**IBSEM: AN INDIVIDUAL-BASED ATLANTIC SALMON POPULATION MODEL**

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# ONLINE S2 FILE

# PARAMETERIZATION OF MODEL

B.1 PHYSICAL ENVIRONMENT

The environmental conditions for the freshwater phase are modelled on those encountered in the Os river (Rådgivende Biologer, 2012). For the oceanic phase, the temperatures reproduce the monthly average sea surface temperatures (SSTs) measured in the 30 years period 1982-2012 in the Norwegian Sea (NOAA\_ERSST\_V3 data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at <http://www.esrl.noaa.gov/psd/>).

Table A gives the standard values of the environmental parameters.

|  |  |
| --- | --- |
| **Freshwater stage** | **Oceanic stage** |
| **Oselva river, Hordaland (N)** | **Norwegian Sea** |
| **River area=250,000 m2** | **-** |
| **Average water temperatures (ºC)** |
| Month | River | Sea |
| January | 2.00 | 4.82 |
| February | 2.00 | 4.65 |
| March | 2.00 | 4.67 |
| April | 5.00 | 5.16 |
| May | 11.00 | 6.3 |
| June | 16.00 | 7.91 |
| July | 18.00 | 9.15 |
| August | 18.00 | 9.3 |
| September | 14.00 | 8.26 |
| October | 9.00 | 6.96 |
| November | 5.00 | 5.89 |
| December | 3.00 | 5.23 |
| Standard deviation $σ\_{T}$ on monthly temperatures | 1.0 | 0.3 |

**Table A** Environmental parameters.

B.2 DEMOGRAPHY

The Individual-Based Salmon Eco-genetic Model (IBSEM) reproduces the life cycle of an Atlantic salmon (Salmo salar L.) population. The model divides the life history of the individuals into three main phases: embryonic (egg to the end of endogenous feeding on its embryonic yolk-sac reserves, E), freshwater (juvenile, J), and oceanic (adult, A).

The equations described in S1 File have been parameterized to reproduce the demographics Atlantic salmon in the river Os in Norway. The following tables list the settings of the parameters.

*B.2.1 Growth*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **Phase** | ***X* (Age)** | **Value** | **Measurement unit** | **Source** |
| $$A\left(X\right)$$ | *J* | *p0* | 0.75 | g/days | \* |
| *p1* | 0.7 | g/days | \* |
| *p2* | 0.5 | g/days | \* |
| *sm* (young-of-the-year) | 0.7 | g/days | \* |
| *sm* (older) | 0.6 | g/days | \* |
| *A* | *0SW* | 4.6 | g/days | \* |
| *1SW*, *2SW*, *3SW* | 2.2 | g/days | \* |
| $$b\left(X\right)$$ | *J*, *A* | *p0*, *p1*, *p2*, *sm* | 0.31 | - | (1) |
| $$d\left(X\right)$$ | *J* | *p0*, *p1*, *p2*, *sm* | 0.374 | 1/ºC | (1) |
| *A* | *0SW*, *1SW*, *2SW*, *3SW* | 0.33 | 1/ºC | \* |
| *g*$\left(X\right)$ | *J* | *p0*, *p1*, *p2*, *sm* | 0.201 | 1/ºC | (1) |
| *A* | *0SW*, *1SW*, *2SW*, *3SW* | 0.2 | 1/ºC | \* |
| $$s\_{1}$$ | *E* | *eg* | 1.6345 | - | (2) |
| $$s\_{2}$$ | *E* | *eg* | 12.991 | mm | (2) |
| $$T\_{L}\left(X\right)$$ | *J* | *p0*, *p1*, *p2* | 7 | ºC | (3) \*\* |
| *sm* | 0 | ºC | (3) \*\* |
| *A* | *0SW*, *1SW*, *2SW*, *3SW* | 2 | ºC | \* |
| $$T\_{U}\left(X\right)$$ | *J* | *p0*, *p1*, *p2* | 24 | ºC | (3) \*\* |
| *sm* | 24 | ºC | (3) \*\* |
| *A* | *0SW*, *1SW*, *2SW*, *3SW* | 20 | ºC | \* |
| $$β\_{dens}(X)$$ | *J* | *p0* | 20 | - | (4) \*\* |
| *p1*, *p2* | 70 | - | (4) \*\* |
| $$δ\_{f}^{A}\left(X\right)$$ | *J* | *p0*, *p1*, *p2* | 1.3 | - | \* |
| *sm* | 2.0 | - | \* |
| *A* | *0SW*, *1SW*, *2SW*, *3SW* | 1.2 | - | \* |
| $$δ\_{w}^{A}\left(X\right)$$ | *all* | *all* | 1 | - | \* |
| $$σ\left(X\right)$$ | *E* | *al* | 0.035 | - | (2) |
| *J* | *p0* | 0.25 | - | \* |
| *p1*, *p2* | 0.08 | - | \* |
| *sm* | 0.09 | - | \* |
| *A* | *0SW*, *1SW*, *2SW*, *3SW* | 0.1 | - | \* |
| 1. Elliott and Hurley, (1997)
2. Gilbey and Verspoor, (2005)
3. Forseth et al., (2001)
4. Piou and Prevost (2012)
 | \* fitted to experimental data (Rådgivende Biologer, 2012)\*\* modified to fit experimental data (Rådgivende Biologer, 2012) |

