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Supplement of

Particulate organic carbon dynamics in the Gulf of Lion shelf (NW Mediterranean) using a coupled hydrodynamic–biogeochemical model

Gaël Many et al.

Correspondence to: Gaël Many (gael.many@outlook.fr)

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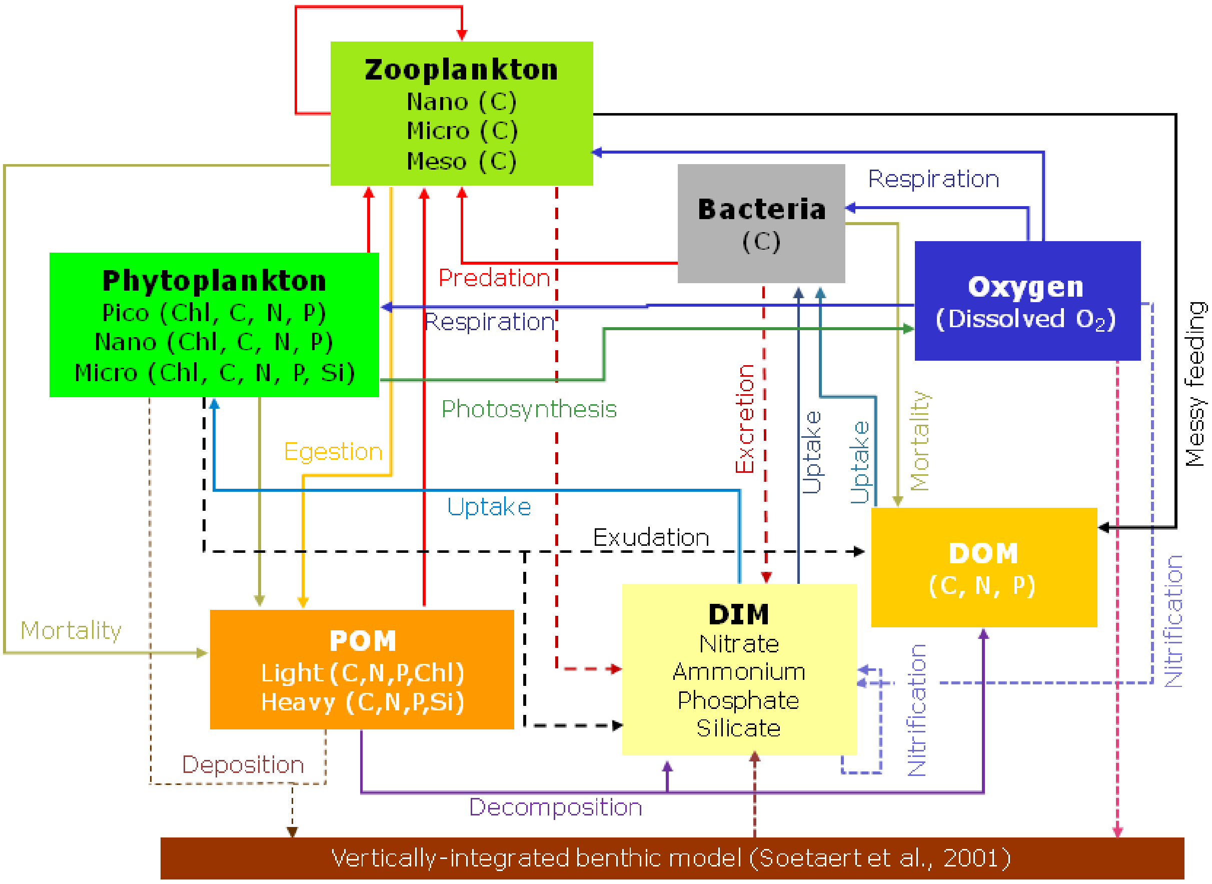
Figure S1. Schematics of the biogeochemical model Eco3M-S.



DIM: dissolved inorganic matter, DOM: dissolved organic matter, POM: particulate organic matter, C: carbon, N: nitrogen, P: phosphorus, Chl: chlorophyll, Si: silicium.

Table S1. Name and units of the state variables of the biogeochemical model

State Variables	Description	Unit
Nut_1 (NO_3), Nut_2 (NH_4), Nut_3 (PO_4), Nut_4 (SiO_4)	Nitrate, ammonium, phosphate, silicate, with X = C (carbon), N (nitrogen), P (phosphorus) or Si (silica)	mmol X m^{-3}
$XPhy_1$, $XPhy_2$, $XPhy_3$	Pico-, nano-, micro- phytoplankton in X, X = C, N, P or Si	mmol X m^{-3}
$ChlPhy_1$, $ChlPhy_2$, $ChlPhy_3$	Pico-, nano- micro- phytoplankton in chlorophyll	mg Chl m^{-3}
$CZoo_1$, $CZoo_2$, $CZoo_3$	Nano-, micro- and meso-zooplankton	mmol C m^{-3}
CBac	Bacteria	mmol C m^{-3}
DOX	Dissolved organic X, X=carbon, nitrogen and phosphorus	mmol X m^{-3}
$XDet_Y$	Heavy (Y=H) and light (Y=L) particulate organic X, X= carbon, nitrogen, phosphorus, silica and chlorophyll	mmol X m^{-3}
DOx	Dissolved oxygen	mmol O_2 m^{-3}

Table S2. Equations of the biogeochemical rates of change of the state variables

$$\frac{dC\,Phy_i}{dt} = GPP_i - RespPhy_i - Exu_{i,C} - MortPhy_{i,C} - \sum_{j=1}^{3} Graz_{j,CPhy_i} \qquad (S1)$$

$$\frac{dN\,Phy_i}{dt} = \sum_{j=1}^{2} UptPhy_{i,Nut_j} - Exu_{i,N} - MortPhy_{i,N} - \sum_{j=1}^{3} Graz_{j,NPhy_i} \qquad (S2)$$

X=P,Si

$$\frac{dX\,Phy_i}{dt} = UptPhy_{i,XO_4} - Exu_{i,X} - MortPhy_{i,X} - \sum_{j=1}^{3} Graz_{j,XPhy_i} \qquad (S3)$$

$$\frac{dChl\,Phy_i}{dt} = SynthChl_i - MortPhy_{i,Chl} - \sum_{j=1}^{3} Graz_{j,ChlPhy_i} \qquad (S4)$$

