ESTIMATION OF DEB PARAMETERS TO SIMULATE SHIJIMI GROWTH IN LAKE JUSAN

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1. INTRODUCTION

Lake Jusan, located in Aomori Prefecture, is one of the important fishing grounds of shijimi (*Corbicula japonica*) in Japan. To maintain this fishery sustainable, interrelationship between water quality and shijimi population must be concerned. Water quality simulation is necessary to quantify this interrelationship, and because it is long-term and continuous process, simulation of shijimi growth/population is also necessary. Dynamic energy budget (DEB) model is an individual growth model that has been applied widely on many species of bivalve and provided a proper accuracy, therefore this model is expected to be applied to shijimi growth in Lake Jusan.

In DEB model, a species is characterized by a set of parameters, therefore estimation of these parameters is a critical step to obtain reasonable results. In this study, all parameters are estimated, and verified by using experiment data and data obtained from literatures.

2. DEB MODEL

DEB theory (Kooijman, 2009) describes energy flux of an individual organism by three state variables: structural volume (V), reserve (E) and reproduction reserve (E_R). Energy from assimilation ($\dot{p}_A$) is stored in reserve from which it is utilized for maintenance, growth and reproduction. A fixed fraction κ of the utilized energy ($\dot{p}_C$) is used for growth ($\dot{p}_G$) and somatic maintenance ($\dot{p}_M$), with a priority for maintenance. The remaining fraction ($1\text{-}\kappa$) is directed to maturity maintenance ($\dot{p}_J$) and maturation ($\dot{p}_R$). Once the individual reaches puberty volume (V_P), energy for maturation is stored into E_R and emptied at spawning. Scheme of DEB model is shown in Fig. 1, equations are shown in Table 1.

During starvation ($\kappa \cdot \dot{p}_C > \dot{p}_A$), growth stops and $\dot{p}_C$ equals to maintenance. For prolong starvation and E is empty, maintenance is paid from E_R, and then if E_R is empty, body volume shrinks to pay maintenance need.

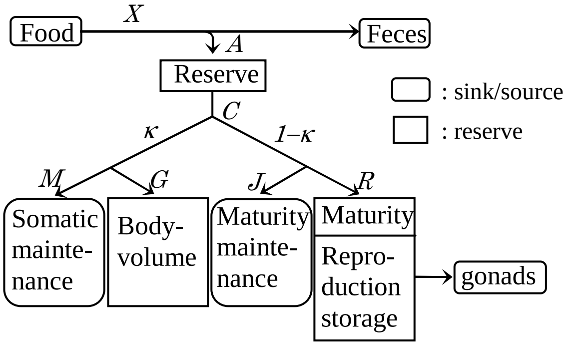

Fig.1 Schematic diagram of DEB model.

Table 1. Equations of the DEB model

Equation	Definition
$k(T)=k_1 e^{\left(\frac{T_A}{T_1}-\frac{T_A}{T}\right)}\left(1+e^{\left(\frac{T_{AL}}{T}-\frac{T_{AL}}{T_L}\right)}+e^{\left(\frac{T_{AH}}{T_H}-\frac{T_{AH}}{T}\right)}\right)^{-1}$	Temperature dependence
$\dot{p}_C = k(T)\cdot\frac{[E]}{[E_G]+\kappa\cdot[E]}\left(\frac{[E_G]\cdot\{\dot{p}_{Am}\}\cdot V^{2/3}}{[E_m]}+\dot{p}_M\right)$	Utilization rate
$\dot{p}_A = k(T)\cdot f\cdot\{\dot{p}_{Am}\}\cdot V^{2/3}$	Assimilation rate
$f=\frac{X}{X+X_K}$	Functional response
$\dot{p}_M = k(T)\cdot[\dot{p}_M]\cdot V$	Maintenance rate
$\dot{p}_J = k(T)\cdot min(V,V_P)\cdot[\dot{p}_M]\cdot\frac{1-\kappa}{\kappa}$	Maturity maintenance rate
$\frac{dE}{dt}=\dot{p}_A-\dot{p}_C$	Reserve dynamic
$\frac{dE_R}{dt}=(1-\kappa)\cdot\dot{p}_C-\dot{p}_J$	Repro. reserve dynamic
$\frac{dV}{dt}=\frac{\kappa\cdot\dot{p}_C-\dot{p}_M}{[E_G]}$	Struc. volume dynamic
$TDFW=\frac{E}{\mu_E}+\frac{k_R\cdot E_R}{\mu_E}+V\cdot\rho$	Total dry flesh weight

Effect of temperature on physiological rates is expressed by temperature dependence coefficient. Structural volume (V) refers to volume of dry flesh, excluding shell, and can be calculated with regard to diameter by using shape coefficient (δ): $V = (\delta L)^3$.

3. PARAMETER ESTIMATION

In this study, diameter refers to the longest diameter (the length) of shijimi. Conversion from total fresh weight (including shell) converted to dry flesh volume was done by using two coefficients: 1 g fresh weight = 0.026 g dry flesh (Nakamura et al., 1988); volume specific dry flesh weight, ρ = 0.2 g cm^{-3} (Ren et al., 2008). From relationship between dry flesh volume and diameter, then the shape coefficient was obtained as 0.302 (R^2 = 0.82, n = 42).

