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Genetic-based biomonitoring in an annular flume

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Highlights

- eNA degradation experiments were performed in an annular flume.
- Flow velocity measurements were in line with previous investigations.

Overview

Biodiversity across the globe has followed trends of decline (e.g. in abundance and genetic diversity) resulting from a number of human-induced drivers, i.e. climate change, pollution, invasive alien species, land use change and overexploitation (Purvis et al., 2019). For example, the most recent Living Planet Report by WWF (2022) reported an 83% decline in abundance between 1970 and 2018 within 6,617 monitored freshwater populations of a wide variety of vertebrate species. To monitor the effects of the aforementioned drivers, as well as to track progress by conservation and restoration efforts, there is a need for monitoring methods that can record high-resolution biodiversity data across large geographic scales (Bush et al., 2017).

The analysis of environmental DNA and RNA (eDNA and eRNA; i.e. eNA) has the potential to address these monitoring needs (Taberlet et al., 2018). eNA is the genetic material released by species into their environments in various forms (such as mucous, faeces, and skin tissue). The detection of this species-specific genetic material suspended in sampled water reflects the presence of the associated species and provides a non-invasive sampling method.

In lotic systems, i.e. rivers and streams, eNAs may be deposited or transported downstream, which spatially distances the genetic signal from its host. This depends on, for instance, the characteristics of the released eNA, the rate of eNA degradation and the flow characteristics of the system (Jane et al., 2015; Deiner & Altermatt 2014). As a result, a water sample collected in lotic systems contains a genomic 'cocktail', which may indicate species presence on extensive geographic scales (Deiner et al., 2016). Yet to estimate species distributions at finer scales, knowledge of the age of sampled eNA (the time between release by the organism and capture by the practitioner) should be combined with knowledge of the hydrodynamics within a system to yield estimates of the transported distance of sampled eNA. As of this moment, no such techniques have been studied in combination.

To address this knowledge gap, the authors have conducted a set of laboratory experiments. The objective of these experiments is to assess the viability of degrading eRNA-eDNA ratios as an indicator for the age of the sampled material under conditions with flow. Four different flow velocity conditions were created in a rotating annular flume (depth = 19.7 cm; Ø = 3.7 m), which features counter-rotating bottom and top components. The tested angular velocities of the top lid ($v_{top\ lid}$) were 0.00, 0.35, 1.05, and 1.80 m/s, with velocities of the bottom in a constant ratio ($v_{top\ lid}/v_{bottom} = \mathbf{1.8}$). Each of the configurations was tested over the duration of a seven day run. As a source of eNA, water previously inhabited by wild-type zebrafish (Danio rerio) was added to the flume. Concentrations of eRNA and

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eDNA were measured over the duration of the experiments by sampling water at multiple time points. Three samples were taken per time point to account for the observed spatial heterogeneity in the distribution of eNA (Wilcox et al., 2016). eNA concentrations were subsequently quantified using ddPCR by targeting a 73 base pair fragment of the frequently used cytochrome c oxidase subunit 1 gene. To characterize the vertical velocity profile in the flume, measurements were taken using an acoustic Doppler velocimeter (ADV). Validation of these measurements was done by comparison with a previous annular flume investigation under near-identical conditions (Booij, 1994). Flow velocity measurements of both investigations were in agreement, approximating the conditions to which the eNA was subjected in the flume experiments.

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Comparison of hydrodynamic conditions with literature

As the eNA was subjected to four different rotational velocity configurations, a first step was the description of the flow velocities in the flume. A vertical flow velocity profile was therefore measured using an ADV. As to validate our measurements (see Figure 1), additional data points were extracted from a previous annular flume investigation (Booij, 1994) which used an identical rotational velocity configuration ($\boldsymbol{v_{top\ lid} = 1.05\ m/s}$). Concurrently, this allowed us to supplement the velocity profile with data points that could not be obtained due to limitations of our measuring equipment. The velocity profiles of both investigations are in agreement, and produced the expected s-shaped curve with velocities increasing near the bottom and the top of the flume. To further characterize the conditions within the flume, we plan to create a vertical profile of the Reynolds shear stress using the ADV data which is once more validated by, and supplemented with, data from Booij (1994).

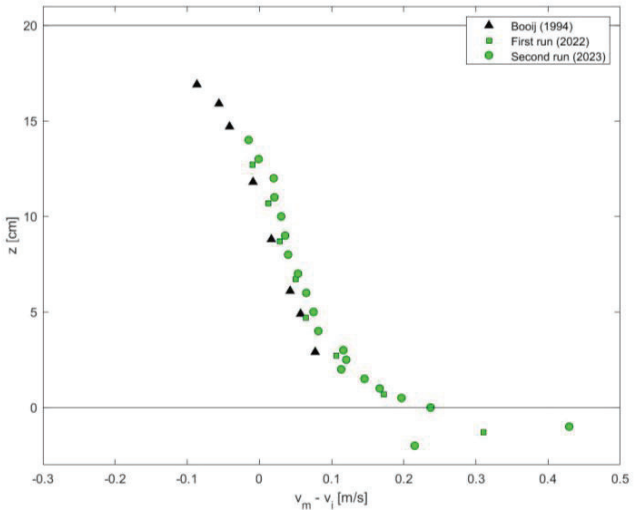

Figure 1. Comparison of the vertical velocity profile in the stream-wise direction with data from Booij (1994). $v_{top\ lid}$ *= 1.05 m/s;* v_m *= measured velocity in streamwise direction;* v_i *= velocity of the instrument mounted to the flume.*

Preliminary observations in eNA results

Preliminary analyses of the eNA samples confirm the expected decrease of both eDNA and eRNA concentrations throughout the experiment, regardless of the imposed flow velocity. Degradation rates of both eDNA and eRNA were more rapid during the first days of each experimental run, which decreased towards the end of each run. In addition, regardless of flow velocity, concentrations of eRNA generally decreased at higher rates than eDNA.