Zooplankton (Zoo_i, i=1,2,3)

$$\frac{dCZoo_i}{dt} = GrowthZoo_{i,C} - \sum_{j=1}^{3} Graz_{j,CZoo_i} - RespZoo_i^{add} - K \left(\delta_{i,1} + \delta_{i,2}\right) MortZoo_{i,C} - \delta_{i,3} PredZoo_{3,C} \qquad (S5)$$

Bacteria (Bac)

$$\frac{dCBac}{dt} = GrowthBac - MortBac_C - \sum_{j=1}^{3} Graz_{j,CBac} \qquad (S6)$$

Particulate organic matter – light detritus (Det_L)

X ∈ [C, N, P]

$$\frac{dXDet_L}{dt} = \sum_{i=1}^{3} MortPhy_{i,X} + \sum_{i=1}^{3} Eges_{i,X} + \sum_{i=1}^{2} fr_{Det_L}^{MortZoo_i} MortZoo_{i,X} + fr_{Det_L}^{MortZoo_3} PredZoo_{3,X} \quad K$$
$$- Rem_{XDet_L} - \sum_{j=1}^{3} Graz_{j,XDet_L} \qquad (S7)$$

$$\frac{dSiDet_L}{dt} = MortPhy_{3,Si} + fr_{Det_L}^{Eges_{Si}} \cdot \sum_{i=2}^{3} Eges_{i,Si} - Rem_{SiDet_L} \qquad (S8)$$

$$\frac{dChlDet_L}{dt} = \sum_{i=1}^{3} MortPhy_{i,Chl} + \sum_{i=1}^{3} Eges_{i,Chl} - Rem_{ChlDet_L} \tag{S9}$$

Particulate organic matter – heavy detritus (Det_H)

$X \in [C, N, P]$,

$$\frac{dXDet_H}{dt} = \sum_{i=1}^{2} \left(1 - fr_{Det_L}^{MortZoo_i}\right) MortZoo_{i,X} + \left(1 - fr_{Det_1}^{MortZoo_3}\right) PredZoo_{3,X} - Rem_{XDet_H} - \sum_{i=1}^{3} Graz_{i,XDet_H} \tag{S10}$$

$$\frac{dSiDet_H}{dt} = \left(1 - fr_{Det_L}^{Eges_{Si}}\right) \cdot \sum_{i=2}^{3} Eges_{i,Si} - Rem_{SiDet_H} \tag{S11}$$

Dissolved organic matter (DOM)

$X \in [C, N, P]$,

$$\frac{dDOX}{dt} = \sum_{i=1}^{3} Exu_{i,X} + \sum_{i=1}^{3} MessyFeed_{i,X} + MortBac_X + Rem_{XDet_L} + Rem_{XDet_H} - UptBac_{DOX} \tag{S12}$$

Dissolved inorganic nutrients

$$\frac{dNO_3}{dt} = Nitrif - \sum_{i=1}^{3} UptPhy_{i,NO_3} \tag{S13}$$

$$\frac{dNH_4}{dt} = \sum_{i=1}^{3} ExcZoo_{i,NH_4} + ExcBac_{NH_4} - Nitrif - \sum_{i=1}^{3} UptPhy_{i,NH_4} - UptBac_{NH_4} \tag{S14}$$

$$\frac{dPO_4}{dt} = \sum_{i=1}^{3} ExcZoo_{i,PO_s} + ExcBac_{PO_s} - \sum_{i=1}^{3} UptPhy_{i,PO_s} - UptBac_{PO_4} \tag{S15}$$

$$\frac{dSiO_4}{dt} = Exu_{3,Si} + Rem_{SiDet_L} + Rem_{SiDet_H} - UptPhy_{3,SiO_4} \tag{S16}$$

Dissolved oxygen

$$\frac{dDOx}{dt} = \sum_{i=1}^{3} (GPP_i - RespPhy_i)\gamma_{C/DOx} - \sum_{i=1}^{3} \left(RespZoo_i + RespZoo_i^{add}\right)\gamma_{C/DOx} - RespBac\ \gamma_{C/DOx} - Nitrif\gamma_{NH_4/DOx} \tag{S17}$$

