Appendix S1. Hydrodynamic drag and energy expenditure: mathematical model

The hydrodynamic model provides equations of motion for the whale during the different phases of the lunge. The energy budget that results from such simulation of the whale's motion is as follows:

- *Pre-engulfment*:

$$\Delta KE = -\Delta Q_{drag}{}^{shape} + \Delta Q_{thrust}{}^{pre} \approx \Delta Q_{thrust}{}^{pre} \qquad \text{(eqn. S1.1)}$$

- *Engulfment*:

$$-\Delta KE = -\Delta Q_{drag}{}^{engulfment} - \Delta Q_{drag}{}^{shape} + \Delta Q_{thrust}{}^{open/close} \qquad \text{(eqn. S1.2)}$$

The negative term $-\Delta Q_{drag}{}^{engulfment}$ corresponds to the energy losses due to engulfment drag (F_{ED}), and the positive terms $\Delta Q_{thrust}{}^{pre}$ and $\Delta Q_{thrust}{}^{open/close}$ to the (thrust) energy gained from swimming strokes during pre-engulfment and engulfment, respectively (both mouth opening and closing stages). The term $-\Delta Q_{drag}{}^{shape}$ (negative) would represent the losses due to shape drag F_{SD} , active and/or passive. Note that during pre-engulfment $F_{ED} \equiv 0$ in Eqn. 1.1. Moreover, it is assumed that F_{SD} is much smaller than fluking thrust during that particular phase (and only during that phase). The left-hand-side (LHS) of both Eqs. S1.1 and S1.2 represent the change of kinetic energy in each phase, namely $\Delta KE \equiv ½\, \rho_w\, (V_c(0)^2 - V_c(t_{engulf})^2)$, between the moment of mouth opening (time = *0*) and that of mouth closure (time = t_{engulf}). Both LHS's are equal in magnitude following an assumption of repeated lunges being performed with approximately identical initial and final velocities (i.e. see Fig. 9 of Goldbogen et al. 2006 or Fig. 2 of Goldbogen et al. 2011).

The mechanical energy expended (ΔQ_{lunge}) will depend on the specific actions by a whale to complete a lunge. Given that such action is to vary both within and among individuals, three scenarios are considered herein:

1) For coasting during engulfment, i.e., with no fluking thrust and with shape drag being exclusively passive:

$$\begin{aligned}\Delta Q_{lunge} &= \Delta Q_{thrust}{}^{pre} + \Delta Q_{drag}{}^{engulfment} \\ &= 2\Delta KE - \Delta Q_{drag}{}^{shape}\end{aligned} \qquad \text{(eqn. S1.3)}$$

2) For using fluking thrust during engulfment as a means to cancel shape drag:

$$\begin{aligned}\Delta Q_{lunge} &= \Delta Q_{thrust}{}^{pre} + \Delta Q_{drag}{}^{engulfment} + \Delta Q_{thrust}{}^{open/close} \\ &= 2\Delta KE + \Delta Q_{drag}{}^{shape}\end{aligned} \qquad \text{(eqn. S1.4)}$$

3) For coasting during engulfment, but with using the tail and flukes as hydrodynamic brakes (i.e., active shape drag,) rather than for thrust:

$$\begin{aligned}\Delta Q_{lunge} &= \Delta Q_{thrust}{}^{pre} + \Delta Q_{drag}{}^{engulfment} + \Delta Q_{drag}{}^{shape} \\ &= 2\Delta KE\end{aligned} \qquad \text{(eqn. S1.5)}$$

Both eqns. S1.1 and S1.2 were used to arrive at the above results, with the constraint $\Delta Q_{thrust}{}^{open/close} = 0$ invoked for eqns. 4 and 6, and the constraint $\Delta Q_{thrust}{}^{open/close} - \Delta Q_{drag}{}^{shape} = 0$ for eqn. S1.4. Whether fluking action is being used for thrusting or breaking during the engulfment phase is currently unknown, mostly because it is unknown when mouth opening precisely occurs. Given that tag data, nor video data (Calambokidis *et al.* 2007), is unambiguous enough to completely support any one of the above three scenarios during the engulfment phase, and similarly to Goldbogen et al. (2011), eqn. S1.5 is used to estimate ΔQ_{lunge} in this study (and in Table S2). Note that averaged tag data (and frequency maxima) also provided the needed velocity input data (namely $V_c(0)$ and $V_c(t_{engulf})$) for the modeling of engulfment at various body sizes.

The shape drag values obtained in the modeling of the third scenario were used also to get a rough estimate of the muscular energy expenditures related to the other two engulfment scenarios of eq. S1.3 and S1.4. Over the ranges of initial velocities ($V_c(0)$) and drag coefficient considered, the modeling suggest $\Delta Q_{drag}{}^{engulfment} \sim {}^{3}/_{4}\ \Delta Q_{drag}{}^{shape}$ (and thus $\Delta Q_{drag}{}^{shape} \sim {}^{4}/_{7}\ \Delta KE$ from eqn. S1.1). Therefore, the $\Delta Q_{drag}{}^{shape}$ term in eqn. S1.3 and S1.4 representing as much as 28% (at most) of the lunge energy.