Supplementary material to "Pre-operational short-term forecasts for the Mediterranean Sea biogeochemistry": Equations of the BFM Model

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Ocean Science Discussions

The equations of the BFM model are the translation of the computer routines of BFM v2.0 software into analytical expressions, the notation used is described in the following:

- $\frac{\partial A_B}{\partial t}\Big|_{C_B}^{D}$ is the rate of change in time for the functional group A and C (the flux is directed from C to A), due to the process D, with respect the chemical component B. A and C are elements of a set of 51 concentrations vector and the correspondent functional groups abbreviations are:

  1. $O2o$ oxygen;
  2. $N1p$ nutrient phosphate, $N3n$ nutrient nitrate, $N4n$ nutrient ammonia, $N5s$ Silicate;
  3. $P^{(1)}$ diatoms, $P^{(2)}$ flagellates, $P^{(3)}$ picophytoplankton, $P^{(4)}$ dinoflagellates;
  4. $B^{(1)}$ pelagic bacteria;
  5. $Z^{(3)}$ carnivorous mesozooplankton, $Z^{(4)}$ omnivorous mesozooplankton;
  6. $Z^{(5)}$ microzooplankton, $Z^{(6)}$ heterotrophyc nanoflagellates;
  7. $R^{(1)}$ Dissolved labile matter, $R^{(2)}$ Dissolved semilabile carbon (sugars), $R^{(7)}$ refractory dissolved carbon.
  8. $R^{(6)}$ particulate organic matter;

  If an abbreviation is followed by a letter ($c \quad p \quad n \quad s \quad i$) the term represents the chemical concententration (respectively c-arbon p-hosphorus n-itrogen s-ilica and i for chlorophyll) of the specific functional group. Carbon and chlorophyll-a components are in $mgCm^{-3}$ and $mgchlam^{-3}$ units, the other components are in $mmolm^{-3}$, i.e. $N1p$ is expressed in $mmolPm^{-3}$. The generic phytoplanker $P^{(?)}$ is described by four components $P_c^{(?)}$, $P_p^{(?)}$, $P_n^{(?)}$, $P_i^{(?)}$, diatoms have an additional component for silica $P_s^{(1)}$. Bacteria are described by three components $B_c^{(1)}$, $B_p^{(1)}$, $B_n^{(1)}$, zooplankters $Z^{(?)}$ are described also by three component $Z_c^{(?)}$, $Z_p^{(?)}$, $Z_n^{(?)}$. Labile dissolved organic matter is described by four components $R_c^{(1)}$, $R_p^{(1)}$, $R_n^{(1)}$, $R_s^{(1)}$, semi labile and refractory dissolved organic matter are described by carbon component $R_c^{(2)}$ and $R_c^{(2)}$ respectively. Particulate organic matter is described by four components $R_c^{(6)}$, $R_p^{(6)}$, $R_n^{(6)}$, $R_s^{(6)}$,

- $Qab(C)$ is the ratio between intracellular chemical concentration a and b of functional group C. For example $Qpc(P^{(1)}) = \frac{P^{(1)}p}{P^{(1)}c}$.

- each term preceded by $p\_$ is a parameter described in the tables floating through-out the text.

1 Phytoplankton

1.1 Carbon component of Phytoplankton functional Group

$$\left.\frac{\partial P_c}{\partial t}\right|_{bio}^{-} = +\left.\frac{\partial P_c}{\partial t}\right|_{O^{(3)}}^{gpp} - \left.\frac{\partial P_c}{\partial t}\right|_{R_c^{(2)}}^{exc} - \sum_{j=1,6}\left.\frac{\partial P_c}{\partial t}\right|_{R_c^{(j)}}^{lys} - \left.\frac{\partial P_c}{\partial t}\right|_{O^{(3)}}^{rsp} - \left.\frac{\partial P_c}{\partial t}\right|_{R_c^{(2)}}^{npp} + +netgrowth - \left\{\sum_{k=4,6}\left.\frac{\partial Z_c^{(k)}}{\partial t}\right|_{P_c}^{prd}\right\} \quad (1)$$

$$\left.\frac{\partial R_c^{(1)}}{\partial t}\right|_{bio}^{-} = +\sum_{i=1,4}\left.\frac{\partial P_c^{(i)}}{\partial t}\right|_{R_c^1}^{lys} \quad (2)$$