Table S3. List of biogeochemical fluxes and functions

Symbol	Definition	Unit
GPP_i	Phytoplankton i gross primary production	mmol C m^{-3} d^{-1}
$\mu^{NR}_{Phy_i}$	Phytoplankton i maximal growth rate in nutrient-replete (NR) conditions	d^{-1}
μ_{Phy_i}	Phytoplankton i growth rate	d^{-1}
gml_i	Growth multi-nutrient limitation function for phytoplankton i	-
$f^{Q}_{Phy_i,Xlim}$	Phytoplankton i growth quota function, Xlim = N, P, Si	-
$f^{Q}_{Upt\ Phy_i,X}$	Phytoplankton i quota function for uptake of nutrient XNut, X = N, P, Si	-
$RespPhy_i$	Phytoplankton i respiration rate	mmol C m^{-3} d^{-1}
$UptPhy_{i,Nut_j}$	Phytoplankton i uptake rate of nutrient Nut_j, where $Nut_1 = NO_3$, $Nut_2 = NH_4$, $Nut_3 = PO_4$, $Nut_4 = SiO_4$	mmol m^{-3} d^{-1}
$V^{max}_{Phy_i,X}$	Phytoplankton i maximum carbon specific gross uptake rate of XNut, where X = N, P, Si	mol X mol C^{-1} m^{-3} d^{-1}
$(X/C)_{Phy_i}$	Phytoplankton I internal X/C quota, X = C, N, P, Si, Chl	mol X mol C^{-1}
$Exu_{i,X}$	Phytoplankton i exudation rate of DOX, where X = C, N, P, or SiO_4	mmol X m^{-3} d^{-1}
$SynthChl_i$	Phytoplankton i chlorophyll synthesis rate	mg Chl m^{-3} d^{-1}
$\rho_{Phy_i,Chl}$	Phytoplankton i chlorophyll synthesis regulation term	g Chl mol N^{-1}
$MortPhy_{i,X}$	Phytoplankton i mortality rate in X, where X = C, N, P, Si or Chl	mmol X m^{-3} d^{-1} or mg Chl m^{-3} d^{-1}
$Graz_{i,XPrey}$	Zooplankton i grazing rate on XPrey, where Prey = Phy_i, Zoo_i, Bac, $Det_{L,H}$ and X = C, N, P, Si or Chl	mmol X m^{-3} d^{-1} or mg Chl m^{-3} d^{-1}
$(X/C)_{Prey}$	X/C quota in zooplankton prey, where Prey = Phy_i, Zoo_i, Bac, $Det_{L,H}$	mol X mol C^{-1}
$MessyFeed_{i,X}$	Zooplankton i messy feeding rate, X = C, N, P	mmol X m^{-3} d^{-1}
$Eges_{i,X}$	Zooplankton i egestion rate in X, X = C, N, P, Si or Chl	mmol X m^{-3} d^{-1}
$GrowthZoo_{i,C}$	Zooplankton i net growth rate in carbon	mmol C m^{-3} d^{-1}
$RespZoo_i$	Zooplankton i respiration rate	mmol C m^{-3} d^{-1}
$FoodZoo_{i,X}$	Zooplankton i food flux in X, where X = C, N, P	mmol X m^{-3} d^{-1}
$(X/C)_{FoodZoo_i}$	Zooplankton i food X/C quota, where X = C, N, P	mol X mol C^{-1}
$ExcZoo_{i,XNut}$	Zooplankton i excretion of dissolved inorganic nutrient XNut, where XNut = NH_4, PO_4	mmol X m^{-3} d^{-1}
$RespZoo^{add}_i$	Zooplankton i additional respiration rate	mmol C m^{-3} d^{-1}
$MortZoo_{i,X}$	Zooplankton i mortality rate in X, X = C, N, P	mmol X m^{-3} d^{-1}
$PredZoo_{3,X}$	Mortality of zooplankton 3 through predation by higher trophic level rate in X, X = C, N, P	mmol X m^{-3} d^{-1}
$UptBac_{DOX}$	Bacteria uptake of dissolved organic X, where X = C, N, P	mmol X m^{-3} d^{-1}
$UptBac_{XNut}$	Bacteria uptake of dissolved inorganic nutrient XNut, XNut = NH_4, PO_4	mmol X m^{-3} d^{-1}
$UptBac^{max}_{XNut}$	Bacteria maximal uptake of dissolved inorganic nutrient XNut, XNut = NH_4, PO_4	mmol X m^{-3} d^{-1}
$GrowthBac$	Net bacterial production	mmol C m^{-3} d^{-1}
$GrowthBac^*$	Potential net bacterial production	mmol C m^{-3} d^{-1}
$(X/C)_{FoodBac}$	Bacteria food X/C quota, where X = C, N, P	mol X mo C^{-1}

$(X/C)_{DOM}$	Dissolved organic matter X/C quota, where X = C, N, P	mol X mol C^{-1}
$FoodBac_X$	Bacteria food flux in X, X = C, N, P	mmol X m^{-3} d^{-1}
$ExcBac_{XNut}$	Bacteria excretion of dissolved inorganic nutrient XNut, XNut = NH_4, PO_4	mmol X m^{-3} d^{-1}
RespBac	Bacteria respiration rate	mmol C m^{-3} d^{-1}
$MortBac_X$	Bacteria mortality rate in X, X = C, N, P	mmol X m^{-3} d^{-1}
Nitrif	Nitrification flux	mmol N m^{-3} d^{-1}
Rem_{XDet_Y}	Decomposition of XDetY, X = C, N, P, Si, Chl and Y= L (light), H (heavy)	mmol X m^{-3} d^{-1}
f^T	Temperature function for phytoplankton growth, zooplankton grazing, bacterial growth, decomposition and nitrification processes	-
PAR(z)	Photosynthetically active radiation at the depth z	J m^{-2} d^{-1}
PAR_{surf}	Photosynthetically active radiation at the surface: PARsurf = PAR(z=0)	J m^{-2} d^{-1}

Table S4. Equations of the biogeochemical processes

1. Phytoplankton:	
Gross primary production and growth rates	$$GPP_i = \frac{a_{Chl,Phy_i}\,\varphi_{max,Phy_i}\,PAR(z)\,f^T_{Phy}\,ChlPhy_i}{1+\tau_{Phy_i}\cdot\sigma_{Phy_i}\cdot PAR(z)+\tau_{Phy_i}\cdot\frac{k_d}{k_r}\cdot\left(\sigma_{Phy_i}\cdot PAR(z)\right)^2} \quad (S18)$$ $$\mu^{NR}_{Phy_i} = \frac{1}{CPhy_i}\cdot GPP_i \quad (S19)$$ $$\mu_{Phy_i} = gml_i\cdot\mu^{NR}_{Phy_i} \quad (S20)$$ with $$\begin{cases} gml_i = 0 & \text{if } (X_{lim}/C)_{Phy_i} < (X_{lim}/C)^{min}_{Phy_i} \text{ or} \\ gml_i = f^Q_{Phy_i,X_{lim}} & \text{if } (X_{lim}/C)_{Phy_i} \in \left[(X_{lim}/C)^{min}_{Phy_i},(X_{lim}/C)^{max}_{Phy_i}\right] \text{ or} \\ gml_i = 1 & \text{if } (X_{lim}/C)_{Phy_i} > (X_{lim}/C)^{max}_{Phy_i} \end{cases} \quad (S21)$$ where Xlim such as $\frac{(X_{lim}/C)_{Phy_i}}{(X_{lim}/C)^{max}_{Phy_i}} = \min\left(\frac{(X_{lim}/C)_{Phy_i}}{(X_{lim}/C)^{max}_{Phy_i}}\right)$ with $X\in[N,\ P,\ Si]$ and $$\begin{cases} f^Q_{Phy_1,X_{lim}} = 1-\frac{(X_{lim}/C)^{min}_{Phy_1}}{(X_{lim}/C)_{Phy_1}} \\ f^Q_{Phy_i,X_{lim}} = \frac{(X_{lim}/C)_{Phy_i}-(X_{lim}/C)^{min}_{Phy_i}}{(X_{lim}/C)_{Phy_i}-(X_{lim}/C)^{min}_{Phy_i}+\beta_{Phy_i,X}} \quad i=2,3 \text{ and } X_{lim}\in[N,\ P] \\ f^Q_{Phy_3,X_{lim}} = \frac{(Si/C)_{Phy_3}-(Si/C)^{min}_{Phy_3}}{(Si/C)_{Phy_3}-(Si/C)^{min}_{Phy_3}+\beta_{Phy_3,Si}}\,\frac{\left((N/C)_{Phy_3}\right)^\alpha}{\left((N/C)_{Phy_3}\right)^\alpha+(k_{Si})^\alpha} \end{cases} \quad (S22)$$
Nutrient uptake	$$UptPhy_{i,NO_3} = V^{max}_{Phy_i,N}\cdot\frac{NO_3}{NO_3+k_{Phy_i,NO_3}}\cdot\left(1-(\delta_{i,1}+\delta_{i,2})\,Inhib\,.\frac{NH_4}{NH_4+k_{inhib}}\right)CPhy_i \quad (S23)$$ $$UptPhy_{i,NH_4} = V^{max}_{Phy_i,N}\cdot\frac{NH_4}{NH_4+k_{Phy_i,NH_4}}\cdot CPhy_i \quad (S24)$$

