Supplementary Materials: Compiled Data on Animal Swimming Kinematics

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1. Description of Data Collection Process

The swimming dataset presented in the main text is digitized from previous studies. Suitable data sources were identified through a general literature survey and through reference to previous data compilations, Eloy (2012) and van Weerden *et al.* (2014). For each source, five distinct quantities are recorded : frequency (f), amplitude (A), velocity (V), wavelength (λ), and body length (ℓ). These values are used to calculate three dimensionless quantities: the Strouhal number (St), the slip ratio (V/c), and the Reynolds number (Re),

$$St = \frac{2fA}{V}, \quad V/c = \frac{V}{f\lambda}, \quad Re = \frac{\rho V \ell}{\mu}. \tag{1.1}$$

Wherever possible, frequency, amplitude, velocity and wavelength are taken directly from the referenced source or calculated from other reported quantities such as wave speed ($f\lambda$) or stride length (V/f). In the case of Bainbridge (1958) wavelength data is not provided. Consequently, the value of λ is instead referenced from other sources, see the source summary for further details.

2. Exclusions from Dataset

The dataset is restricted to swimming species with geometries which satisfy the assumptions of our analysis. In particular, this excludes any species with a high aspect ratio tail, such as most scombrids and cetaceans, as they do no meet the slenderness requirements of Lighthill's elongated body theory. Swimmers with a tapered trailing edge, such as salamanders and tadpoles, are also excluded. In these cases, momentum is shed along the entire length of the tapered region and consequently thrust production is poorly characterized by the motions of the tail tip alone.

3. Source Summaries

The following section provides a brief description of the experimental process in each of the referenced sources. In particular, the swimming conditions and fish population used within each study are summarized, along with the size and range of the collected dataset.

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A number datapoints were taken directly from the meta-analysis of van Weerden. Kinematics taken from this source are identified in the the left most column of the data table. Summaries for these sources are not included here, the reader is instead referred to van Weerden *et al.* (2014) for further info.

Bainbridge (1958) - *The speed of swimming of fish as related to size and to the frequency and amplitude of the tail beat.*

Bainbridge presents kinematic data extracted from video recordings of three different fish species: Dace (Leuciscus leuciscus), Trout (Salmo irideus), and Goldfish (Carassius auratus). Recordings of individuals from each species are taken during steady swimming in a current generating tank. Within the source paper, frequency, amplitude, and swimming speed are reported for each swimming recording, however, wavelength is omitted. Consequently, the wavelength value used in our analysis is instead referenced from other sources. For Goldfish (Carassius Auratus), it is calculated based on the specific wavelength reported for common goldfish in Blake *et al.* (2009). For Rainbow Trout (Salmo Iridius) it is calculated based on the wavelength relation reported in Webb *et al.* (1984). In each case the referenced sources report the specific wavelength to be independent of swimming velocity. No suitable data could be found for the wavelength of Dace (Leuciscus leuciscus), and as a result they are not included in our compiled dataset. In total, this paper provides 113 unique data points for our analysis. These points span 3 unique Trout individuals and 2 unique Goldfish, with swimming speeds ranging from 1-16BL/s. This data is extracted from the plots of amplitude, frequency, and swimming speed presented in figures 8, 10, 12, and 14 of the source paper.

Blake *et al.* (2009) - *Swimming in four goldfish carassius auratus morphotypes: understanding functional design and performance employing artificially selected forms.*

Blake et al. present kinematic data extracted from video recordings of goldfish (Carassius orates) during steady swimming in a current generating tank. The study presents kinematic data for four distinct goldfish morphotypes: Common, Comet, Fantail, and Eggfish. These morphotypes are primarily distinguished by differences in body and tail shape. The resulting dataset contains swimming kinematics for a single individual of each morphoptype, with swimming speeds varying from 1 to 7 BL/s. In total, this paper provides 16 unique data points. This data is extracted from the plots of amplitude, frequency, and swimming speed presented in figure 5 of the source paper and the reported wavelength for each morphotype.

Langerhans (2009) - *Trade-off between steady and unsteady swimming underlies predator-driven divergence in gambusia anis.*

Langerhans presents kinematic data extracted from video recordings of mosquitofish (Gambusia affinis) during steady swimming in a current generating tank. The study presents kinematic data for Mosquitofish taken from two distinct environments: high predation and low predation. The resulting dataset contains swimming kinematics for three individuals from each category, with all individuals swimming at an imposed speed of approximately 7BL/s. In total, this paper provides 6 unique data points for our analysis. This data is extracted from the plots of amplitude, frequency, and wavelength presented in figure 4 of the source paper.

Long *et al.* (1996) - *Functions of fish skin: flexural stiffness and steady swimming of longnose gar, lepisosteus osseus.*

Long et al. present kinematic data extracted from video recordings of the Longnose Gar (lepisosteus osseus) during steady swimming in a flow tank. Within the study, kinematic data is recorded for three distinct individuals swimming at speeds ranging from 0.25 to 1 BL/s. For each swimming speed, kinematics are reported as the average amplitude, wavelength, and frequency, across all three animals. In total, this paper provides 7 unique data points for our analysis. This data is extracted from the plots of amplitude, wavelength, frequency, and swimming speed presented in figures 5, 6, and 7 of the source paper.

Videler & Wardle (1978)- *New kinematic data from high-speed cine film recordings of swimming cod (gadus morhua).*

Videler and Wardle present kinematic data extracted from video recordings of cod (gadus morhua) trained to swim steadily back and forth along a track. Within their study they examine the swimming behavior of 8 individual fish, but present numerical results for just a single swimmer which produced the most consistent bouts of steady swimming. The velocity, wavelength, frequency, and amplitude of the animal's swimming gait are reported for each recording. In total, this paper provides six unique data points for our analysis. These points are extracted from fig. 5 of the source paper, which tabulates the kinematic parameters of the fish for 6 different swimming velocities.

Videler & Hess (1984) - *Fast continuous swimming of two pelagic predators, saithe (pollachius virens) and mackerel (scomber scombrus): a kinematic analysis.*

Videler and Hess present kinematic data extracted from video recordings of the Saithe (Pollachus Virens) during steady swimming along a 14m track in a tank. Within the study, kinematic data is recorded for single specimen. An initial set of recordings was made when specimen had grown to a length of 0.35m and second set was taken a few months later when it had grown to 0.4m. Across all measurements, swimming speeds ranged from 1 to 6 BL/s. In total, this paper provides 13 unique data points for our analysis. This data is extracted from the tabulated kinematics in table 1 of the source paper.

Webb & Keyes (1982)- *Swimming kinematics of sharks*

Webb and Keyes present kinematic data extracted from video recordings of the blacktip shark. (Carcharhinus melanopterus) during steady swimming in a large aquarium. Within the study, kinematic data is recorded for 7 distinct individuals with swimming speeds ranging from 1 to 4 BL/s. In total, this paper provides 13 unique data points for our analysis. This data is extracted from the plots presented in figures 4 and 5 of the source paper.

Webb (1986) -*Kinematics of lake sturgeon, acipenser fulvescens, at cruising speeds*

Webb presents kinematic data extracted from video recordings of Lake Sturgeon (acipenser fulvescens) during steady swimming in a current generating flume. The resulting dataset contains swimming kinematics for 10 unique individuals, with swimming speeds varying from 1 to 3 BL/s (body lengths per second). In total, this paper provides 57 unique data points for our analysis. This data is extracted from the plots of amplitude, wavelength, frequency, and swimming speed presented in figures 1 and 2 of the source paper.

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