# Supplement S1

Table S1. Bioenergetic model parameter values for humpback whales. See 'Materials and Methods' and Electronic Supplement S2 for details.

| Parameter | Symbol | Unit | Values | Sources |
|---|---|---|---|---|
| *Von Bertalanffy length-at-age models* | | | | |
| Asymptotic size (male) | $L_{\infty}$ | meters | 12.63±0.002 | Derived from Chittleborough (1965) data |
| Asymptotic size (female) | $L_{\infty}$ | meters | 13.41±0.002 | Derived from Chittleborough (1965) data |
| Growth rate coefficient ($yr^{-1}$) (male) | $k$ | unitless | 0.65±0.001 | Derived from Chittleborough (1965) data |
| Growth rate coefficient($yr^{-1}$) (female) | $k$ | unitless | 0.52±0.001 | Derived from Chittleborough (1965) data |
| Age when the average size is zero (male) | $t_0$ | age | -0.68±0.002 | Derived from Chittleborough (1965) data |
| Age when the average size is zero (female) | $t_0$ | age | -0.84±0.003 | Derived from Chittleborough (1965) data |
| *Length-at-age models* | | | | |
| Mean length calf male (0-1 years old) | $L$ | meters | 6.54±1.18 | This study |
| Mean length calf female (0-1 years old) | $L$ | meters | 6.51±1.07 | This study |
| Mean length juvenile male (1-5 years old) | $L$ | meters | 11.36±1.11 | This study |
| Mean length juvenile female (1-5 years old) | $L$ | meters | 11.54±1.34 | This study |
| Mean length adult male (> 6 years old) | $L$ | meters | 12.61±0.01 | This study |
| Mean length adult female (> 6 years old) | $L$ | meters | 13.36±0.08 | This study |
| *Weight-at-age models* | | | | |
| Mean mass calf male (0-1 years old) | $M$ | tonnes | 6.67±2.11 | This study |
| Mean mass calf female (0-1 years old) | $M$ | tonnes | 6.84±2.19 | This study |
| Mean mass juvenile male (1-5 years old) | $M$ | tonnes | 19.95±4.60 | This study |
| Mean mass juvenile female (1-5 years old) | $M$ | tonnes | 21.65±5.53 | This study |
| Mean mass adult male (> 6 years old) | $M$ | tonnes | 30.00±1.23 | This study |
| Mean mass adult female (> 6 years old) | $M$ | tonnes | 35.37±2.09 | This study |
| *Basal metabolic rate* | | | | |
| Intercept | $a$ | unitless | 0.70 | Kleiber (1975) |
| slope | $b$ | unitless | 0.67-0.75 | Kleiber (1975), White & Seymour (2005) |
| *Growth costs* | | | | |
| Proportion of body mass that is lipid (mean) | $P_{lip}$ | % | 47-52 | Lockyer et al. (1985), Lockyer (1986), Víkingsson (1990) |
| Energetic density of lipid | $ED_{lip}$ | kcal $g^{-1}$ | 9.50 | Brody (1945) |
| Energetic density of protein | $ED_{pro}$ | kcal $g^{-1}$ | 5.65 | Brody (1945) |
| Proportion of lean tissue that is water | $P_{water}$ | % | 60-75 | Lockyer (1981) |