	$\mathrm{UptPhy}_{i,XO_4} = V^{max}_{Phy_i,X} \cdot \frac{XO_4}{XO_s + k_{Phy_i,XO_4}} \cdot CPhy_i, \quad X \in [P, Si]$ (S25) with $V^{max}_{Phy_i,X} = \mu^{NR}_{Phy_i} \cdot (X/C)^{max}_{Phy_i}, \quad X \in [N, P, Si]$ (S26)
Exudation of dissolved organic carbon	$\mathrm{Exu}_{i,C} = (1 - gml_i) \cdot GPP_i$ (S27)
Exudation of dissolved organic X ($X \in [N, P]$) or SiO_4 resulting from nutrient uptake	$\mathrm{Exu}_{i,N} = \sum_{j=1}^{2} \left(1 - f^{Q}_{Upt\, Phy_i,X}\right) \cdot \mathrm{UptPhy}_{i,Nut_j}$ (S28) $\mathrm{Exu}_{i,X} = \left(1 - f^{Q}_{upt\, X,Phyi}\right) \cdot \mathrm{UptPhy}_{i,Nut_j}, \quad j = 3,4 \quad X \in [P, Si]$ (S29) where $f^{Q}_{Upt\, Phy_i,X} = \left(\frac{(X/C)^{max}_{Phy_i} - (X/C)_{Phy_i}}{(X/C)^{max}_{Phy_i} - (X/C)^{min}_{Phy_i}}\right)^2, \quad X \in [N, P, Si]$ (S30)
Respiration	$\mathrm{RespPhy}_i = k_{resp,Phy_i} \cdot gml_i \cdot GPP_i + \sum_j r_{Phy_i,Nut_j} \mathrm{UptPhy}_{i,Nut_j}$ (S31)
Chlorophyll synthesis	$\mathrm{SynthChl}_i = \rho_{Phy_i,Chl} \cdot \sum_{j=1}^{2} \mathrm{UptPhy}_{i,Nut_j}$ (S32) $\rho_{Phy_i,Chl} = \frac{(Chl/N)^{max}_{Phy_i} \cdot \mu_{Phy_i}}{a_{Chl,Phy_i} \cdot \varphi_{max,Phy_i} \cdot PAR(z) \cdot (Chl/C)_{Phy_i}} \cdot \frac{1 - \frac{(Chl/N)_{Phy_i}}{(Chl/N)^{max}_{Phy_i}}}{1.05 - \frac{(Chl/N)_{Phy_i}}{(Chl/N)^{max}_{Phy_i}}}$ (S33)
Mortality	$\mathrm{MortPhy}_{i,X} = \tau_{mort,Phy_i} \cdot f^{T}_{Phy_i} \cdot XPhy_i, \quad X \in [C, N, P, Si, Chl]$ (S34)
2. Zooplankton:	
Grazing	$\mathrm{Graz}_{i,XPrey} = \frac{f^{T}_{Zoo} \cdot g_{Zoo_i} \cdot pref_{i,Prey} \cdot (CPrey)^2 \cdot (X/C)_{Prey} \cdot CZoo_i}{k_{g,Zoo_i} \cdot \left(\sum_{Prey} pref_{i,Prey} \cdot CPrey\right) + \sum_{Prey} pref_{i,Prey} \cdot (CPrey)^2},$ $X \in [C, N, P, Si, Chl]$ (S35)
Messy feeding	$\mathrm{MessyFeed}_{i,X} = \psi_{Zoo_i} \sum_{Prey} \mathrm{Graz}_{i,XPrey}, \quad X \in [C, N, P]$ (S36)
Egestion	$\mathrm{Eges}_{i,X} = (1 - \beta_{Zoo_i}) \cdot (1 - \psi_{Zoo_i}) \sum_{Prey} \mathrm{Graz}_{i,XPrey}, \quad X \in [C, N, P]$ (S37) and $\mathrm{Eges}_{i,Y} = \sum_{Prey} \mathrm{Graz}_{i,YPrey}, \quad Y \in [Si, Chl]$ (S38)

