Biology 301 Laboratory
Fast-Start Performance in Fishes

Perca flavescens

Introduction

A fast-start is a high acceleration behaviour which fish use to escape from predators. One type of fast-start is the *C-start,* which has two stages. In **Stage 1**, the fish bends (in a "*C*") around the center of mass. In **Stage 2**, the fish bends in the opposite direction and initiates forward movement. In this laboratory, students will quantify the fast-start behaviour of fresh water perch (*Perca flavescens*) in three stages of their development, starting with a newly hatched larvae. Larval fish suffer from high predation, so fast-start behaviour is important for their survival.

The fast-start performances have already been collected using high-speed video, and stored on the WebFX environment, with a motion analysis program that allows students to quantify the fast-start performance.

> The original version of the motion analysis program was written by Erik Anderson, a former graduate student in the St.F.X. Comparative Biomechanics Laboratory (*CBL*), for his masters thesis research. The first version was modified by Rachel Bland, a former St.F.X. computer science student, who worked as a computer programmer in the *CBL*. Her version (HBMA5.2.EXE) was developed for a laboratory in Human Kinetics 375, and was subsequently modifed (by M.E. DeMont) for use in this laboratory. The program was written in *LabVIEW* (National Instruments), using Graftek Imaging *IMAQ* Imaging for *LabVIEW*.

The data were collected in the summer of 1998 by Justin MacKenzie, who was a NS Links funded student in the *CBL*. The data were collected as part of a collaborative research project with G.E. Newsome, St.F.X. Biology.

The fast-start performance of three fish will be examined in this laboratory (*click on the photograph for a larger image*):

(1) a newly hatched larvae - in all discussions that follow this is called **larvae**

(2) a four month old fish (roughly one-half year old) - called **half**

(3) a one year old fish - called **one**

To collect the data, fish were placed in a small aquarium. A high-speed video camera was positioned about the aquarium, and appropriate lens were used to magnify the image sufficiently to clearly view the fast-start behaviour. (**Note**: *since different magnifications were used, then different calibration settings will be needed for each analysis, as described below*.) The images were collected at 500 frames s^{-1}. The high-speed video camera, which is produced by Redlake Imaging, is shown below.

To simulate an attack from a predator, the bottom of the aquarium was struck with a blunt object (a hand-held trigger for a 35mm camera flash). Thus the time of the stimulus event can be seen on the recorded images as a bright flash of light. The length of time of the flash was about $1/500^{th}$ of a second, so the flash disrupts only one frame of the data. Notice that there is a short delay between the stimulus and the start of the fast-start behaviour. This is due to the time required for transmission through the neural pathways used in the escape behaviour!

Procedure

Find the fast-start data and the motion analysis program, by performing the following steps:

- Open: *My Computer*
- Open: *apps on 'Caesar' (S:)*
- Open: *Biomechanics*
- Open: *Programs*
- Launch: *FastStart.EXE*

- To see the data, click on **one** of the following boxes: *larvae, half or one*
- Click on *Accept Settings* (and wait!)

Further explanation on the functionality of the program will be given in the laboratory, however online help is available by clicking on the *HELP* button at the bottom of the screen (just above *STOP*). To **EXIT** from the program, click the *STOP* botton, and then go to *File* at the top of the screen, and *Close* the program.

1.) Open one of the data files, and use the frame viewer (at the bottom of the screen) to either step through the sequence, or view it as a movie by moving the slider to the right.

2.) Observe the flash of light, and the subsequent fast-start behaviour.

3.) View the sequence again to identify the two separate stages of the fast-start.

4.) In Stage 1, estimate the location of the center of mass of the fish, in relation to the anterior tip of the head.

5.) Now digitize the movement of this location in **Stage 2** of the fast-start response. (**Note:** *the program was written to calculate three points on each frame.*) The data will be stored in the root directory of your *H: drive*, with a file name that corresponds to the fish used in the analysis (ie. one.txt). The following data are needed for the *Calibration Settings*, and should be inserted in both the *X Step* and *Y Step* window. The units will be *centimeters*, which will also be the units of measurements of the digitized displacements.

- *Larvae* - 0.00524
- *Half* - 0.0200
- *One* - 0.0331

6.) Using Microscoft Excel calculate the velocity (V) of the center of mass of all three fish during **Stage 2,** and identify the **maximum** velocity of the center of mass. (**Note**: *the motion analysis program provides the x and y coordinates of the point - so use these to calculate the velocity in the x-coordinate, then the y-coordinate, and then use vector mathematics to calculate the net velocity between each time interval.*)

7.) Calculate the **maximum** Reynolds numbers (Re) of the movements characterized in (*6*). The equation for the Reynolds number is:

$$Re = (l\ V)/v_k$$

where l is the characteristic length of the fish, V is the velocity of the center of mass, and v_k is the kinematic viscosity of water (1.004×10^{-6} m^2 s^{-1}). To calculate the characteristic length of the fish, use the photographs given above. Compare the maximum Reyolds numbers of all three fish, and comment on the nature of the flow. Does this explain why the **larvae** perch is shaped differently than the **half** and **one** year old perch?

8.) Use the **maximum** velocity calculated in (*6*) to *estimate* the maximum drag force on all three fish. The drag force is defined as:

$$Drag = 0.5\ S\ d\ C_d\ V^2$$

where S is the area of the fish, d is the density of the water (1.0×10^3 kg m^{-3}), C_d is the drag coefficient, and V is the velocity. For area measurements, use the *maximum* frontal area, which can be estimated from the photographs of the fish, assuming a cylindrical cross-section. To *estimate* the drag coefficient, use the following equation:

$$Cd = 0.4 + \frac{24}{Re} + \frac{6}{1+\sqrt{Re}}$$

which is the drag coefficient for a sphere for *Re* less that about 100,000.

Pass in the spread sheet with the digitized displacement vs time data, the velocity, Reynolds number and drag force calculations, and the answer to the question in (7). Check the units of measurements!

References

P. Domenici and R.W. Blake (1997). The kinematics and performance of fish fast-start swimming. **J. exp. Biol.** 200, 1165-1178.

M.E. Hale (1996). The development of fast-start performance in fishes: Escape kinematics of the chinook salmon (*Oncorhynchus tshawytscha*). **Amer. Zool.**, 36: 695-709.

S. Vogel (1994). Life in Moving Fluids. Princeton University Press.

Back to Biology 301

Edwin DeMont, Associate Professor
Biology Department, St. Francis Xavier University
P.O. Box 5000, Antigonish, Nova Scotia, B2G 2W5 Canada
Voice 902-867-5116 FAX 902-867-2389
edemont@stfx.ca - November 30, 1999