$$\left.\frac{\partial R_c^{(6)}}{\partial t}\right|_{bio}^{-} = +\sum_{i=1,4}\left.\frac{\partial P_c^{(i)}}{\partial t}\right|_{R_c^6}^{lys} \quad (3)$$

$$\left.\frac{\partial R_c^{(2)}}{\partial t}\right|_{bio}^{-} = +\sum_{i=1,4}\left.\frac{\partial P_c^{(i)}}{\partial t}\right|_{R_c^{(2)}}^{exc} + \sum_{i=1,4}\left.\frac{\partial P_c^{(i)}}{\partial t}\right|_{R_c^{(2)}}^{npp} - \sum_{i=1,4} netgrowth_i \quad (4)$$

$$\left.\frac{\partial O2o(t)}{\partial t}\right|_{bio}^{-} = \frac{1}{12}\left(-\sum_{i=1,4}\left.\frac{\partial P_c^{(i)}}{\partial t}\right|_{O^{(3)}}^{rsp} + \sum_{i=1,4}\left.\frac{\partial P_c^{(i)}}{\partial t}\right|_{O^{(3)}}^{gpp}\right) \quad (5)$$

Terms in curly parentheses are described respectively in Microzooplankton and Mesozooplankton sections.

1.1.1 Gross primary production ($\left.\frac{\partial P_c}{\partial t}\right|_{O^{(3)}}^{gpp}$)

- sum (carbon uptake maximum)
- $Photo_{max}$ (maximum synthesis)
- $eiPi$ (limiting factor due to light)
- $iN5s$ (nutrient limitation due to intra-extracellular silicate only diatoms)
- et (temperature limitation factor $t_o = 10^o$ C)
- t (temperature expressed in Celsius degrees)
- Irr (irradiance expressed in $\mu E m^{-2} day^{-1}$)
- $sunq$ (photoperiod expressed in hours, currently 24)
- $L_{p_o,1}(x)$ is the function $min(1, max(p_o, x))$

- p_o (minimum limitation costant, currently 10^{-12})

$$
\begin{aligned}
\left.\frac{\partial P_c}{\partial t}\right|_{O^{(3)}}^{gpp} &= p\_sum(P) * et * iN5s * \frac{sunq}{24} * eiPi * P_c && (6)\\
sum &= Photo_{max} * eiPi && (7)\\
Photo_{max} &= p\_sum(P) * et * iN5s * \frac{sunq}{24} && (8)\\
eiPi &= 1 - exp\left(-Qchlc(P) * \frac{p\_alpha\_chl(P)}{Photo_{max}} * Irr\right) && (9)\\
iN5s &= min\left(1, max\left(p_o, \frac{Qsc(P^{(1)}) - p\_qslc(P^{(1)})}{p\_qsRc(P^{(1)}) - p\_qslc(P^{(1)})}\right)\right) && (10)\\
et &= p\_q10^{\frac{t-t_o}{t_o}} && (11)
\end{aligned}
$$

Phytoplankton parameters						Details
		$P^{(1)}$	$P^{(2)}$	$P^{(3)}$	$P^{(4)}$	
a_{01}	$pq10$	2.0	2.0	2.0	2.0	parameter temperature limitation
a_{02}	p_sum	2.5	3.0	3.5	1.5	uptake parameter
a_{10}	p_qslc	0.0054	0.0	0.0	0.0	minimum s quota
a_{13}	p_qsRc	0.01	0.0	0.0	0.0	s uptake factor based on C as. quota
a_{27}	p_alpha_chl	1.38e-05	4.6e-06	1.52e-05	6.8e-06	initial slope PI curve
$P^{(1)}$ = diatoms, $P^{(2)}$ = flagellates, $P^{(3)}$ = picophytoplankton, $P^{(4)}$ = dinoflagellates						

1.1.2 Rate apporting over dissolved labile carbon ($R_c^{(1)}$) and particulate organic matter carbon POM ($R_c^{(6)}$)($\left.\frac{\partial P_c}{\partial t}\right|_{R_c^{(2)}}^{lys}$, $\left.\frac{\partial P_c}{\partial t}\right|_{R_c^{(6)}}^{lys}$)