Zooplankton growth	$GrowthZoo_{i,C} = k_{c,Zoo_i} \cdot \left(Graz_{i,CPrey} - Eges_{i,C} - MessyFeed_{i,C}\right)$ (S39)
Basal respiration	$RespZoo_i = \left(1 - k_{c,Zoo_i}\right) \cdot \left(Graz_{i,CPrey} - Eges_{i,C} - MessyFeed_{i,C}\right)$ (S40)
Dissolved inorganic matter excretion and additional respiration	$FoodZoo_{i,C} = GrowthZoo_{i,C}$ (S41) $FoodZoo_{i,X} = \left(Graz_{i,XPrey} - Eges_{i,X} - MessyFeed_{i,X}\right) \quad X \in [N, P]$ (S42) $(X/C)_{FoodZoo_i} = \frac{FoodZoo_{i,X}}{FoodZoo_{i,C}}, \quad X \in [N, P]$ • If the most limiting element is carbon, that is $(N/C)_{FoodZoo_i} > (N/C)_{Zoo_i}$ and $(P/C)_{FoodZoo_i} > (P/C)_{Zoo_i}$: $ExcZoo_{i,XNut} = FoodZoo_{i,X} - (X/C)_{Zoo_i} \cdot FoodZoo_{i,C}$, $X \in [N, P]$ and $XNut \in [NH_4, PO_4]$ (S43) • If the food is carbon-enriched and the most limiting element is X_1= [N or P] found by the following conditions $\min_{X \in [N, P]}\left(\frac{(X/C)_{FoodZoo_i}}{(X/C)_{Zoo_i}}\right)$ and $\left(\frac{(X_1/X_2)_{FoodZoo_i}}{(X_1/X_2)_{Zoo_i}}\right) < 1$ (X_2= [N or P] being in excess relative to X_1) then: $\begin{cases} ExcZoo_{i,X_2Nut} = FoodZoo_{i,X_2} - \frac{(X_2/C)_{Zoo_i}}{(X_1/C)_{Zoo_i}} \cdot FoodZoo_{i,X_1} \\ RespZoo_i^{add} = FoodZoo_{i,C} - \frac{1}{(X_1/C)_{Zoo_i}} \cdot FoodZoo_{i,X_1} \end{cases}$ (S44)
Mortality and predation by higher trophic level	For $i \in [1,2]$ $\begin{cases} MortZoo_{i,C} = \tau_{mort,Zoo_i} \cdot f_{Zoo}^{T} \cdot CZoo_i \\ MortZoo_{i,X} = (X/C)_{Zoo_i} \cdot MortZoo_{i,C} \end{cases}$ (S45) For Zoo_3 $\begin{cases} PredZoo_{3,C} = \tau_{pred} \cdot f_{Zoo}^{T} \cdot (CZoo_3)^2 \\ PredZoo_{3,X} = (X/C)_{Zoo_3} \cdot PredZoo_{3,C} \end{cases}$ (S46)
<u>3. Bacteria:</u>	
Uptake of dissolved organic matter	$UptBac_{DOX} = \mu_{Bac} \cdot \left(\frac{DOC}{DOC + k_{DOC}}\right) \cdot (X/C)_{DOM} \cdot CBac$ (S47)
Uptake and release of nutrients, and net bacterial growth	$GrowthBac^{*} = \omega_{Bac} \cdot UptBac_{DOC}$ (S48) $(X/C)_{FoodBac} = \frac{1}{\omega_{Bac}}(X/C)_{DOM} \quad X \in [N, P]$

$$UptBac_{XNut}^{max} = \mu_{Bac} \cdot (X/C)_{Bac} \cdot \frac{XNut}{XNut + k_{XNut,\ Bac}} \cdot CBac \quad , \quad X \in [N, P]$$

(S49)

- If the most limiting element is carbon, *i.e.* $(N/C)_{FoodBac} > (N/C)_{Bac}$ and $(P/C)_{FoodBac} > (P/C)_{Bac}$:

$$\begin{cases} UptBac_{XNut} = 0 \quad \text{with} \quad X \in [N,\ P] \\ ExcBac_{XNut} = UptBac_{DOX} - \mathit{Growth}\ Bac^{*} \cdot (X/C)_{Bac} \quad \text{with} \quad X \in [N,\ P \\ G\mathit{rowthBac} = \mathit{GrowthBac}^{*} \end{cases}$$

(S50)

- If the food has a deficit in element X_1 with X_1=P or N, and the element X_2 with $X_2 \neq X_1$=N or P is in excess relative to carbon. That is, $(X_1/C)_{FoodBac} \leq (X_1/C)_{Bac}$ and $(X_2/C)_{FoodBac} > (X_2/C)_{Bac}$

$$\begin{cases} UptBac_{X_1 Nut} = \min\left[UptBac_{X_1 Nut}^{max}, GrowthBac^{*} \cdot (X_1/C)_{Bac} - UptBac_{DOX} \right. \\ UptBac_{DOX_2} = 0 \\ ExcBac_{X_1 Nut} = 0 \\ ExcBac_{X_2 Nut} = UptBac_{DOX_2} - G\mathit{rowthBac}^{*} \cdot (X_2/C)_{Bac} \\ G\mathit{rowthBac} = \dfrac{UptBac_{DOX_1} + UptBac_{X_1 Nut}}{(X_1/C)_{Bac}} \end{cases}$$

(S51)

- If the food has both deficit in nitrogen and phosphorus and X_1 is the most limiting element with X_1=P or N, that is $(X_1/C)_{FoodBac} \leq (X_2/C)_{Bac}$ and $(X_2/C)_{FoodBac} \leq (X_2/C)_{Bac}$ with $(X_2/X_1)_{FoodBac} \leq (X_2/X_1)_{Bac}$.

$$UptBac_{X_1 Nut}^{*} = \min\left[UptBac_{X_1 Nut}^{max}, GrowthBac \cdot (X_1/C)_{Bac} - UptBac\right.$$

$$\text{If } UptBac_{DOX_2} \leq \left(\mathit{UptBac}_{DOX_1} + \mathit{UptBac}_{X_1 Nut}\right) \cdot (X_2 / X_1)_{Bac}$$

$$\begin{cases} UptBac_{X_2 Nut} = \min\left[UptBac_{X_2 Nut}^{max}, \left(UptBac_{DOX_1} + \mathit{UptBac}_{X_1 Nut}^{*}\right) \cdot (X_2/X_1)_{Bac} - UptBac\right. \\ ExcBac_{X_2 Nut} = 0 \\ UptBac_{X_1 Nut} = \min\left[UptBac_{X_1 Nut}^{*}, \left(UptBac_{X_2 Nut}^{max} + UptBac_{DOX_2}\right) \cdot (X_1/X_2)_{Bac} - UptBa\right. \\ ExcBac_{X_1 Nut} = 0 \\ GrowthBac = \dfrac{UptBac_{DOX_1} + UptBac_{X_1 Nut}}{(X_1/C)_{Bac}} \end{cases}$$