According to DEB assumption, in related species the volume-specific maintenance cost [$\dot{p}_M$] should be similar, and then the value of 24 J cm^{-3} d^{-1} was taken as similar as that for *M balthica* (van der Veer et al., 2006). This value was used to estimate the surface area specific assimilation rate {$\dot{p}_{Am}$}, according to: $V_m^{1/3} = \kappa\cdot\{\dot{p}_{Am}\}/[\dot{p}_M]$, where V_m is volume for the maximum diameter (L_m). by using L_m of 5.8 cm (Oshima et al.,

Keywords: DEB model, parameterization, shijimi, Lake Jusan
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2004) and κ of 0.55 (will be discussed later), it was found that $\{\dot{p}_{Am}\}$ = 76.43 J cm^{-2} d^{-1}. Since the maximum storage density $[E_m]$ is proportional to L_m, by using $[E_m]$ data several species in van der Veer et al., (2006), $[E_m]$ for shijimi was set to 2100 J cm^{-3}.

Arrhenius temperature T_A, can be estimated as negative slope of the straight line relationship between metabolic rate (ln scale) and T^{-1}, where T is temperature (in Kelvin). Effect of temperature on the filtration rate of shijimi is shown on Fig. 2. Based on this figure, the lower (T_L) and upper (T_H) boundary of tolerance range were set as 279K and 308K, respectively, and T_A was obtained as 5000 K. By using time dependence equation (Table 1) and setting the reference temperature (T_1) as 298K and k_1 as 1, the Arrhenius temperature for rate of decrease at lower boundary (T_{AL}) and upper boundary (T_{AH}) are obtained as 1.5×10^5K and 3.0×10^4K, respectively.

All parameters are obtained, except volume specific cost of growth $[E_G]$, the functional response (f) and κ. $[E_G]$ was set similar as that for *M balthica*, that is 1900 J cm^{-3} (van der Veer et al., 2006), since they have similar L_m. Assuming f constant, together with κ they were estimated simultaneously by performing DEB simulation. They were adjusted therefore fit with observed data. Two points observation are available; point 1 and point 2, located at east part and south part of the lake, respectively. From adjustment, the best value for κ was 0.55 while f was 0.33 and 0.47 at point 1 and 2 respectively (Fig. 3a). Long-term simulation is necessary to fine-tuning κ value. This value should provide spawning occurrence every year (Fig. 3b). Parameters triggering spawning are temperature higher than 22^{o}C and gonad index higher than 35%

4. DISCUSSION

Food availability is characterized by f ranging from 0 (no food) to 1 (always available). In this study, food is quantified by chlorophyll-a concentration. At point 1 and point 2, the f values are different. One of the possible explanations is that food did not spread uniformly in entire the lake. In this case hydrodynamic behavior plays the main rule. Another possibility is that food competition among individuals or species occurred in the lake. In shijimi case, population density at point 1 was much higher than that at point 2, therefore food availability at point 2 was higher.

In conclusion, all DEB parameters required to simulate shijimi growth in Lake Jusan have been obtained. Further investigation on hydrodynamic behavior in the lake is necessary in order to examine the variability of food availability in the entire lake.

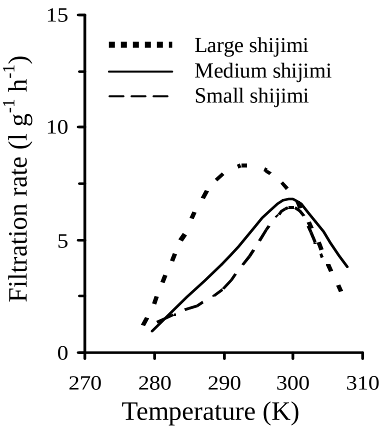

Fig. 2 Filtration rate per dry flesh weight at various temperature for shijimi (after Nakamura et al., 1988)

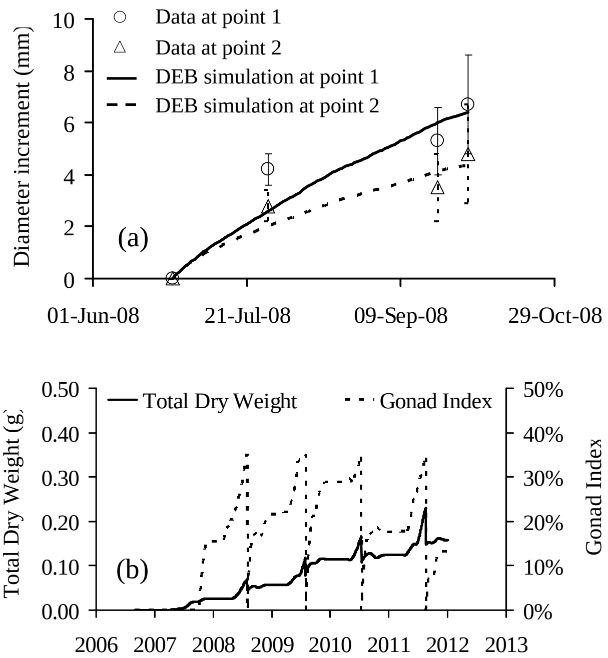

Fig. 3 (a) Comparison of shijimi growth between DEB simulation and field data. (b) Adjustment of κ therefore spawning occurs every year.

ACKNOWLEDGEMENTS

The first author is recipient of the Indonesian Government scholarship. This work was supported by MEXT KAKENHI 21360230. The authors are very grateful to Marko Jusuf for discussions and helpful suggestions about DEB theory.

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