ECASA WP 4
Application of the DEB model to the sites of Baie des Veys (Normandy, France) and Loch Creran (Scotland)

Aline Gangnery, Cédric Bacher, Stéphane Pouvreau

Introduction

The DEB (Dynamic Energy Budget) model describes the energy flows through an organism and also changes in the environment with varying food densities and temperature. The model allows to simulate individual growth rate and reproduction. The background of the DEB theory can be found in Kooijman (2000). This theory was recently applied to several bivalve species (van der Veer et al., 2006) and particularly, a parameterisation was specifically developed for the Pacific oyster, *Crassostrea gigas* (Pouvreau et al., 2006). The DEB model was proposed as a modelling tool within the ECASA project to assess *i*) the impact of bivalves on their environment (*e.g.* estimation of ingestion fluxes) and *ii*) the response of bivalves to modifications of their environment (*e.g.* modification of the individual growth rate). In this work, we applied the model to two study sites of the ECASA project: the Baie des Veys (France) and Loch Creran (Scotland). Both sites support the cultivation of *C. gigas*. Goodness of fit of the model was evaluated according to the procedure defined within the ECASA project (Portilla and Tett, 2007). This note aims to make a synthesis of results obtained through this application.

Material and methods

Two datasets were available for the two sites.
Individual growth of oysters was followed in the Baie des Veys between March 2002 and August 2003. Flesh dry mass and shell length were measured at each sampling date and the oyster population was sampled 16 times during the survey. Water temperature and concentration in chlorophyll *a* were also followed near the growth site. Water temperature was recorded continuously and chlorophyll *a* concentration was determined every second week. In Loch Creran, individual growth was followed between May 2005 and July 2006. Flesh dry mass and shell length were also measured at each sampling date and the population was sampled 10 times during the survey. Water temperature and concentration in chlorophyll *a* were determined *ca.* each month.

For both sites, forcing variables of the DEB model were water temperature and chlorophyll *a*, which represents available food for oysters. Individual growth was simulated by the model and then compared to observed data. Three cases were studied:
- Case a : the model was calibrated for the Baie des Veys (see list of parameters in Annex 1),
- Case b: the model was validated on Loch Creran with parameters used for the Baie des Veys,
- Case c: the model was calibrated and a new simulation was conducted with a new set of parameters.

For case c, the calibration was done on the X_k and shape parameters. The X_k parameter is the half saturation coefficient of the functional response of assimilation to food concentration. The functional response is represented by the equation:

$$f=\frac{[X]}{[X]+X_K}$$

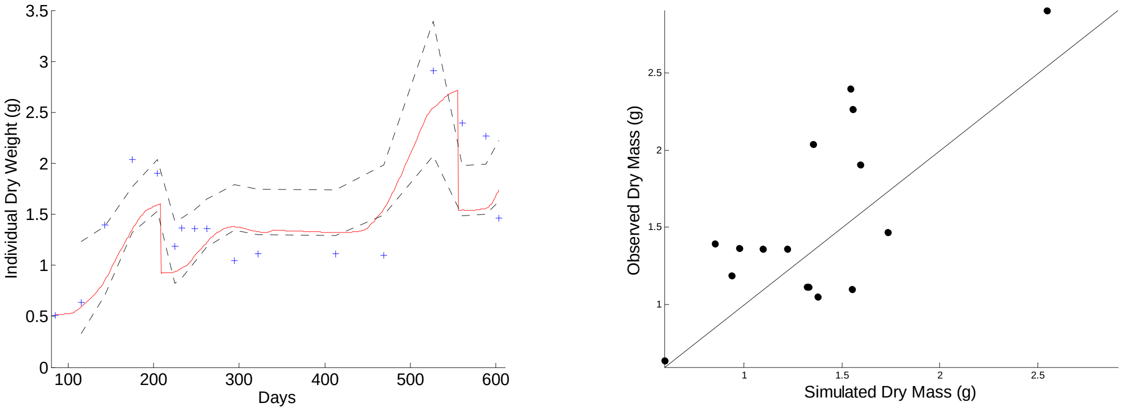
where X is food density (*i.e.* the concentration in chlorophyll *a* in µg.l^{-1}).
X_k depends on the site, reflecting the variable composition of food in different environment and modulates the food really usable by the oyster.
The shape parameter allows to convert the individual flesh dry mass into shell length. It is usually specific of the species but can vary according the site.
Both X_k and the shape are key parameters, classically used when a calibration has to be done.