(S52)

	else $$\begin{cases} UptBac_{X_2Nut} = 0 \\ ExcBac_{X_2Nut} = UptBac_{DOX_2} - \left(UptBac_{DOX_1} + UptBac_{X_1Nut}\right) \cdot \left(X_2 / X_1\right) \\ UptBac_{X_1Nut} = UptBac_{X_1Nut}^{*} \\ ExcBac_{X_1Nut} = 0 \\ GrowthBac = \dfrac{UptBac_{DOX_1} + UptBac_{X_1Nut}}{\left(X_1/C\right)_{Bac}} \end{cases}$$ (S53)
Respiration	$RespBac = GrowthBac \cdot \left(\frac{1}{\omega_{Bac}} - 1\right)$ (S54)
Mortality	$MortBac_X = \tau_{mort,\ Bac} \cdot f_{Bac}^{T} \cdot \left(X/C\right)_{Bac} \cdot CBac \quad , \quad X \in [C, N, P]$ (S55)
4. Other process:	
Decomposition	$Rem_{XDet_{L,H}} = \tau_{rem,\ XDet} \cdot XDet_{L,H}$ (S56)
Nitrification	$Nitrif = \tau_{nitrif} \cdot NH_4 \cdot f_{Nitrif}^{T} \cdot \left(1 - \frac{PAR(z)}{PAR_{surf}}\right)$ (S57)
Temperature function for phytoplankton, zooplankton and bacterial growth, and nitrification	$f^{T}(T) = Q_{10}^{\left(\frac{T - T^{REF}}{10}\right)}$, Q_{10} and T^{REF} empirical constants (S58)

$\delta_{i,j}$ is the Kronecker symbol, equals to 1 if i=j, to 0 else

Table S5. List of model parameters

Symbol	Description	Unit	Value			Reference
Phytoplankton			**Phy_1**	**Phy_2**	**Phy_3**	
φ_{max, Phy_i}	Maximum quantum yield	mmol C J^{-1}	2.2e-4	2.6e-4	3.6e-4	1,2,c
a_{Chl, Phy_i}	Chl-specific absorption coeff.	m^2 mg Chl^{-1}	0.032	0.016	0.013	2,c
τ_{Phy_i}	Renewal time of photosystems	d	2.3e-8	3.5.e-8	4.7e-8	3,c
σ_{Phy_i}	Cross-section of photosystems	m^2 J^{-1}	18	12	9	4,5,c
k_d	Dimensionless photoinhibition rate	-	2.6e-8	2.6e-8	2.6e-8	6
k_{rep}	Rate of repair of photoinhibition damaged PSII	d	2.3e-9	2.3e-9	2.3e-9	6
$(N/C)_{min, Phy_i}$	Minimal internal N/C quota	mol N (mol C)$^{-1}$	0.05	0.05	0.05	7,8,9
$(N/C)_{max, Phy_i}$	Maximal internal N/C quota	mol N (mol C)$^{-1}$	0.2	0.2	0.2	7,8,9
$(P/C)_{min, Phy_i}$	Minimal internal P/C quota	mol P (mol C)$^{-1}$	0.004	0.002	0.002	8,10,11
$(P/C)_{max, Phy_i}$	Maximal internal P/C quota	mol P (mol C)$^{-1}$	0.019	0.019	0.019	8,10,11
$(Si/C)_{min, Phy_i}$	Minimal internal Si/C quota	mol Si (mol C)$^{-1}$	-	-	0.05	9,11
$(Si/C)_{max, Phy_i}$	Maximal internal Si/C quota	mol Si (mol C)$^{-1}$	-	-	0.19	9,11
$(Chl/N)_{max, Phy_i}$	Maximal internal Chl/N quota	mg Chl (mol N)$^{-1}$	2.3	2.3	2.3	12,13,c
Q^{10}_{Phy}	Temperature coefficient	-	2.0	2.0	2.0	14
T^{REF}_{Phy}	Reference temperature	°C	14	14	14	15, c
k_{resp, Phy_i}	Respiration cost for growth	-	0.3	0.25	0.2	13,14,16,c
$\beta_{Phy_i, N}$	Nitrogen parameter for growth rate limitation	mol N (mol C)$^{-1}$	-	0.0072	0.002	c
$\beta_{Phy_i, P}$	Phosphorus parameter for growth rate limitation	mol P (mol C)$^{-1}$	-	0.0002	0.0005	c
$\beta_{Phy_i, Si}$	Silica parameter for growth rate limitation	mol Si (mol C)$^{-1}$	-	-	0.004	c
k_{Si}	Nitrogen parameter for growth rate limitation by silica	mol N (mol C)$^{-1}$	-	-	0.1	c
k_{Phy_i, NO_3}	Half saturation constant for NO_3	mmol N m^{-3}	0.5	0.7	1	11,15,17,18, c
k_{Phy_i, NH_4}	Half saturation constant for NH_4	mmol N m^{-3}	0.1	0.3	0.7	15,17,18,c
k_{inhib}	Inhibition coefficient by NH_4	mmol N m^{-3}	0.578	0.578	-	17
Inhib	Inhibition parameter by NH_4	-	0.82	0.82	-	17
k_{Phy_i, PO_4}	Half saturation constant for PO_4	mmol P m^{-3}	0.005	0.015	0.05	11,18,19,c
k_{Phy_i, SiO_4}	Half saturation constant for SiO_4	mmol Si m^{-3}	-	-	1.2	11,c
r_{Phy_i, NO_3}	Respiration cost for NO_3 uptake	mol C (mol N)$^{-1}$	0.397	0.397	0.397	16
r_{Phy_i, NH_4}	Respiration cost for NH_4 uptake	mol C (mol N)$^{-1}$	0.198	0.198	0.198	16
r_{Phy_i, PO_4}	Respiration cost for PO_4 uptake	mol C (mol P)$^{-1}$	0.155	0.155	0.155	16
r_{Phy_i, SiO_4}	Respiration cost for SiO_4 uptake	mol C (molSi)$^{-1}$	-	-	0.14	16
τ_{mort, Phy_i}	Natural mortality rate	d^{-1}	0.27	0.19	0.17	7,20,c
w_{s, Phy_i}	Sinking rate	m d^{-1}	-	-	0.7	7,15,c