- sdo (nutrient stress lysis)
- iN (nutrient limitation (Liebig Rule))
- $iN1p$ (nutrient intracellular limitation Phosphate Droop formulation)
- $iNIn$ (nutrient intracellular limitation Nitrate Droop formulation)
- sdo_{P4} (extra lysis only for $P^{(4)}$)
- $L_{p_o,1}(x)$ is the function $min(1, max(p_o, x))$
- p_o (minimum limitation costant, currently 10^{-12})
- $\Delta_{i,j}$ is (Kronecker Delta $\Delta_{i,j} = 1$ if $i = j$, $\Delta_{i,j} = 0$ if $i \neq j$)

$$\left.\frac{\partial P_c}{\partial t}\right|_{R_c^1}^{lys} = (1 - pe_{R6}) * sdo * P_c + sdo_{P4} r \quad (12)$$

$$\left.\frac{\partial P_c}{\partial t}\right|_{R_c^6}^{lys} = pe_{R6} * sdo * P_c \quad (13)$$

$$sdo = \frac{p\_thdo(P)}{iN + p\_thdo(P)} * p\_sdmo(P) \quad (14)$$

$$iN = min(iN1p, iNIn) \quad (15)$$

$$iN1p = L_{p_o,1}\left(\frac{Qpc(P) - p\_qplc(P)}{p\_qpRc(P) - p\_qplc(P)}\right) \quad (16)$$

$$iNIn = L_{p_o,1}\left(\frac{Qnc(P) - p\_qnlc(P)}{p\_qnRc(P) - p\_qnlc(P)}\right) \quad (17)$$

$$sdo_{P4} = p\_seo * \frac{P_c}{P_c + 100} \quad (18)$$

Phytoplankton parameters						Details
		$P^{(1)}$	$P^{(2)}$	$P^{(3)}$	$P^{(4)}$	
a_{04}	*p_sdmo*	0.0	0.0	0.0	0.0	max. specific nutrient-stress lysis rate
a_{05}	*p_seo*	0.0	0.0	0.0	0.0	extra lysis rate for $P^{(4)}$
a_{08}	*p_qnlc*	0.00687	0.00687	0.00687	0.00687	minimum n quota
a_{09}	*p_qplc*	0.0004288	0.0004288	0.0004288	0.0004288	minimum p quota
a_{11}	*p_qnRc*	0.0126	0.0126	0.0126	0.0126	n uptake factor based on C as. quota
a_{12}	*p_qpRc*	0.0007862	0.0007862	0.0007862	0.0007862	p uptake factor based on C as. quota
a_{21}	*p_thdo*	0.0	0.0	0.0	0.0	half value for nutrient stress lysis
a_{22}	*p_res*	5.0	0.0	0.0	2.5	sinking velocity
a_{23}	*p_chPs*	1.0	0.0	0.0	0.0	half value of SIO4_lim
$P^{(1)}$ = diatoms, $P^{(2)}$ = flagellates, $P^{(3)}$ = picophytoplankton, $P^{(4)}$ = dinoflagellates						

1.1.3 excretion ($\left.\frac{\partial P_c}{\partial t}\right|_{R_c^{(2)}}^{exc}$)

- *sea* (activity excretion)
- *set* (total excretion)
- *sum* (carbon uptake maximum)

$$\left.\frac{\partial P_c}{\partial t}\right|_{R_c^{(2)}}^{exc} = (seo + sea) * P_c \quad (19)$$

$$set = seo + sea \quad (20)$$

$$seo = 0 \quad (21)$$

$$sea = sum * p\_pu\_ea(P) \quad (22)$$

Phytoplankton parameters						Details
		$P_c^{(1)}$	$P_c^{(2)}$	$P_c^{(3)}$	$P_c^{(4)}$	
a_{06}	*p_pu_ea*	0.05	0.1	0.1	0.15	activity excretion
$P_c^{(1)}$ = diatoms, $P_c^{(2)}$ = flagellates, $P_c^{(3)}$ = picophytoplankton, $P_c^{(4)}$ = dinoflagellates						

1.1.4 Total respiration ($\frac{\partial P_c}{\partial t}\Big|_{O^{(3)}}^{rsp}$)

- *srt* (total respiration)
- *sra* (activity)
- *srs* (rest)
- *sum* (carbon uptake maximum)
- *et* (Temperature limitation factor $t_o = 10^o$ C)

$$\left.\frac{\partial P_c}{\partial t}\right|_{O^{(3)}}^{rsp} = srt * P_c \tag{23}$$
$$srt = sra + srs \tag{24}$$
$$sra = (sum - set) * p\_pu\_ra(P) \tag{25}$$
$$srs = et * p\_srs(P) \tag{26}$$
$$et = p\_q10^{\frac{t-t_o}{t_o}} \tag{27}$$