For each simulation, the goodness of fit of the model was estimated by fitting a linear regression between observed and simulated values and comparing the resulting slope and intercept to 1 and 0, respectively. The regression equation was also used to show the reliability of model predictions through the estimation of 95% prediction limits.

Results

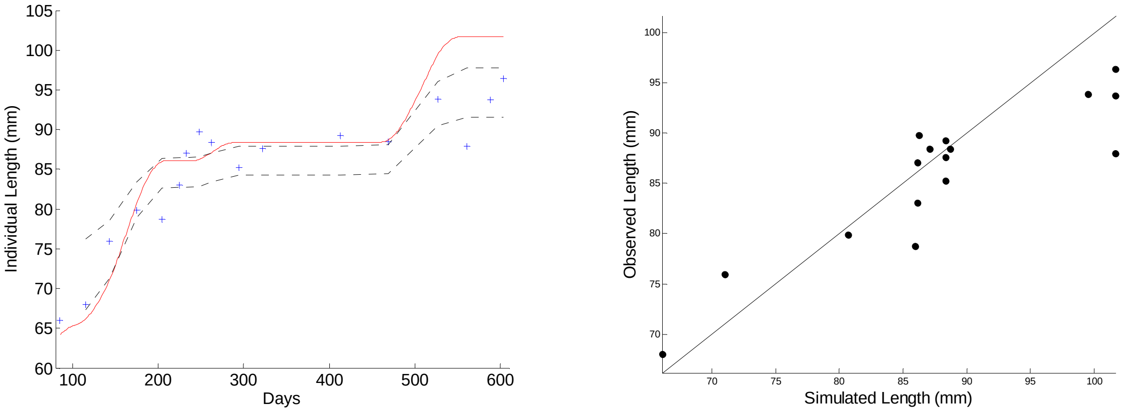
Case a: Calibration in the Baie des Veys

For individual dry mass as well as for shell length, the model explains a significant part of variance in observations (Table 1 and 2). However, if the model reliability was classified excellent for individual dry mass, it was classified fair for shell length. Concerning dry mass, the model simulated well two spawning periods, which occurred at the end of July-beginning of August in 2002 and 2003 (Figure 1). The model under estimated growth during the spring period and over estimated growth during the fall and winter periods (September to March). For shell length, misfit of the model essentially appeared for larger individuals for which shell length is over estimated by the model (Figure 2).



a) b)

Figure 1: Application of the model to the Baie des Veys. a) Variation of observed values of individual dry mass (blue crosses), simulated values (red line) and confidence interval at 95% of predictions obtained with the linear regression between observed and simulated values (black dotted lines). b) Simulated *vs.* observed values of flesh dry mass.



a)

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Figure 2: Application of the model to the Baie des Veys. a) Variation of observed values of individual shell length (blue crosses), simulated values (red line) and confidence interval at 95% of predictions obtained with the linear regression between observed and simulated values (black dotted lines). b) Simulated *vs.* observed values of shell length.

Table 1: Results of model performance for individual dry mass in the Baie des Veys.

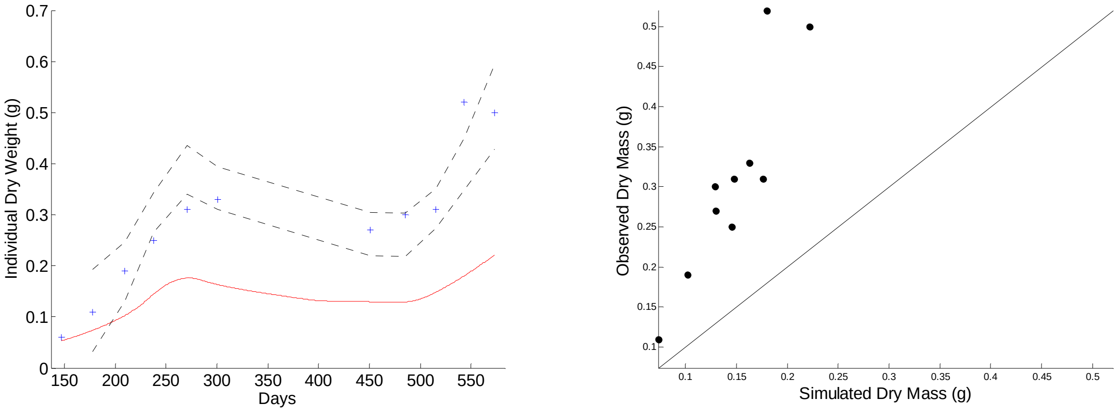
n, number of independent observations used in test		14	
Model performance			
r^2, % of variance	0.55	*p*, on null hypothesis	0.001
Regression intercept	0.19	*Standard error of intercept*	0.34
t (intercept different from 0)	0.56	*p (intercept different from 0)*	0.58
Regression slope	0.998	*Standard error of slope*	0.24
t (slope different from 1)	0.0048	*p (slope different from 1)*	0.99
Model conclusion			
Model explains a significant part of variance in observations		YES	
Model reliability class		Excellent	