Zooplankton			Zoo1	Zoo2	Zoo3	
g_{Zoo_i}	Maximum grazing rate	d^{-1}	5.83	3.9	1.9	7,21,22,c
k_{g,Zoo_i}	Half saturation constant	mmol C m^{-3}	5	8.5	20	23,c
Ψ_{Zoo_i}	Messy feeding fraction	-	0.23	0.23	0.23	7,24
β_{Zoo_i}	Assimilation efficiency	-	0.6	0.6	0.6	7,24
k_{c,Zoo_i}	Net growth efficiency	-	0.8	0.8	0.8	7,24
$(N/C)_{Zoo_i}$	Internal N/C quota	mol N (mol $C)^{-1}$	0.18	0.18	0.18	7,10,25
$(P/C)_{Zoo_i}$	Internal P/C quota	mol P (mol $C)^{-1}$	0.013	0.013	0.013	10,25,C
τ_{mort,Zoo_i}	Natural mortality rate	d^{-1}	0.09	0.03	-	20,c
τ_{pred}	Predation mortality rate	m^3 (mmol C $d)^{-1}$	-	-	0.05	20,c
$fr_{Det_L}^{Eges_{Si}}$	Ratio light/heavy Si detritus in residu of egestion		-	-	0.8	c
$fr_{Det_L}^{MortZoo_i}$	Ratio light/heavy detritus in zooplankton loss term	-	1	1	0.95	c
Q_{Zoo}^{10}	Temperature coefficient	-	2.0	2.0	2.0	7
T_{Zoo}^{REF}	Reference temperature	°C	20	20	20	c
$pref_{i,Prey}$	Preference of Zooplankton i for Prey	-				

Zooi/Prey	Bacteria	Phy_1	Phy_2	Phy_3	Zoo_1	Zoo_2	Det_L
Zoo_1	0.35	0.65	0	0	0	0	0
Zoo_2	0.08	0.06	0.25	0.2	0.25	0.2	0.05
Zoo_3	0	0	0	0.5	0	0.45	0.05

Bacteria				
μ_{Bac}	Maximum DOC uptake	d^{-1}	3.67	15,24,c
k_{DOC}	Half-saturation for DOC uptake	mmol C m^{-3}	25	24
ω_{Bac}	Bacteria gross growth efficiency	-	0.3	24,c
$(N/C)_{Bac}$	Bacteria internal N/C quota	mol N (mol $C)^{-1}$	0.232	10
$(P/C)_{Bac}$	Bacteria internal P/C quota	mol P (mol $C)^{-1}$	0.022	10,28
$k_{NH_4,Bac}$	Half-saturation for NH_4 uptake	mmol N m^{-3}	0.2	24,c
$k_{PO_4,Bac}$	Half-saturation for PO_4 uptake	mmol P m^{-3}	0.007	27,c
$\tau_{mort,Bac}$	Bacteria natural mortality rate	d^{-1}	0.60	20
Q_{Bac}^{10}	Temperature coefficient	-	2.95	10
T_{Bac}^{REF}	Reference temperature	°C	20	c

Non-living matter				
$\tau_{rem,CDet}$	Detritus decomposition rate, C	d^{-1}	0.04	24,c
$\tau_{rem,NDet}$	Detritus decomposition rate, N	d^{-1}	0.05	24,c
$\tau_{rem,PDet}$	Detritus decomposition rate, P	d^{-1}	0.06	28,c
$\tau_{rem,ChlDet}$	Detritus decomposition rate, Chl	d^{-1}	0.1	c

$\tau_{rem,\ SiDet}$	Detritus remineralisation rate, Si	d^{-1}	0.005	20
$w_{s,\ Det_L}$	Light detritus sinking rate	$m\ d^{-1}$	0.7	15,c
$w_{s,\ Det_H}$	Heavy detritus sinking rate	$m\ d^{-1}$	90	15,c
Q_{rem}^{10}	Temperature coefficient for decomposition	-	2.95	10
T_{rem}^{REF}	Reference temperature for decomposition	°C	20	c
τ_{nitrif}	Nitrification rate	d^{-1}	0.06	15,c
Q_{nitrif}^{10}	Temperature coefficient for nitrification	-	2.37	10
T_{nitrif}^{REF}	Reference temperature for nitrification	°C	10	c
Chemical model				
$\gamma_{C/DOx}$	Mole of DOx used per mole of C in oxic respiration	mol O_2 (mol C)$^{-1}$	1	29
$\gamma_{NH_4/DOx}$	Mole of DOx used per mole of NH_4 in nitrification	mol O_2 (mol NH_4)$^{-1}$	2	29

C: carbon ; N: nitrogen ; P: phosphorus ; Si: silicate ; NO_3: nitrate ; NH_4: ammonium ; PO_4: phosphate ; SiO_4: silica ; Phy1: pico-phytoplankton ; Phy2: nano-phytoplankton ; Phy3: micro-zooplankton ; Zoo1: nano-zooplankton ; Zoo2: micro-zooplankton ; Zoo3: meso-zooplankton ; DOC: Dissolved organic carbon ; c: Calibration ; (1) Babin et al. (1996); (2) Claustre et al. (2005) ; (3) Laney et al. (2005) ; (4) Moore et al. (2003) ; (5) Gorbunov et al. (1999) ; (6) Oliver et al. (2003) ; (7) Raick et al. (2005) ; (8) Riegman et al. (2000) ; (9) Geider et al. (1998) ; (10) Vichi et al. (2007) ; (11) Sarthou et al. (2005) ; (12) van den Meersche et al. (2004) ; (13) Sondergaard and Theil-Nielsen (1997) ; (14) Soetaert et al (2001) ; (15) Lacroix and Grégoire (2002) ; (16) Cannell and Thornley (2000) ; (17) Harrison et al. (1996) ; (18) Tyrrell and Taylor (1996) ; (19) Timmermans et al. (2005) ; (20) Fasham et al. (2006) ; (21) Christaki et al. (2002) ; (22) Nejstgaard et al. (1997) ; (23) Hansen et al. (1997); (24) Anderson and Pondaven (2003); (25) Goldman et al. (1987) ; (26) Liu and Dagg (2003) ; (27) Thingstad et al. (1993) ; (28) Thingstad (2005) ; (29) Grégoire et al. (2008)

