Modelling effects of spatiotemporal temperature variation on native and alien fish species in riverine ecosystems using thermal imagery

Frank Collas[a,b,*], Wimala van Iersel[c], Menno Straatsma[c], Rob Leuven[a,b]
[a] Radboud University, Department of Animal Ecology and Ecophysiology, Institute for Water and Wetland Research, The Netherlands
[b] Netherlands Centre of Expertise on Exotic Species (NEC-E), Nijmegen, The Netherlands
[c] Utrecht University, Geosciences, Utrecht, The Netherlands

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Introduction

Environmental stressors such as global warming and invasive alien species are increasingly impacting riverine ecosystems, thereby influencing water usage and biodiversity (Leuven et al. 2011; Van Vliet et al. 2013).

Water temperature is a key factor affecting distribution of native and alien freshwater fish species. When temperatures become too high detrimental stress occurs in many species ultimately resulting in mortality. The thermal limits of fish species were used to derive species sensitivity distributions (SSDs; Leuven et al. 2011), which allow to predict potentially affected fractions and habitat suitability in relation to changing water temperature regimes.

As water temperature of riverine ecosystems are expected to increase, thermal limits of fish species can be exceeded, urging the need to assess effects of ecological rehabilitation measures on temperature regimes of rivers. Recently, several side channels have been built in the floodplains of the river Rhine, though temperature regimes remain unclear.

The high spatiotemporal variability of water temperature limits the use of point measurements to accurately assess effects on fish species in rivers and side channels (Leuven et al. 2011). Potentially, unmanned airborne vehicles (UAVs) could provide temperature field with a spatial resolution of less than 1 m depending on flight elevation. UAVs can be employed with a thermal infrared sensor, potentially enabling spatial monitoring of water temperature in side-channels with a width up to 30 m.

The temperature of an object can be derived from its thermal infrared radiation (TIR) after correction for its emissivity. Water temperature assessed with remote sensing measures only the upper 0.1 mm of the water column (Handcock et al., 2012). The highly reflective water surface can disturb the thermal signal of the water by reflecting thermal radiation from the sun and surrounding objects via the water surface into the sensor (Anderson and Wilson, 1984). This effect varies over time, due to changes in solar angle and wind conditions. Hence, it remains unclear whether water temperature can be estimated with sufficient accuracy for freshwater fish habitat monitoring using UAV thermal imagery.

The present research aims to predict the ecological potential of a side channel during a hot summer day using UAV derived water temperature measurements. The research questions are: 1) How accurate can water temperature in side-channels be measured using UAV thermal imagery? 2) What is the spatiotemporal temperature variation of a side channel during a summer day? 3) What is the ecological potential of a side channel taking water temperature into account?

Method

Monitoring consisted of simultaneously collecting thermal imagery using a UAV and *in-situ* water temperature measurements using temperature loggers. The Sensefly Ebee UAV (SenseFly, 2017) employed with the ThermoMAP sensor was used to collect thermal imagery at 07:15h, 13:00h, 15:00h and 19:30h on August 29th 2017. Flight duration was approximately 15 minutes. *In-situ* water measurements were carried out with the Hobo Onset sensor 10 cm below the water surface at 24 locations distributed across the side channel covering variation in its depth and width. Before each flight, the vertical position of each logger was adjusted to ensure the positioning at 10 cm below the water surface. The loggers measured water temperature with a frequency of 0.1 Hz.

The UAV imagery were processed into orthophotos using SenseFly Postflight Terra. UAV imagery was geo-referenced using 23 ground control points. The TIR values of the

* Corresponding author
Email address: f.collas@science.ru.nl (F..Collas)
*URL:*http://www.ru.nl/environmentalscience/staff/individual-staff/collas/ (F. Collas)