Table 2: Results of model performance for individual shell length in the Baie des Veys.

n, number of independent observations used in test		14	
Model performance			
r^2, % of variance	0.80	*p*, on null hypothesis	$3.2\text{x}10^{-6}$
Regression intercept	29.07	*Standard error of intercept*	7.69
t (intercept different from 0)	3.78	*p (intercept different from 0)*	0.002
Regression slope	0.65	*Standard error of slope*	0.087
t (slope different from 1)	4.09	*p (slope different from 1)*	0.0011
Model conclusion			
Model explains a significant part of variance in observations		YES	
Model reliability class		Fair	

Case b: Validation in Loch Creran

Regression models explain a significant part of the variance in observations for dry mass as for shell length (Table 3 and 4). For dry mass, the model class is good because the intercept was not significantly different from 0. However, the model largely under estimated the observed values (Figure 3). For shell length, the model class is fair because both the slope and the intercept were significantly different from 1 and 0, respectively. Simulated values were also largely under estimated compared to observed values (Figure 4). For both variables, prediction limits showed that the regression model between observed and simulated variables was reliable despite the poor ability of the model to reproduce observations.



a)

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Figure 3: Application of the model to Loch Creran with parameters from the Baie des Veys. a) Variation of observed values of individual dry mass (blue crosses), simulated values (red line) and confidence interval at 95% of predictions obtained with the linear regression between observed and simulated values (black dotted lines). b) Simulated *vs.* observed values of flesh dry mass.

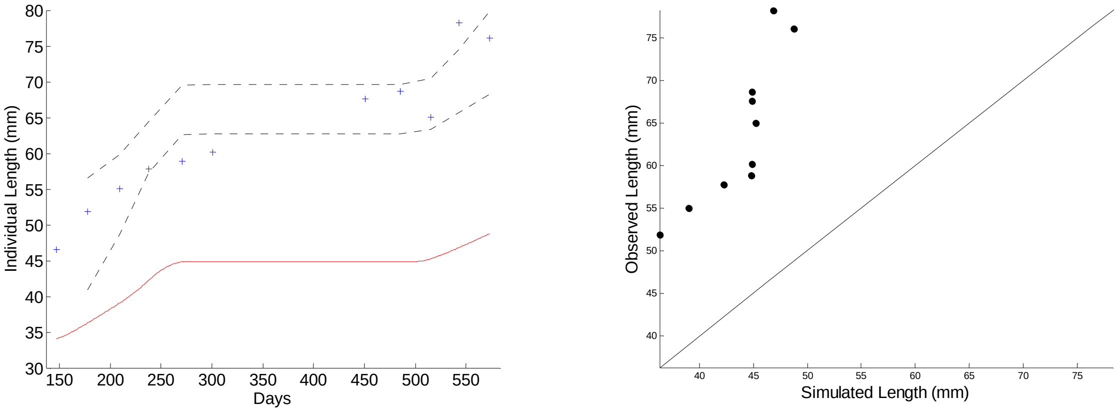

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Figure 4: Application of the model to Loch Creran with parameters from the Baie des Veys. a) Variation of observed values of individual shell length (blue crosses), simulated values (red line) and confidence interval at 95% of predictions obtained with the linear regression between observed and simulated values (black dotted lines). b) Simulated *vs.* observed values of shell length.