Text S1. Description of the biogeochemical model

The biogeochemical model Eco3M-S described in detail by Auger et al. (2011) and Ulses et al. (2021) represents the decoupled cycles of carbon (C), nitrogen (N), phosphorus (P), silica (Si) and oxygen (O_2) and the dynamics of different plankton groups. It includes 35 state variables. Three size-classes of phytoplankton (pico-, nano-, and micro-phytoplankton), three size-classes of zooplankton (nano-, micro-, and meso-zooplankton), and one class of bacteria are accounted for. The relative internal composition, i.e., the stoichiometry, is considered as variable for phytoplankton and constant for heterotroph organisms. Four dissolved inorganic nutrients are considered. Nitrate and ammonium are distinguished owing to their distinct roles in the functioning of pelagic ecosystem (new versus regenerated production). Inorganic dissolved phosphorus (phosphate) is considered due to its important role in the control of the primary productivity at some periods of the year in the Mediterranean Sea (Diaz et al., 2001; Marty et al., 2002; Pasqueron de Fommervault et al., 2015). Dissolved organic matter (DOM) is considered in the model under the forms of C, N, and P. Particulate organic matter (POM, under the forms of C, N, P, Si, and chlorophyll) is divided into two weight classes, namely light and heavy. List of state variables is given in Table S1. The food-web structure of the model and the biogeochemical processes interacting between compartments are schematically represented in Figure S1.

The representation of the phytoplankton processes is derived from the model Eco3M presented and validated in Baklouti et al. (2006). This model was extended to represent the various phytoplankton functional types computed in terms of carbon, nitrogen, phosphorus, silica (only for micro-phytoplankton), and chlorophyll contents with potential multi-nutrient limitation for their growth. The processes that drive the phytoplankton dynamics are the gross primary production (Eq. S18-S22), the autotrophic respiration (Eq. S31), the chlorophyll synthesis (Eq. S32-S33), the exudation of dissolved organic carbon (Eq. S27), the uptake of nutrient (Eq. S23-S26), the exudation of dissolved organic matter following the uptake of nutrients (Eq. S28-S30), and the natural mortality (e.g., including viral lyses) (Eq. S34) (Tables S2-S5).

The zooplankton and bacteria model is an adapted version of the stoichiometric model developed for heterotrophs by Anderson and Pondaven (2003) and applied in the Ligurian Sea by Raick et al. (2005). The grazing (Eq. S35), egestion (Eq. S37-S39), messy feeding (Eq. S36), excretion (Eq. S41-S44), respiration (Eq. S40-S44), mortality (Eq. S45) and predation by higher trophic levels (Eq. S46) are the main processes driving the dynamics of zooplankton biomass at each time step in the model (Tables S2-S5). The processes that drive the dynamics of the bacteria compartment are the uptake of DOM (Eq. S47) and of nutrients (Eq. S48-S53), the excretion of nutrients (Eq. S48-S53), the respiration (Eq. S54), and the mortality (Eq. S55) (Tables S2-S5). The process of decomposition of POM (Eq. S56), represented in an implicit way, here stands for the hydrolysis activity of the particle-attached bacterial community. This process feeds DOM pool and silicates. Finally the oxygen dynamics is driven by the gross primary production, the autotrophic and heterotrophic respiration and the nitrification (Eq. S57) (Tables S2-S5).

Text S2. Coupling of the hydrodynamic and biogeochemical models

The "Source Splitting" coupling method (Butenschön et al., 2012) was used to couple the hydrodynamic and the biogeochemical modes. It consists of an off-line forcing of the biogeochemical model by the daily averaged outputs of the physical model. It is then assumed that biogeochemical properties do not significantly impact hydrodynamics.

The rate of change of the concentration C of each biogeochemical state variable (Table S1) was the sum of a physical rate of change and the biogeochemical one (Table S2). The physical rate of the concentration C was computed by using the following advection-diffusion equation:

$$\frac{\partial C}{\partial t} + \frac{\partial uC}{\partial x} + \frac{\partial vC}{\partial y} + \frac{\partial (w-w_s)C}{\partial z} = \frac{\partial}{\partial z}\left(K_z \frac{\partial C}{\partial z}\right) + F_C \qquad \text{(S59)}$$

where u, v, w are the three components of the current velocity, Kz is the vertical diffusivity calculated by the hydrodynamic model, w_s is the settling velocity and F_c is the source or sink term for C from rivers, atmosphere or sediment. The advection and diffusion of the biogeochemical variables were calculated using the QUICKEST (QUICK with Estimated Streaming Terms) scheme (Leonard, 1979) on the horizontal and with a centred scheme on the vertical. We used a time step of 10 minutes for the advection and diffusion of biogeochemical variables

The photosynthetically available irradiance at the surface, PAR_{surf}, is assumed to be 43 % of the three-hourly fields of sea solar radiation provided by the meteorological ECMWF model. The percent of reflected irradiance, i.e. albedo, is set to 0.05. The attenuation of light availability for the photosynthesis with depth is computed by distinguishing the parts of light penetrating in low and short wavelength as follows:

$$PAR(z) = PAR_{surf}(1 - albedo)\left(p_1 \cdot e^{-\int_0^z k_{w,l}+k_{p,l}\sum_{i=1,3} ChlPhy_i(z)^{lc_l} dz} + (1-p_1)e^{-\int_0^z k_{w,s}+k_{p,s}\sum_{i=1,3} ChlPhy_i(z)^{lc_s} dz}\right) \quad \text{(S60)}$$

where p_l is the percent of PAR with long wavelength and is set to 0.5, k_w is the background extinction coefficient of water (m^{-1}), chosen as in Pope and Fry (1997), k_p is the extinction coefficient due to self-shading of phytoplankton cells ((mg Chl)$^{-1}$ m^{-2}) and lc constants chosen as in Bricaud et al. (2004). $ChlPhy_i$ is the concentration of phytoplankton i expressed in mg Chl m^{-3} (Table S1). The indices “s” and “l” stand for short and long wavelengths, respectively.

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