Estimating fish swimming speed using non-invasive backpack sensors in a laboratory flume at high flow velocities

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The response of fish to hydraulic conditions with velocities exceeding their sprint swimming speed and strong spatial velocity gradients was observed using wild-caught brown trout in a laboratory flume. Absolute flow velocities in the flume ranged from 2.3 to 8.5 body lengths per second (BL/s) for fish with BL of 20 to 34 cm. Positions and trajectories were acquired at 60 Hz using a calibrated array of infrared video cameras. The observed movement velocity was superimposed on two-dimensional numerical models of the local flow fields to obtain the relative fish speed. Additionally, one group of fish were equipped with non-invasive backpack sensors attached to the dorsal fins. The total pressure, linear acceleration, magnetic field intensity and rate of rotation was recorded at 100 Hz, and data were synchronized to each video-frame using a novel electromagnetic pulse system. Separate tests showed that there were no significant differences in the swimming activity of wild-caught brown trout with or without dorsal fin mounted sensors.

This study presents the results of the daylight experiments, where the majority of fish maintained positive rheotaxis, descending at mean swimming speed exceeding 1.5 BL/s. We provide evidence that the swimming speed of brown trout under extreme hydraulic conditions correlate with the tail-beat frequency which can be derived from gyroscope sensor data as well as the accelerometer data averaged over time scales larger than those corresponding to single tail beat movements. Experiments confirm that the relationship between the tail-beat frequency and swimming speed is dependent on the fish body length and exhibits unique features for tail-beat frequencies above 5 Hz. These findings are well-supported by fundamental research on fish locomotion for multiple freshwater species. Our results provide valuable insight into the response of brown trout to high-speed flows commonly found in fishways, intake structures and within turbines and pumps.