Figures and Tables

**Figures**

A diagram of a fish and an egg diagram

Description automatically generated

**Figure 1.** The DEBkiss model (diagram adapted from Jager et al., 2013) with stage-specific survival parameters. The hypothesized parameters for hypoxia stress mechanisms are highlighted in red boxes. The left panel shows the energy budget for the full life cycle and the right panel shows the stage-specific survival modification.

A graph of a function

Description automatically generated with medium confidence

**Figure 2.** Predicted (lines) and observed data (dots) for the DEBkiss model of *M. menidia*. The state variables are (A) total length (mm) over time (days), (B) cumulative reproduction (eggs) over time (days), (C) egg buffer mass (mg) over time (days), and (D) survival over time (days). Predicted data lines were calculated with the parameter values listed in Table 1.

A graph of oxygen

Description automatically generated

**Figure 3.** The effect of DO on correction factor *c* at three different values of the exponential parameter *Z*. Actual estimated *Z* values are listed in Table 4, and the three *Z* values used in this figure are sample values to show how *Z* affects the relationship between DO and *c*.

**A diagram of a graph

Description automatically generated with medium confidence**

**Figure 4.** Best fit of DEBkiss model to experimental data from four DO levels, showing early life data only. The best fitting model was selected based on the requirement that all three response variables’ predicted values are affected by the hypoxia correction factor and based on lowest AICc. (A) is total length (mm) over time (days), (B) is egg buffer mass (mg) over time (days), and (C) is survival over time (days), with means rather than all data plotted for survival for ease of viewing. Full datasets used to estimate the correction factor parameter *Z* are plotted in Figure S1.

**Tables**

**Table 1.** DEBkiss parameters, their abbreviations, and their fixed or estimated values from fitting to full life data. Units are given with the value unless the parameter is a unitless ratio.

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Symbol** | **Fixed or estimated** | **Value** |
| Max. area-specific assimilation rate | *JaAm* | Estimated | 0.333 mg mm-2 d-1 |
| Max. volume-specific maintenance rate | *JvM* | Fixed | 0.0214 mg mm-3 d-1 |
| Initial egg buffer mass | *WB0* | Fixed | 0.15 mg |
| Total length at puberty | *LVp* | Fixed | 102 mm |
| Yield of assimilates on volume | *yAV* | Fixed | 0.8 |
| Yield of egg buffer on assimilates | *yBA* | Fixed | 0.95 |
| Yield of structure on assimilates | *yVA* | Estimated | 0.365 |
| Fraction of assimilates allocated to soma | *κ* | Fixed | 0.8 |
| Scaled food level | *f* | Fixed | 1 |
| Scaled food level for embryo | *fB* | Fixed | 1 |
| Mortality rate for embryos | *μemb* | Estimated | 0.0639 |
| Mortality rate for larvae | *μlar* | Estimated | 0.0294 |

**Table 2.** Fluxes, state variables, and differential equations in the DEBkiss model.

|  |  |  |  |
| --- | --- | --- | --- |
| **Flux** | **Symbol** | **Equation** | **Units** |
| Assimilation flux | *JA* |  | mg day-1 |
| Maintenance flux | *JM* |  | mg day-1 |
| Flux to structural growth | *JV* |  | mg day-1 |
| Flux to reproduction buffer | *JR* |  | mg day-1 |
| Flux to maturity | *JJ* |  | mg day-1 |
|  | | | |
| **State Variable** | **Symbol** | **Equation** | **Units** |
| Structural dry mass over time | *WV* |  | mg day-1 |
| Continuous reproduction rate | *R* |  | eggs day-1 |
| Egg buffer (yolk) mass | *WB* |  | mg day-1 |
| Survival | *S* |  | unitless  (range 0-1) |
|  | | | |
| **Other variables and conversions** | **Symbol** | **Equation** | **Units** |
| Total physical length | *LM* |  | mm |
| Volumetric length | *L* |  | mm (cubic root of volume) |
| Shape coefficient | *δM* |  | unitless |
| Dry weight density of structure | *dV* |  | mg mm-3 |
| Dry mass at puberty | *WVp* |  | mg |
| Volume-specific maturity maintenance costs | *JvJ* | *-* | mg mm-3 day-1 |
| Structural volume at puberty | *LVp3* | - | mm-3 |
| Scaled measure of resource availability | *f* | - | unitless  (range 0-1) |

