Methods Used for Estimating Maintenance

**Method 1: Estimate with DEBkiss parameter estimation**

Summary: ran DEBkiss estimation using package by T. Jager with survival functions added by R. Nisbet. First determined initial parameters by fixing all parameters and manually adjusting based on visual assessment of fit to data. Then ran optimization with 1-2 parameters free at a time.

Data

* Total length up to 110 (early life version) or 323 (full life version) days-post fertilization (dpf)
* Cumulative reproduction (full life version only) – 317 to 378 dpf
* Egg buffer mass at fertilization and hatching when it reaches zero (6 dpf)
* Survival – proportion surviving to 47 dpf (early life version) or 136 dpf (full life version)

Best value of maintenance (specific maintenance costs, sJM in code or *JMv* in DEBkiss book)

* About **0.015** mg assimilates mm-3 fish day-1
* Can convert to mass-specific maintenance rate by dividing by dry weight density (*dV*): 0.015 mg mm-3 day-1 / 0.288 mg mm-3 = 0.0521 day-1
  + Because dry weight density is mass/volume (Eq. 2.4 in DEBkiss book)

Notes on equations

* sJM is volume-specific maintenance rate, a primary parameter. In DEBkiss book it is *JMv.*
* It influences growth and reproduction
* DEBkiss code equations for estimating it:
  + Growth rate:

JM = sJM \* L3 ; where JM is flux to somatic maintenance and L3 is volume

JV = yVA \* (kappa \* JA – JM) ; where JV is flux to growth, yVA is yield coef for growth, JA is assimilates flux

dWV = JV ; where dWV is change in body mass

* Reproduction:

sJJ = sJM \* (1-kappa)/kappa ; where sJJ is the volume-specific maturity maintenance cost

Before puberty: JJ = sJJ \* L3 ; where JJ is maturity maintenance flux

After puberty: JJ = sJJ \* (WVp/dV) ; where WVp is mass at puberty and dV is dry weight density

JR = (1-kappa) \* JA – JJ ; where JR is reproduction flux

dcR = yBA \* JR / WB0 ; where dcR is change in cumulative reproduction, yBA is yield coef for egg production, WB0 is egg mass

**Method 2: Calculate from starvation data**

Summary: Under the assumption that all weight lost during starvation is used for maintenance, I used data on *Menidia beryllina* larvae dry weights during starvation to calculate mass-specific weight change over time (or proportion of initial weight lost). The final step is converting it to volume-specific mass lost over time for use as sJM in the Jager DEBkiss code.

Data

* Dry weight of *M. beryllina* when starved at three ages (dph, days post hatch): 7-14dph, 14-21dph, and 21-28dph. (Letcher & Bengtson, 1993)
* This was measured at three different temperatures and averaged across 18 larvae per temperature.
  + There were 15 mortalities throughout all three experiments, they do not specify which treatments.
  + Dry weight density was calculated from egg weight data (Klahre, 1997) and a known egg radius of 0.5mm.
    - Volume = (4/3)π0.53 = 0.52 mm3 and mean egg dry weight = 0.15 mg
    - *dV* = 0.15/0.52 = 0.288 mg mm-3

Best value of maintenance (sJM)

* The linear and exponential equations gave similar rates.
* 25°C is the closest temperature to the rest of the data we have (24°C).
* sJM ranged from 0.019 to 0.025 across the three ages and linear/exponential calculations, and the average of those six values (bold numbers in tables) is **0.0214** mg assimilates \* mm-3 \* day-1.

Calculations

* I calculated maintenance rate (kM0, units of mg assimilates \* mg dry weight-1 \* day-1, or units of just day-1) two ways: assuming exponential (based on Stevenson et al.) or linear relationship between dry weight and time during the starvation period. The rates were similar between exponential vs linear.
  + Stevenson et al uses this exponential equation: 🡪 solve for kM0 🡪
    - Where MV is dry weight at time t, and MV0 is initial dry weight.
  + Linear relationship:
* I calculated sJM, because kM is mass-specific and the Jager DEBkiss code uses volume-specific maintenance cost as a primary parameter. I multiplied kM0 by dV (0.288 mg mm-3) to get sJM.
  + E.g.: 0.01653 mg assimilates mg-1 day-1 \* 0.288 mg mm-3 = 0.00476 mg assimilates mm-3 day-1
* The data are summarized below, grouped by age/temperature combinations and averages calculated for each temperature, age, and all values.

kM0 calculated from exponential equation

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 21°C | 25°C | 28°C | Age avg |
| 7dph | 0.01653 | 0.06644 | 0.04892 | 0.04396 |
| 14dph | 0.04486 | 0.08625 | 0.10850 | 0.07987 |
| 21dph | 0.05728 | 0.07234 | 0.05634 | 0.06198 |
| Temp. avg | 0.03955 | 0.07501 | 0.07125 | 0.06194 |

kM0 calculated from linear equation

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 21°C | 25°C | 28°C | Age avg |
| 7dph | 0.01651 | 0.06527 | 0.04845 | 0.04341 |
| 14dph | 0.04449 | 0.08372 | 0.10357 | 0.07726 |
| 21dph | 0.05652 | 0.07083 | 0.05562 | 0.06099 |
| Temp. avg | 0.03917 | 0.07327 | 0.06921 | 0.06055 |

sJM calculated from exponential equation

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 21°C | 25°C | 28°C | Age avg |
| 7dph | 0.00476 | **0.01913** | 0.01409 | 0.01266 |
| 14dph | 0.01292 | **0.02484** | 0.03125 | 0.02300 |
| 21dph | 0.01650 | **0.02083** | 0.01623 | 0.01785 |
| Temp. avg | 0.01139 | 0.02160 | 0.02052 | 0.01784 |

sJM calculated from linear equation

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 21°C | 25°C | 28°C | Age avg |
| 7dph | 0.00475 | **0.01880** | 0.01395 | 0.01250 |
| 14dph | 0.01281 | **0.02411** | 0.02983 | 0.02225 |
| 21dph | 0.01628 | **0.02040** | 0.01602 | 0.01757 |
| Temp. avg | 0.01128 | 0.02110 | 0.01993 | 0.01744 |