**Table B** Growth parameters setting.

*B.2.2 Mortality*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **Phase** | ***X* (Age)** | **Value** | **Measurement unit** | **Source** |
| $$dsp\left(X,s\right)$$ | J | *p0*, *s*=*warm* | 0.983 | - | (1) \*\* |
| *p0*, *s*=*cold* | 0.9988 | - | (1) \*\* |
| *p1*, *p2*, *s*=*warm* | 0.9986 | - | (1) \*\* |
| *p1*, *p2*, *s*=*cold* | 0.999 | - | (1) \*\* |
| *sm* | 0.999 | - | (1) \*\* |
| $$k\_{1}$$ | A | *0SW*, *1SW*, *2SW*, *3SW* | 950 | 1/mm | (1) \*\* |
| $$k\_{2}$$ | A | *0SW*, *1SW*, *2SW*, *3SW* | -1.55 | - | (1) \*\* |
| *m* | E | eg | -3.16 | 1/g | \* |
| q | E | *eg* | 1.12 | - | \* |
| $$α(X)$$ | E | *eg* | 0.62 | - | \*\* \*\*\* |
| J | *p0* | 0.28 | - | \*\* \*\*\* |
| *p1*, *p2*, | 0.3 | - | \*\* \*\*\* |
| $$β(X)$$ | E | *eg* | 0.26 | m2/egg | \*\* \*\*\* |
| J | *p0* | 830 | - | \*\* \*\*\* |
| *p1*, *p2*, | 280 | - | \*\* \*\*\* |
| $$δ\_{f}^{S}\left(X\right)$$ | E | eg | 0.8 | - | \* |
| J | *p0, p1*, *p2*, *sm* | 0.8 | - | \* |
| A | *0SW*, *1SW*, *2SW*, *3SW* | 0.6 | - | \* |
| $$δ\_{w}^{S}\left(X\right)$$ | *all* | *all* | 1 | - | \* |
| 1. Piou and Prevost (2012)
2. Gilbey and Verspoor, (2005)
3. Forseth et al., (2001)
 | \* fitted to experimental data (Rådgivende Biologer, 2012)\*\* fitted to exponential curve in Gilbey and Verspoor, (2005)\*\*\* modified to fit experimental data (Rådgivende Biologer, 2012) |