Phytoplankton parameters						Details
		$P^{(1)}$	$P^{(2)}$	$P^{(3)}$	$P_c^{(4)}$	
a_{03}	*p_srs*	0.1	0.05	0.1	0.1	respiration rate 10 degrees C
a_{07}	*p_pu_ra*	0.1	0.1	0.2	0.1	activity respiration rate
$P^{(1)}$ = diatoms, $P^{(2)}$ = flagellates, $P^{(3)}$ = picophytoplankton, $P^{(4)}$ = dinoflagellates						

1.1.5 Net primary production ($\frac{\partial P_c}{\partial t}\Big|_{O^{(3)},R_c^{(2)}}^{npp}$)

- *slc* (specific carbon loss term)

$$\left.\frac{\partial P_c}{\partial t}\right|_{R_c^{(2)}}^{npp} = max(0, (sum - slc) * P_c) \tag{28}$$
$$slc = set + srt + sdo \tag{29}$$

1.1.6 Excretion of sugars (*netgrowth*)

- *runn* (actual uptake of Nitrate)
- *rumn*3 (max. pot. uptake of $N^{(3)}$)
- *rumn*4 (max. pot. uptake of $N^{(4)}$)
- *rupn* (nitrate uptake based on net assimilation)
- *misn* (intracellular missing amount of Nitrate)
- *sadap* (adaption rate with existing quota in cell)
- *runp* (actual phosphate uptake)
- *rupp* (phosphate uptake based on c uptake)
- *misp* (intracellular missing amount of P)
- *rump* (max potential uptake)
- *sum* (carbon uptake maximum)
- *slc* (specific carbon loss term)

$$netgrowth = max\left(min\left(\left.\frac{\partial P_c}{\partial t}\right|^{npp}_{O^{(3)},R_c^{(2)}}, \frac{runn}{p\_qnlc(P)}, \frac{runp}{p\_qplc(P)}\right), 0\right) \quad (30)$$

$$runn = min\,(rumn, rupn + misn) \quad (31)$$

$$rumn = rumn3 + rumn4 \quad (32)$$

$$rumn4 = p\_qun(P) * N^{(4)} * P_c \quad (33)$$

$$rumn3 = p\_qun(P) * N^{(3)} * P_c * cqun3 \quad (34)$$

$$cqun3 = \frac{p\_ln4(P)}{p\_ln4(P) + N^{(4)}} \quad (35)$$

$$rupn = p\_xqn(P) * p\_qnRc(P) * \left.\frac{\partial P_c}{\partial t}\right|^{npp}_{O^{(3)},R_c^{(2)}} \quad (36)$$

$$misn = sadap * (p\_xqn(P) * p\_qnRc(P) * P_c - P_n) \quad (37)$$

$$runp = min\,(rump, rupp + misp) \quad (38)$$

$$rump = p\_qup(P) * N^{(1)} * P_c \quad (39)$$

$$rupp = p\_qpRc(P) * p\_xqp(P) * \left.\frac{\partial P_c}{\partial t}\right|^{npp}_{O^{(3)},R_c^{(2)}} \quad (40)$$

$$misp = sadap * (p\_xqp(P) * p\_qpRc(P) * P_c - P_p) \quad (41)$$

$$sadap = max\,(0.05, sum - slc) \quad (42)$$

Phytoplankton parameters						Details
		$P^{(1)}$	$P^{(2)}$	$P^{(3)}$	$P^{(4)}$	
a_{08}	*p_qnlc*	0.00687	0.00687	0.00687	0.00687	minimum n quota
a_{09}	*p_qplc*	0.0004288	0.0004288	0.0004288	0.0004288	minimum p quota
a_{11}	*p_qnRc*	0.0126	0.0126	0.0126	0.0126	n uptake factor based on C as. quota
a_{12}	*p_qpRc*	0.0007862	0.0007862	0.0007862	0.0007862	p uptake factor based on C as. quota
a_{14}	*p_qun*	0.025	0.025	0.025	0.025	max. potential uptake of $N^{(3)}$, $N^{(4)}$
a_{15}	*p_qup*	0.0025	0.0025	0.0025	0.0025	max. potential uptake of p
a_{17}	*p_xqn*	2.0	2.0	2.0	2.0	n uptake factor based on C as. quota
a_{18}	*p_xqp*	2.0	2.0	2.0	2.0	p uptake factor based on C as. quota
a_{19}	*p_xqs*	1.5	0.0	0.0	0.0	s uptake factor based on C as. quota
a_{24}	*p_ln4*	1.0	0.5	0.1	1.0	specific affinity for nitrates vs ammonia
$P^{(1)}$ = diatoms, $P^{(2)}$ = flagellates, $P^{(3)}$ = picophytoplankton, $P^{(4)}$ = dinoflagellates						

