The following supplement accompanies the article

Vertical particle fluxes dominate integrated multi-trophic aquaculture (IMTA) sites: implications for shellfish–finfish synergy

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SUPPLEMENT

Ecosystem and Dynamic Energy Budget (DEB) model

Model equations:

$$\frac{dFW}{dt} = +FW_{production} - Sh_{ingestion} \pm FW_{mixing}$$

$$\frac{dFF}{dt} = +FF_{production} - FF_{sinking} - Sh_{ingestion} \pm FF_{mixing}$$

$$\frac{dShF}{dt} = +Sh_{egestion} - ShF_{sinking} - Sh_{ingestion} \pm ShF_{mixing}$$

$$\frac{dD}{dt} = +D_{production} - D_{sinking} - Sh_{ingestion} \pm D_{mixing} \quad , \quad D_{production} = D_{sinking}$$

$$\frac{dP}{dt} = +P_{production} - P_{sinking} - Sh_{ingestion} \pm P_{mixing} \quad , \quad P_{production} = P_{sinking}$$

Table S1. Carbon fluxes.

Term	Symbol	Units	Equation/source
Fish Waste in a given cell	FW	mg C m^{-3}	
Fish Waste Production	$FW_{production}$	mg C m^{-3} d^{-1}	$fwr \cdot V_f^{-1}$
Fish Waste production rate	fwr	mg C d^{-1} $farm^{-1}$	Table 2 and conversion factors (see 'Materials and methods')
Farm Volume	V_f	m^3	8678.7
FW ingested by shellfish	$Sh_{ingestion}$	mg C m^{-3} d^{-1}	$FW \cdot PR_i \cdot \rho \cdot mw^{-1} \cdot z^{-1}$
Individual pumping rate	PR_i	m^3 d^{-1} $indiv^{-1}$	From DEB model (see 'Materials and methods') for 0.015 kg mussel
Mussel density per area	ρ	kg m^{-2}	30
Mussel individual weight	mw	kg $indiv^{-1}$	0.015
Depth	z	m	15
Fish Waste mixing with each cell that is connected	FW_{mixing}	mg C m^{-3} d^{-1}	$- Exch_{exit} \cdot FW + Exch_{enter} \cdot FW_{enter}$
Exchange coefficient leaving to adjacent cell	$Exch_{exit}$	d^{-1}	Figure 2 and Filgueira et al. (2012)

Term	Symbol	Units	Equation/source
Exchange coefficient entering from adjacent cell	$Exch_{enter}$	d^{-1}	Figure 2 and Filgueira et al. (2012)
Fish Waste in adjacent cell	FW_{enter}	mg C m^{-3}	
Fish Faeces in a given cell	FF	mg C m^{-3}	
Fish Faeces Production	$FF_{production}$	mg C m^{-3} d^{-1}	$ffr \cdot V_f^{-1}$
Fish Faeces production rate	ffr	mg C d^{-1} $farm^{-1}$	Table 2 and conversion factors (see 'Materials and methods')
Fish Faeces Sinking	$FF_{sinking}$	mg C m^{-3} d^{-1}	$FF \cdot ffsr \cdot z^{-1}$
Fish Faeces sinking rate	ffsr	m d^{-1}	Table 1
FF ingested by shellfish	$Sh_{ingestion}$	mg C m^{-3} d^{-1}	$FF \cdot PR_i \cdot \rho \cdot mw^{-1} \cdot z^{-1}$
Fish Faeces mixing with each cell that is connected	FF_{mixing}	mg C m^{-3} d^{-1}	$- Exch_{exit} \cdot FF + Exch_{enter} \cdot FF_{enter}$
Fish Faeces in adjacent cell	FF_{enter}	mg C m^{-3}	
Shellfish Faeces in a cell	ShF	mg C m^{-3}	
Shellfish egestion	$Sh_{egestion}$	mg C m^{-3} d^{-1}	$ER_i \cdot \rho \cdot mw^{-1} \cdot z^{-1}$
Individual egestion rate	ER_i	mg C d^{-1} $indiv^{-1}$	From DEB model (see 'Materials and methods') for 0.015 kg mussel
Shellfish Faeces Sinking	$SfF_{sinking}$	mg C m^{-3} d^{-1}	$ShF \cdot shfsr \cdot z^{-1}$
Shellfish Faeces sinking rate	shfsr	m d^{-1}	Table 1
ShF ingested by shellfish	$Sh_{ingestion}$	mg C m^{-3} d^{-1}	$ShF \cdot PR_i \cdot \rho \cdot mw^{-1} \cdot z^{-1}$
Shellfish Faeces mixing with each cell that is connected	ShF_{mixing}	mg C m^{-3} d^{-1}	$- Exch_{exit} \cdot ShF + Exch_{enter} \cdot ShF_{enter}$
Shellfish Faeces in adjacent cell	ShF_{enter}	mg C m^{-3}	
Detritus in a given cell	D	mg C m^{-3}	
Detritus Production	$D_{production}$	mg C m^{-3} d^{-1}	$D_{production} = D_{sinking}$
Detritus Sinking	$D_{sinking}$	mg C m^{-3} d^{-1}	$D \cdot dsr \cdot z^{-1}$
Detritus sinking rate	dsr	m d^{-1}	
D ingested by shellfish	$Sh_{ingestion}$	mg C m^{-3} d^{-1}	$D \cdot PR_i \cdot \rho \cdot mw^{-1} \cdot z^{-1}$
Detritus mixing with each cell that is connected	D_{mixing}	mg C m^{-3} d^{-1}	$- Exch_{exit} \cdot D + Exch_{enter} \cdot D_{enter}$
Detritus in adjacent cell	D_{enter}	mg C m^{-3}	
Phytoplankton in a given cell	P	mg C m^{-3}	
Phytoplankton Production	$P_{production}$	mg C m^{-3} d^{-1}	$P_{production} = P_{sinking}$
Phytoplankton Sinking	$P_{sinking}$	mg C m^{-3} d^{-1}	$P \cdot psr \cdot z^{-1}$
Phytoplankton sinking rate	psr	m d^{-1}	
Phytoplankton ingested by shellfish	$Sh_{ingestion}$	mg C m^{-3} d^{-1}	$P \cdot PR_i \cdot \rho \cdot mw^{-1} \cdot z^{-1}$
Phytoplankton mixing with each cell that is connected	P_{mixing}	mg C m^{-3} d^{-1}	$- Exch_{exit} \cdot P + Exch_{enter} \cdot P_{enter}$
Phytoplankton in adjacent cell	P_{enter}	mg C m^{-3}	