**Table C** Mortality parameters setting.

*B.2.3 Maturation and Smolting*

|  |  |  |
| --- | --- | --- |
| **Maturation** |  |  |
| **Parameter** | **Phase** | ***X* (Age)** | **Value** | **Measurement unit** | **Source** |
| $$K\_{1}$$ | J | *p0*, *p1 p2* | 0.13 | 1/mm | (1) \*\* |
| $$K\_{2}$$ | J | *p0*, *p1 p2* | 107 | mm | (1) \*\* |
| $$P\left(X\right)$$ | A | *0SW* | 0 | - | (3) |
| *1SW* | 0.4 | - | (3) \*\* |
| *2SW* | 0.85 | - | (3) \*\* |
| *3SW* | 1 | - | (3) \*\* |
| $$δ\_{f}^{m}\left(X\right)$$ | A | *0SW* | 0 | - | \* |
| *1SW* | 0.25 | - | \* |
| *2SW* | 0.47 | - | \* |
| *3SW* | 1 | - | \* |
| $$δ\_{w}^{m}\left(X\right)$$ | *all* | *all* | 1 | - | \* |
| **Smolting** |  |  |
| **Parameter** | **Phase** | ***X* (Age)** | **Value** |  |  |
| $$K\_{1}$$ | J | *p0*, *p1 p2* | 0.2 | 1/mm | (2) (3) \*\* |
| $$K\_{2}$$ | J | *p0*, *p1 p2* | 103 | mm | (2) (3) \*\* |
| $$τ$$ | J | *p0*, *p1 p2* | 90 | mm | \* |
| 1. Gilbey and Verspoor, (2005)
2. Piou and Prevost (2012)
3. Hedger et al. (2013)
 | \* fitted to experimental data (Rådgivende Biologer, 2012)\*\* modified to fit experimental data (Rådgivende Biologer, 2012) |

**Table D** Maturation and smolting parameters setting.



**Fig A.** Fork length-dependent male parr maturation and smolting probabilities. Equations and parameters as described in Tables D in S1 File and D.

*B.2.4 Reproduction and Straying*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **Phase** | ***X* (Age)** | **Value** | **Measurement unit** | **Source** |
| $$c\_{1}$$ | A | *1SW*, *2SW*, *3SW* | 0.86 | 1/g | (1) |
| $$c\_{2}$$ | A | *1SW*, *2SW*, *3SW* | 1.63 | - | (1) |
| $$c\_{3}$$ | A | *1SW*, *2SW*, *3SW* | 0.166 | 1/g | (1) |
| $$c\_{4}$$ | A | *1SW*, *2SW*, *3SW* | 5.68 | - | (1) |
| $$m\_{min}$$ | J | *p0*, *p1 p2* | 0.1 | - | \* |
| $$m\_{max}$$ | J | *p0*, *p1 p2* | 0.3 | - | \* |
| $$m\_{post}$$ | A | *1SW*, *2SW*, *3SW* | 0.95 | - | \* |
| *rs*(*sex*) | A | *1SW*, *2SW*, *3SW* | *sex=male 0.05 sex=female 0.3* | - | (2) |
| σ | A | *1SW*, *2SW*, *3SW* | 0.05 | - | \* |
| $$σ\_{NE}$$ | A | *1SW*, *2SW*, *3SW* | 0.1 | - | \* |
| $$σ\_{WE}$$ | A | *1SW*, *2SW*, *3SW* | 0.02 | - | \* |
| *χ* | A | *1SW*, *2SW*, *3SW* | 0.8 | - | \*\*\* |
| 1. Jonsson et al., (1996)
2. Fleming et al., (1996)
 | \* fitted to experimental data (Rådgivende Biologer, 2012)\*\* modified to fit experimental data (Rådgivende Biologer, 2012)\*\*\* heuristically set |

**Table E** Reproduction and strayers parameters setting.

B.3 SOFTWARE IMPLEMENTATION

The IBSEM model is implemented in C++. With the above parameters, the overall running time (simulating 200 years of evolution) takes approximately 43 minutes on an Intel Core i7-3610QM processor of speed 2.30GHz and memory 32.0 GB, using Windows 7 64-bit operating system.

B.3 SENSITIVITY TESTS

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **Phase** | ***X* (Age)** | **Standard value****(Scenarios 1, 2, 3)** | **Scenario 4** | **Scenario 5** |
| $$δ\_{f}^{A}\left(X\right)$$ | *J* | *p0*, *p1*, *p2* | 1.3 | 1.15 | 1.45 |
| *sm* | 2.0 | 1.5 | 2.5 |
| *A* | *0SW*, *1SW*, *2SW*, *3SW* | 1.2 | 1.1 | 1.3 |
| $$δ\_{f}^{S}\left(X\right)$$ | E | eg | 0.8 | 0.9 | 0.7 |
| J | *p0, p1*, *p2*, *sm* | 0.8 | 0.9 | 0.7 |
| A | *0SW*, *1SW*, *2SW*, *3SW* | 0.6 | 0.8 | 0.4 |

**Table F** Sensitivity tests.

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