**Table 3.** The mean survival to hatching, hatch time (at which egg buffer is zero), length at hatching, length at 15 dph, and survival to 15 dph from the different oxygen treatments in Cross et al. (2019). The control DO level means (7.7 mg l-1) also include data from Murray and Baumann (2018).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **7.7 mg L-1** | **4.2 mg L-1** | **3.1 mg L-1** | **2.7 mg L-1** |
| Survival to hatching | 74.3% | 70.6% | 85.8% | 30.2% |
| Hatch time (egg buffer mass = 0) | 6 days | 7 days | 8 days | 9 days |
| Length at hatching | 5.3 mm | 4.6 mm | 4.4 mm | 4.1 mm |
| Larval length at 15 dph | 15.8 mm | 12.2 mm | 9.2 mm | - |
| Larval survival to 15 dph | 44.0% | 22.2% | 20.9% | 0% |

**Table 4.** The estimated *Z* value, AICc, ΔAICc, and Akaike weights when the correction factors were applied to each parameter or combination of parameters. ΔAICc and Akaike weights were calculated with AICcmin = 794.03 for the *yVA* + *μemb* + *μlar* model.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter(s) affected by hypoxia correction factor** | **Estimated *Z* [95% CI]** | **AICc** | **ΔAICc** | **Akaike weight** |
| *JaAm* | 3.019 [2.512-3.612] | 856.06 | 62.03 | 2.5e-14 |
| *yVA* | 1.818 [1.601-2.342] | 848.65 | 54.62 | 1.0e-12 |
| *JaAm* + *JvM* | 3.105 [2.651-3.726] | 855.00 | 60.97 | 4.2e-14 |
| *yVA* + *JvM* | 1.985 [1.688-2.774] | 850.64 | 56.61 | 3.7e-13 |
| *JaAm* + *μemb* | 2.804 [1.605-3.287] | 823.24 | 29.21 | 3.3e-7 |
| *yVA* + *μemb* | 1.801 [1.570-2.167] | 808.12 | 14.09 | 6.3e-4 |
| *JaAm* + *μlar* | 2.930 [2.165-3.428] | 838.17 | 44.14 | 1.9e-10 |
| *yVA* + *μlar* | 1.767 [1.536-2.111] | 821.30 | 27.27 | 8.7e-7 |
| *JaAm* + *μemb* + *μlar* | 2.819 [1.920-3.286] | 810.21 | 16.18 | 2.2e-4 |
| *yVA* + *μemb* + *μlar* | 1.827 [1.620-2.269] | 794.03 | 0 | 0.72 |
| *JaAm* + *JvM* + *μemb* + *μlar* | 2.913 [2.288, 3.387] | 809.96 | 15.93 | 2.5e-4 |
| *yVA* + *JvM* + *μemb* + *μlar* | 1.981 [1.700, 2.456] | 795.97 | 1.94 | 0.27 |

**Table 5.** The value of the DEBkiss parameters that best reproduce the hypoxia effects observed experimentally, calculated (along with 95% confidence intervals in brackets) for each DO treatment level using the correction factor *c* and the estimated value of *Z* = 1.827.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Product of correction factor and initial parameter value** | | | |
| **7.7 mg L-1** | **4.2 mg L-1** | **3.1 mg L-1** | **2.7 mg L-1** |
| ***yVA*** | 0.333  [0.329, 0.339] | 0.291  [0.284, 0.303] | 0.240  [0.230, 0.257] | 0.199  [0.188, 0.218] |
| ***μemb*** | 0.0701  [0.0689, 0.0709] | 0.0801  [0.0770, 0.0822] | 0.0970  [0.0906, 0.101] | 0.117  [0.107, 0.124] |
| ***μlar*** | 0.0322  [0.0317, 0.0326] | 0.0369  [0.0354, 0.0378] | 0.0446  [0.0417, 0.0466] | 0.0539  [0.0492, 0.0571] |



**Supplemental Figure**

A diagram of a curve

Description automatically generated with medium confidence

**Figure S1.** Best fit of DEBkiss model to all experimental data from four DO levels. The best fitting model was selected based on lowest AICc. (A) is total length (mm) over time (days), (B) is egg buffer mass (mg) over time (days), and (C) is survival over time (days).