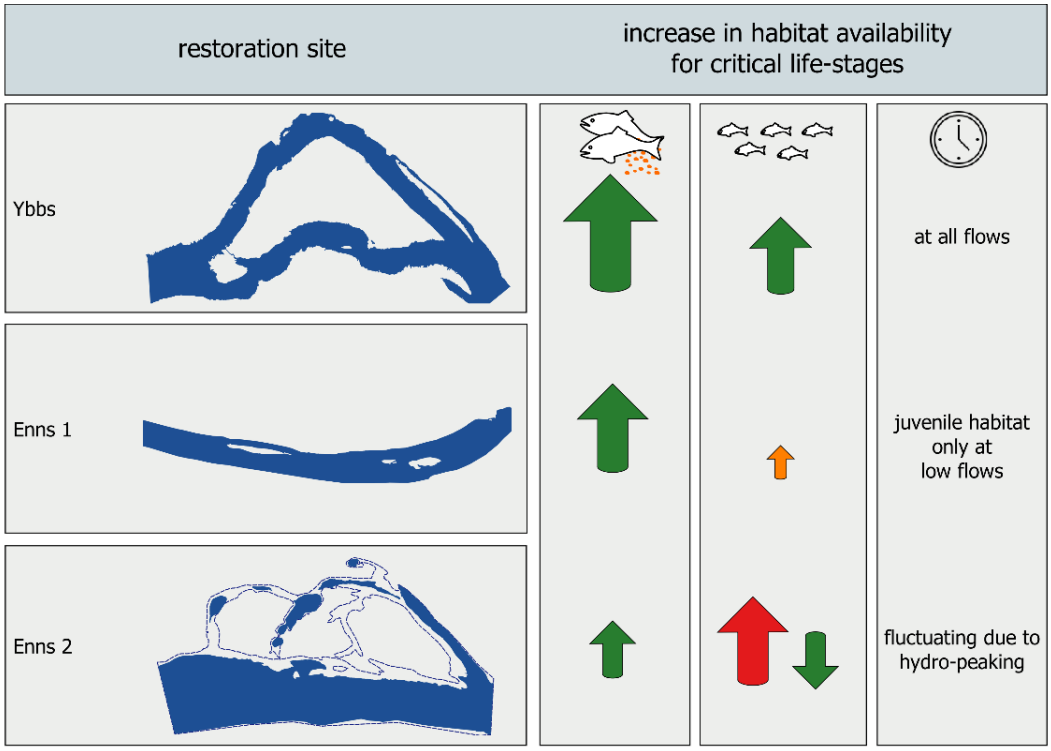

Fig. 1. Increase in habitat availability for critical life-stages of rheophilic species at the investigated restoration sites. Color code of arrows: green – permanently available habitat, orange – only at certain flows, red – temporarily available with stranding risk. The size of the arrows indicates the increase in habitat availability compared to a channelized reference site, following a space-for-time substitution.

With the chosen combination of morphological and hydrological assessments we were able to get a better understanding of fish habitat availability and how it changes with changing flow conditions, e.g. due to hydro-peaking. If fish habitat is mapped only at low flow, as it is frequently done in Austria, the results might not reflect a situation which is limiting for the fish fauna. With a UAV, quantitative habitat mapping can easily be done at multiple flow situations.

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