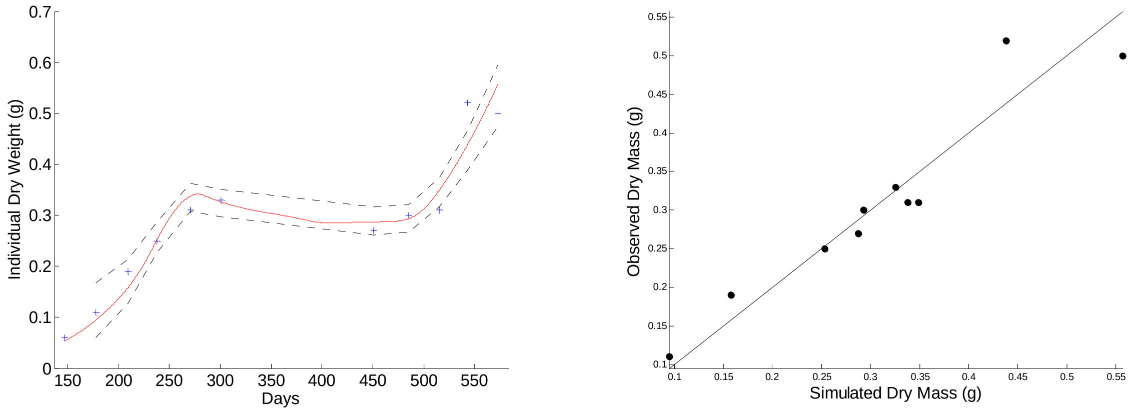
Table 3: Results of model performance for individual dry mass in Loch Creran with parameters from the Baie des Veys.

n, number of independent observations used in test		8	
Model performance			
r^2, % of variance	0.81	*p*, on null hypothesis	$3.49\text{x}10^{-4}$
Regression intercept	-0.09	*Standard error of intercept*	0.07
t (intercept different from 0)	1.26	*p (intercept different from 0)*	0.24
Regression slope	2.69	*Standard error of slope*	0.45
t (slope different from 1)	3.73	*p (slope different from 1)*	0.006
Model conclusion			
Model explains a significant part of variance in observations		YES	
Model reliability class		Good	

Table 4: Results of model performance for individual shell length in Loch Creran with parameters from the Baie des Veys.

n, number of independent observations used in test		8	
Model performance			
r^2, % of variance	0.73	*p*, on null hypothesis	0.0018
Regression intercept	-25.04	*Standard error of intercept*	19.43
t (intercept different from 0)	1.29	*p (intercept different from 0)*	0.24
Regression slope	2.03	*Standard error of slope*	0.44
t (slope different from 1)	2.33	*p (slope different from 1)*	0.048
Model conclusion			
Model explains a significant part of variance in observations		YES	
Model reliability class		Fair	

Case c: Calibration in Loch Creran



a) b)

Figure 5: Application of the model to Loch Creran after a new calibration. a) Variation of observed values of individual dry mass (blue crosses), simulated values (red line) and confidence interval at 95% of predictions obtained with the linear regression between observed and simulated values (black dotted lines). b) Simulated *vs.* observed values of flesh dry mass.

Results showed that the model was classified as excellent for dry mass and shell length. For both variables, the model reproduced well observations (Figure 5 and 6) and the regression models were highly significant with slopes and intercepts not significantly different from 1 and 0, respectively (Table 5 and 6).

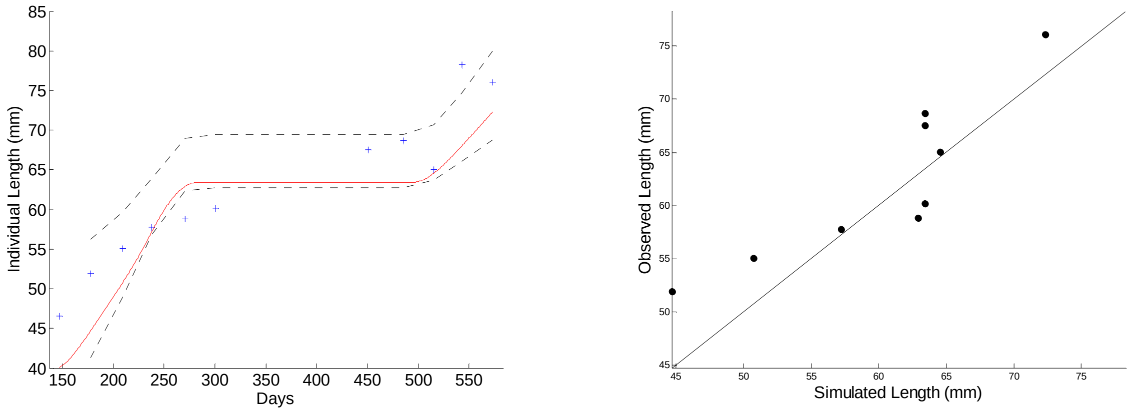


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Figure 6: Application of the model to Loch Creran after a new calibration. a) Variation of observed values of individual shell length (blue crosses), simulated values (red line) and confidence interval at 95% of predictions obtained with the linear regression between observed and simulated values (black dotted lines). b) Simulated *vs.* observed values of shell length.

