*The following supplement accompanies the article*

# Temperature- and income resource availability-mediated variation in reproductive investment in a multiple-batch-spawning Japanese anchovy

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**Supplement.** Further details on parameter estimates of reproductive traits

Table S1. Summary table of parameter estimates and analysis of deviance for generalized linear models for oocyte volumes at early (VE) and late (VL) of vitellogenesis, oocyte growth rate (OGR), and relative egg production rate (REPR) of Japanese anchovy *Engraulis japonicus*. Explanatory variables in the models were selected based on Akaike's information criterion are shown. Temperature (T), body length (BL), and condition factor were used as initial variables. The explained deviance (ED) of each model is shown. The estimate of REPR as a proxy of mean daily spawning time hours follows Yoneda et al. (2013)

| Model summary | Estimate | SE | df | Deviance | p |
|---|---|---|---|---|---|
| (a) VE (family = Gamma [log-link], ED = 82%) | | | | | |
| Intercept (Null) | –3.35 | 0.25 | 63 | 2.5 | |
| T | –0.042 | 0.031 | 1 | 2.0 | <0.001 |
| BL | 0.0055 | 0.021 | 1 | 0.05 | 0.008 |
| (b) VL (family = Gamma [log-link], ED = 73%) | | | | | |
| Intercept (Null) | –2.16 | 0.10 | 43 | 1.60 | |
| T | –0.0045 | 0.0044 | 1 | 1.16 | <0.001 |
| (c) OGR (family = Gaussian, ED = 37%) | | | | | |
| Intercept (Null) | –0.0019 | 0.00046 | 43 | $1.7\times10^{-6}$ | |
| Log(T) | 0.00073 | 0.00015 | 1 | $6.3\times10^{-5}$ | <0.001 |
| (d) REPR (family = Gaussian, ED = 62%) | | | | | |
| Intercept (Null) | 37.3 | 4.00 | 10 | 21.7 | |
| Log(T) | –4.94 | 1.28 | 1 | 13.5 | <0.001 |

Table S2. Summary of estimated oocyte volumes at early (VE) and late (VL) vitellogenesis, increment of oocyte volume (VI), oocyte growth rate (OGR), duration from VE to VL (D), mean daily spawning time (S), and batch intervals (BI) of Japanese anchovy *Engraulis japonicus* (BL = 100 mm) at different temperatures (*T*). Note that VI = VL – VE; D = (VL – VE) / OGR

| *T* (°C) | VE ($mm^3$) | VL ($mm^3$) | VI ($mm^3$) | OGR ($mm^3\ h^{-1}$) | D (h) | S (h) | BI (d) |
|---|---|---|---|---|---|---|---|
| 20 | 0.026 | 0.047 | 0.021 | 0.00029 | 71.9 | 22:24 | 3.93 |
| 24 | 0.022 | 0.039 | 0.017 | 0.00042 | 40.4 | 21:35 | 2.58 |
| 28 | 0.018 | 0.032 | 0.014 | 0.00053 | 26.2 | 20:50 | 1.96 |

Table S3. Summary table for linear mixed effects model estimates fitted using restricted maximum likelihood for egg volume (EV), the amount of carbon (C) and nitrogen (N), ratio of C:N (CN) weight per egg, and carbon (CD) and nitrogen (ND) per dry egg weight of Japanese anchovy *Engraulis japonicus* in relation to temperature (T)

| Model summary | Value | SE | df | *F* | p |
|---|---|---|---|---|---|
| (a) EV | | | | | |
| Intercept | 0.95 | 0.073 | | | |
| Log(T) | –0.22 | 0.024 | 1, 61 | 86.6 | <0.001 |
| (b) C | | | | | |
| Intercept | 44.8 | 2.84 | | | |
| Log(T) | –11.7 | 0.94 | 1, 61 | 156.7 | <0.001 |
| (c) N | | | | | |
| Intercept | 4.42 | 0.21 | | | |
| T | –0.11 | 0.0097 | 1,61 | 136.7 | <0.001 |
| (d) CN | | | | | |
| Intercept | 6.04 | 0.14 | | | |
| Log(T) | –0.49 | 0.047 | 1,61 | 110.9 | <0.001 |
| (e) CD | | | | | |
| Intercept | 647.4 | 29.9 | | | |
| Log(T) | –35.1 | 9.8 | 1, 61 | 12.9 | <0.001 |
| (f) ND | | | | | |
| Intercept | 102.6 | 7.8 | | | |
| Log(T) | 5.4 | 2.5 | 1, 61 | 4.6 | 0.037 |

Table S4. Summary table for linear mixed effects model estimates fitted using restricted maximum likelihood for relative egg production of Japanese anchovy *Engraulis japonicus* in the treatments of high (HF) and low (LF) food ration and starvation (ST) in relation to period of the experiment (early, middle, late) and experiment number (Expt 1 or 2)

| Model summary | Value | SE | df | *F* | p |
|---|---|---|---|---|---|
| (a) HF | | | | | |
| Intercept | 0.99 | 0.077 | | | |
| (b) LF | | | | | |
| Intercept | 0.93 | 0.10 | | | |
| Period (middle) | –0.24 | 0.10 | 2, 56 | 9.92 | <0.001 |
| Period (late) | –0.46 | 0.10 | | | |
| Experiment (Expt 2) | –0.23 | 0.11 | 1, 56 | 4.05 | 0.049 |
| (c) ST | | | | | |
| Intercept | 0.52 | 0.10 | | | |
| Period (middle) | –0.36 | 0.15 | 2, 57 | 4.76 | 0.012 |
| Period (late) | –0.42 | 0.15 | | | |

## LITERATURE CITED

Yoneda M, Kitano H, Selvaraj S, Matsuyama M, Shimizu A (2013) Dynamics of gonadosomatic index of fish with indeterminate fecundity between subsequent egg batches: application to Japanese anchovy *Engraulis japonicus* under captive conditions. Mar Biol 160:2733–2741