Table S2. Equations of the Dynamic Energy Budget (DEB) model (from Filgueira et al. 2011).

Equation		Terms and parameters
$\frac{dE}{dt} = \dot{p}_A - \dot{p}_C$	E	Reserve (J)
	$\dot{p}_A$	assimilation rate (J d^{-1})
	$\dot{p}_C$	mobilization rate of reserve energy (J d^{-1})
$\dot{p}_A = \{\dot{p}_{Am}\} T_D f V^{2/3}$	$\{\dot{p}_{Am}\}$	maximum surface-area-specific assimilation rate (J cm^{-2} d^{-1})
	f	Functional response
	V	structural volume (cm^3)
	T_D	Arrhenius temperature function
$\{\dot{p}_{Am,}\} = \{\dot{p}_{Xm,}\} AE$	$\{\dot{p}_{Xm,}\}$	maximum surface-area-specific ingestion rate (J cm^{-2} d^{-1})
	AE	Absorption efficiency
$f = \frac{X}{X + X_K}$	X	Chlorophyll concentration (µg l^{-1})
	X_K	Half-saturation constant (µg l^{-1})
$\dot{p}_C = \frac{[E]}{[E_G]+\kappa[E]}\left(\frac{[E_G]\{\dot{p}_{Am}\}T_D V^{2/3}}{[E_m]} + \dot{p}_M\right)$	κ	fraction of utilized energy to somatic maintenance and growth
	$[E_G]$	volume-specific costs for structure (J cm^{-3})
	$[E_m]$	maximum energy density (J cm^{-3})
$\dot{p}_M = [\dot{p}_M] T_D V$	$\dot{p}_M$	maintenance rate (J d^{-1})
	$[\dot{p}_M]$	volume-specific maintenance costs (J cm^{-3} d^{-1})
$\frac{dV}{dt} = (\kappa\ \dot{p}_C - \dot{p}_M)/[E_G]$		
$\frac{dE_R}{dt} = (1-\kappa)\dot{p}_C - \left(\frac{1-\kappa}{\kappa}\right) \cdot V \cdot [\dot{p}_M]$	E_R	energy allocated to reproduction buffer (J)
$\frac{dE_R}{dt} = \kappa\ \dot{p}_C - \dot{p}_M \mid \kappa\ \dot{p}_C - \dot{p}_M < 0$		reproduction buffer dynamics when energy storage is too low
$L = \frac{V^{1/3}}{\delta_M}$	L	filter-feeder length (cm)
	δ_M	dimensionless shape coefficient

Table S3. *Mytilus edulis* DEB parameters (Filgueira et al. 2011). $^{*}X_K = X$ in order to make the functional response =1 (see Table S2 and 'Materials and methods').

Parameter	Value
δ_M	0.231
$\{\dot{p}_{Xm}\}$	273
$[\dot{p}_M]$	27.8
$[E_G]$	1900
$[E_m]$	2170
κ	0.45
X_K	X^{*}
T_A	5800
T_L	275
T_H	296
T_{AL}	45430
T_{AH}	31376
AE	Table 1
DW:WW	0.2

LITERATURE CITED

Filgueira R, Rosland R, Grant J (2011) A comparison of scope for growth (SFG) and dynamic energy budget (DEB) models applied to the blue mussel (*Mytilus edulis*). J Sea Res 66:403–410

Filgueira R, Grant J, Bacher C, Carreau M (2012) A physical-biogeochemical coupling scheme for modeling marine coastal ecosystems. Ecol Inform 7:71–80