Appendix A. Larva's geometry

The geometrical aspect of the swimmer is characterized by the half width $w(s)$ of the body along its length, defined as:

$$w(s) = \begin{cases} w_h\sqrt{1-\left(\dfrac{s_b-s}{s_b}\right)^2} & 0 \leqslant s < s_b \\ (-2(w_t-w_h)-w_t(s_t-s_b))\left(\dfrac{s-s_b}{s_t-s_b}\right)^3 + & \\ (3(w_t-w_h)+w_t(s_t-s_b))\left(\dfrac{s-s_b}{s_t-s_b}\right)^2 + w_h & s_b \leqslant s < s_t \\ w_t - w_t\left(\dfrac{s-s_t}{L-s_t}\right)^2 & s_t \leqslant s \leqslant L \end{cases}$$

where L is the body length, $s_b = 0.0862L$, $s_t = 0.3448L$, $w_h = 0.0635L$ and $w_t = 0.0254L$. In the three-dimensional case, the geometry is described in terms of elliptical cross sections with width $w(s)$ and height $h(s)$, where $h(s)$ is given by

$$h(s) = \begin{cases} h_1\sqrt{1-\dfrac{(s-s_1)^2}{s_1^2}} & 0 \leqslant s \leqslant s_1 \\ -2(h_2-h_1)\left(\dfrac{s-s_1}{s_2-s_1}\right)^3 + 3(h_2-h_1)\left(\dfrac{s-s_1}{s_2-s_1}\right)^2 + h_1 & s_1 < s \leqslant s_2 \\ -2(h_3-h_2)\left(\dfrac{s-s_2}{s_3-s_2}\right)^3 + 3(h_3-h_2)\left(\dfrac{s-s_2}{s_3-s_2}\right)^2 + h_2 & s_2 < s \leqslant s_3 \\ h_3\sqrt{1-\left(\dfrac{s-s_3}{L-s_3}\right)^2} & s_3 < s \leqslant L \end{cases}$$

Here we use the following parameter pairs: $(s_1, h_1) = (0.284L, 0.072L)$, $(s_2, h_2) = (0.844L, 0.041L)$ and $(s_3, h_3) = (0.957L, 0.071L)$.

Appendix B. Definition of efficiency

We define the efficiency as follows:

$$\eta = \frac{E_{\text{useful}}}{E_{\text{flow}}}, \tag{B 1}$$

where E_{useful} is the kinetic energy of the fish:

$$E_{\text{useful}} = \frac{1}{2}m\bar{U}^2, \tag{B 2}$$

with $\bar{U}$ the mean velocity of the fish during the simulation time $(T_{prep} + 2T_{prop})$ and m the fish mass.

The term E_{flow} represents the total energy delivered to the fluid,

$$\int_{\tau=0}^{T_{prep}+2T_{prop}} P_{\text{flow}}(t)\, d\tau, \tag{B 3}$$

where P_{flow} is the total instantaneous power delivered to the fluid, which accounts for rate of change of kinetic energy and dissipation due to viscous stresses:

$$P_{\text{flow}} = \frac{d}{dt}\int_{\Omega_f} \rho\frac{u^2}{2}\, d\Omega + \mu\int_{\Omega_f} \left(\nabla\mathbf{u} + (\nabla\mathbf{u})^T\right) : \nabla\mathbf{u}\, d\Omega, \tag{B 4}$$

with Ω_f denoting the spatial region occupied with fluid, and $u^2 = \mathbf{u}\cdot\mathbf{u}$.

Since we have a computational domain with free-space boundary conditions, the velocity field is not completely contained within the computational domain and the evaluation of the above integrals is not trivial. We will discuss the contribution of the velocity field outside our computational domain for each of the two terms in the right hand side of equation B 4.

For the first term we first note that, for a divergence-free velocity field, the following kinematic identity holds (Winckelmans & Leonard 1993):

$$\int_\Omega \mathbf{u} \cdot \mathbf{u} \, d\Omega = \int_\Omega \Psi \cdot \boldsymbol{\omega} \, d\Omega. \tag{B 5}$$

Here Ψ is the streamfunction, defined as the solution of the Poisson equation

$$\nabla^2 \Psi = -\boldsymbol{\omega}, \tag{B 6}$$

hence $\mathbf{u} = \nabla \times \Psi$. The integral on the right-hand side can be computed in Fourier space from a compact vorticity field, and thus the kinetic energy in a domain with free-space boundary conditions can be computed as a function of the vorticity field only. To get the kinetic energy in the fluid domain only, we subsequently subtract the kinetic energy within the fish from this sum. Finally, the time derivative of the integral is computed as a first order finite difference between two timesteps.

In the current case, however, the velocity field inside the swimmer is not divergence free (due to the deformation velocity field of the swimmer - for more details refer to Gazzola *et al.* (2011)). The integral in equation B 5 therefore is an incomplete measure of the total kinetic energy since it neglects the contribution of the potential to the velocity field. After initial tests comparing the influence of the potential, however, we observed that this contribution to both the total kinetic energy as well as its time-derivative was several orders of magnitude smaller than the contribution from the stream function. To save in computational costs we therefore chose to neglect the contribution from the potential and base the efficiency on the kinetic energy due to the vorticity-induced velocity only.

The second integral in Eq. B 4 represents the viscous dissipation term. By systematically increasing the domain size, we found that the contribution this increase is negligible and we therefore compute this integral only inside the computational domain.

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