| Parameter | Symbol | Unit | Values | Sources |
|---|---|---|---|---|
| *Activity costs* | | | | |
| Range swimming speed and proportion of time spent – feeding area (all age-class): | | | | |
| ARS behavior – speed | $V_{\text{ARS-feed}}$ | m s$^{-1}$ | 0.21-0.36 | Zerbini et al. (2006, 2011), Laguerquist et al. (2008), Dalla Rosa (2010), Ware et al. (2011), Kennedy et al. (2014) |
| ARS behavior – proportion time | $T_{\text{ARS-feed}}$ | h | 16 | |
| Transit behavior – speed | $V_{\text{trans-feed}}$ | m s$^{-1}$ | 0.87-1.11 | |
| Transit behavior – proportion time | $T_{\text{trans-feed}}$ | h | 3 | |
| Uncertain behavior – speed | $V_{\text{unc-feed}}$ | m s$^{-1}$ | 0.53-0.67 | |
| Uncertain behavior – proportion time | $T_{\text{unc-feed}}$ | h | 5 | |
| Range swimming speed and proportion of time spent – migration: | | | | |
| Calf and lactating females – speed | $V_{\text{migration}}$ | m s$^{-1}$ | 1.27±0.47 | Gabriele et al. (1996), Mate et al. (1998), Zerbini et al. (2006, 2011), Laguerquist et al. (2008), Burns (2010), Kennedy et al. (2013), Félix & Guzmán (2014), Fossette et al. (2014), Dulau et al. (2017) |
| Juveniles both sexes – speed | $V_{\text{migration}}$ | m s$^{-1}$ | 1.32±0.47 | |
| Adult males – speed | $V_{\text{migration}}$ | m s$^{-1}$ | 1.70±0.45 | |
| Adult females – speed | $V_{\text{migration}}$ | m s$^{-1}$ | 1.42±0.20 | |
| Proportion time (all classes) | $T_{\text{migration}}$ | h | 24 | |
| Range swimming speed and proportion of time spent – breeding area: | | | | |
| ARS behavior (calf and adults) – speed | $V_{\text{ARS-breed}}$ | m s$^{-1}$ | 0.17-0.66 | Mate et al. (1998), Laguerquist et al. (2008), Kennedy et al. (2013), Félix & Guzmán (2014), Fossette et al. (2014), Trudelle et al. (2016), Guzmán & Félix (2017) |
| ARS behavior (calf and mother) – proportion time | $T_{\text{ARS-breed}}$ | h | 15 | |
| ARS behavior (juveniles, pregnant and nonreproductive females) – proportion time | $T_{\text{ARS-breed}}$ | h | 0 | |
| ARS behavior (adult males) – proportion time | $T_{\text{ARS-breed}}$ | h | 11 | |
| Transit behavior (all age-class) – speed | $V_{\text{tran-breed}}$ | m s$^{-1}$ | 0.78-1.24 | |
| Transit behavior (calf and mother) – proportion time | $T_{\text{tran-breed}}$ | h | 5 | |
| Transit behavior (juveniles, pregnant and nonreproductive females) – proportion time | $T_{\text{tran-breed}}$ | h | 12 | |
| Transit behavior (adult males) – proportion time | $T_{\text{tran-breed}}$ | h | 9 | |
| Uncertain behavior (all age-class) – speed | $V_{\text{unc-breed}}$ | m s$^{-1}$ | 0.56-0.67 | |

| Parameter | Symbol | Unit | Values | Sources |
|---|---|---|---|---|
| Uncertain behavior (calf and mother) – proportion time | $T_{\text{unc-breed}}$ | h | 4 | Mate et al. (1998), Laguerquist et al. (2008), Kennedy et al. (2013), Félix & Guzmán (2014), Fossette et al. (2014), Trudelle et al. (2016), Guzmán & Félix (2017) |
| Uncertain behavior (juveniles, pregnant and nonreproductive females) – proportion time | $T_{\text{unc-breed}}$ | h | 12 | |
| Uncertain behavior (adult males) – proportion time | $T_{\text{unc-breed}}$ | h | 4 | |
| Water density | $\rho$ | kg m$^{-3}$ | 1,026 | -- |
| Ratio of active to passive drag | $\lambda$ | unitless | 0.70 | Hind & Gurney (1997) |
| Absolute pitch angle relative to the horizontal | $\theta$ | degree | 53.95 | Narazaki et al. (2018) |
| Propeller efficiency | $\varepsilon_P$ | % | 91 | Goldbogen et al. (2012) |
| Aerobic efficiency | $\varepsilon_A$ | % | 25 | Fish (1996), Ahlborn (2004) |
| Lunge feeding costs during dive | $Q\omega$ | kJ | 16,824 | Goldbogen et al. (2012) |
| Kinematic viscosity | $v$ | m$^2$ s$^{-1}$ | 1.044 E$^{-6}$ | Hind & Gurney (1997) |
| Meeh's constant | $a_{\text{Meeh}}$ | unitless | 0.068-0.080 | Innes et al. (1990), Fish (1993), Ryg et al. (1993), Nousek (2010) |
| Predicted scaling between mass and surface | $b$ | unitless | 0.65-0.70 | Innes et al. (1990), Fish (1993), Ryg et al. (1993), Nousek (2010) |
| *Reproduction costs* | | | | |
| Gestation time from conception | $t_g$ | days | 365 | Matthews (1938), Chittleborough (1958) |
| Birth weight | $M_b$ | kg | 1,700 | Matthews (1938), Chittleborough (1958, 1965) |
| Constant time from the conception prior to the phase of linear growth | $t_c$ | days | 73 | Huggett & Widdas (1951) |
| Proportion of lipid in the milk (changes over rearing time) | $P\text{lip}_m$ | % | 0.20-0.43 | Oftedal (1997) |
| Proportion of protein in the milk changes over rearing time | $P\text{prot}_m$ | % | 0.09-0.16 | Oftedal (1997) |
| Digestibility efficiency for pre-weaned | – | % | 90 | Lockyer (2007) |
| *Assimilation and digestive efficiency* | | | | |
| Digestive efficiency | DE | % | 86 | Lockyer (1981), Fortune et al. (2013) |
| Assimilation efficiency | AE | % | 80 | Lockyer (1981), Markussen et al. (1992) |

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