Table 5: Results of model performance for individual dry mass in Loch Creran after a new calibration.

n, number of independent observations used in test		8	
Model performance			
r^2, % of variance	0.91	*p*, on null hypothesis	1.89×10^{-5}
Regression intercept	0.027	*Standard error of intercept*	0.034
t (intercept different from 0)	0.80	*p (intercept different from 0)*	0.45
Regression slope	0.91	*Standard error of slope*	0.10
t (slope different from 1)	0.87	*p (slope different from 1)*	0.41
Model conclusion			
Model explains a significant part of variance in observations		YES	
Model reliability class		Excellent	

Table 6: Results of model performance for individual shell length in Loch Creran after a new calibration.

n, number of independent observations used in test		8	
Model performance			
r^2, % of variance	0.74	*p*, on null hypothesis	0.0013
Regression intercept	7.13	*Standard error of intercept*	11.86
t (intercept different from 0)	0.60	*p (intercept different from 0)*	0.56
Regression slope	0.93	*Standard error of slope*	0.19
t (slope different from 1)	0.36	*p (slope different from 1)*	0.73
Model conclusion			
Model explains a significant part of variance in observations		YES	
Model reliability class		Excellent	

References

Kooijman, S.A.L.M., 2000. Dynamic energy and mass budgets in biological systems, Cambridge University Press, Cambridge.

Portilla, E., Tett, P. 2007. Assessing goodness of fit for ECASA models.22 p.

Pouvreau, S., Bourles, Y., Lefebvre, S., Gangnery, A., Alunno-Bruscia, M. 2006. Application of a dynamic energy budget model to the Pacific oyster, *Crassostrea gigas*, reared under various controlled conditions. J. Sea Res. 56, 156-167.

Van der Veer, H.W., Cardoso, J.F., van der Meer, J. 2006. Estimation of DEB parameters for various North Atlantic bivalve species. J. Sea Res. 56, 107-124.

Annex 1: List of parameters and initial conditions used for the different case study.

Case a: Calibration of the model in the Baie des Veys.
Case b: Validation of the model in Loch Creran.
Case c: Calibration of the model in Loch Creran.

Parameters	**Symbol**	**Unit**	**Value Case a**	**Value Case b**	**Value Case c**
Half saturation coefficient	X_K	µg.l^{-1}	5.5	-	3.2
Max. surf. area-specific assimilation rate	$\{\dot{p}_{Am}\}$	J.cm^{-2}.d^{-1}	420	-	-
Volume-specific maintenance costs	$[\dot{p}_M]$	J.cm^{-3}.d^{-1}	24	-	-
Maximum storage density	$[E_M]$	J.cm^{-3}	2295	-	-
Volume-specific cost for structure	$[E_G]$	J.cm^{-3}	1900	-	-
Structural volume at puberty	V_p	cm^{-3}	0.3	-	-
Fraction of energy utilisation rate spent on maintenance plus growth	κ	-	0.45	-	-
Shape coefficient	δ_m	-	0.2	-	0.17
Arrhenius temperature	T_A	°K	5800	-	-
Reference temperature	T_1	°K	293	-	-
Lower boundary of tolerance range	T_L	°K	281	-	-
Upper boundary of tolerance range	T_H	°K	305	-	-
Rate of decrease at lower boundary	T_{AL}	°K	75000	-	-
Rate of decrease at upper boundary	T_{AH}	°K	30000	-	-
Fraction of reproduction energy fixed in eggs	κ_R	-	0.7	-	-
Energy content of reserves (in ash-free dry mass)	μ_E	J.mg^{-1}	17.5	-	-
Gonado-somatic threshold for triggering spawning	R_{GS}	%	37	-	-
Temperature for triggering spawning	T_s	°C	18.5	-	-
Initial conditions					
Structural volume	V	J	4000	600	600
Energy storage	E	J	1800	100	100
Energy for development and reproduction	E_R	J	2500	0	0