1.2 Nitrate component of Phytoplankton functional Group

$$\left.\frac{\partial P_n}{\partial t}\right|_{bio}^{-} = +\left.\frac{\partial P_n}{\partial t}\right|_{N^{(3)}}^{upt} + \left.\frac{\partial P_n}{\partial t}\right|_{N^{(4)}}^{upt} - \left.\frac{\partial P_n}{\partial t}\right|_{R_n^{(1)}}^{exc} - \left.\frac{\partial P_n}{\partial t}\right|_{R_n^{(6)}}^{exc} + - \left\{ \sum_{k=4,6} \left.\frac{\partial Z_c^{(k)}}{\partial t}\right|_{P_c}^{prd} * Qnc(P) \right\} \tag{43}$$

$$\left.\frac{\partial N^{(3)}}{\partial t}\right|_{bio}^{-} = -\sum_{i=1,4} \left.\frac{\partial P_n^{(i)}}{\partial t}\right|_{N^{(3)}}^{upt} \tag{44}$$

$$\left.\frac{\partial N^{(4)}}{\partial t}\right|_{bio}^{-} = -\sum_{i=1,4} \left.\frac{\partial P_n^{(i)}}{\partial t}\right|_{N^{(4)}}^{upt} \tag{45}$$

$$\left.\frac{\partial R_n^{(1)}}{\partial t}\right|_{bio}^{-} = +\sum_{i=1,4} \left.\frac{\partial P_n^{(i)}}{\partial t}\right|_{R_n^{(1)}}^{exc} \tag{46}$$

$$\left.\frac{\partial R_n^{(6)}}{\partial t}\right|_{bio}^{-} = +\sum_{i=1,4} \left.\frac{\partial P_n^{(i)}}{\partial t}\right|_{R_n^{(6)}}^{exc} \tag{47}$$

Terms in curly parentheses are described respectively in Microzooplankton and Mesozooplankton sections.

1.2.1 Actual uptake of Nitrate and Ammonia ($\left.\frac{\partial P_n}{\partial t}\right|_{N^{(3)}}^{upt}$, $\left.\frac{\partial P_n}{\partial t}\right|_{N^{(4)}}^{upt}$)

- $runn$ (actual uptake of nitrate)
- $rumn3$ (max. pot. uptake of nitrate)
- $rumn4$ (max. pot. uptake of ammonium)
- $rupn$ (nitrate uptake based on net assimilation)
- $misn$ (intracellular missing amount of nitrate)
- $sadap$ (adaption rate with existing quota in cell)
- sum (carbon maximum uptake)
- slc (specific carbon loss term)

$$\begin{pmatrix} if & runn > 0 & then & \left.\frac{\partial P_n}{\partial t}\right|_{N^{(3)}}^{upt} & = runn * \frac{rumn3}{rumn} \\ if & runn > 0 & then & \left.\frac{\partial P_n}{\partial t}\right|_{N^{(4)}}^{upt} & = runn * \frac{rumn4}{rumn} \\ if & runn \leq 0 & then & \left.\frac{\partial P_n}{\partial t}\right|_{N^{(3)}}^{upt} & = 0 \\ if & runn \leq 0 & then & \left.\frac{\partial P_n}{\partial t}\right|_{N^{(4)}}^{upt} & = runn \end{pmatrix}$$

$$
\begin{aligned}
runn &= min(rumn, rupn + misn) &(48)\\
rumn &= rumn3 + rumn4 &(49)\\
rumn4 &= p\_qun(P) * N^{(4)} * P_c &(50)\\
rumn3 &= p\_qun(P) * N^{(3)} * P_c * cqun3 &(51)\\
cqun3 &= \frac{p\_ln4(P)}{p\_ln4(P) + N^{(4)}} &(52)\\
rupn &= p\_xqn(P) * p\_qnRc(P) * \left.\frac{\partial P_c}{\partial t}\right|_{O^{(3)},R_c^{(2)}}^{npp} &(53)\\
misn &= sadap * (p\_xqn(P) * p\_qnRc(P) * P_c - P_n) &(54)\\
sadap &= max(0.05, sum - slc) &(55)
\end{aligned}
$$

Phytoplankton parameters						Details
		$P^{(1)}$	$P^{(2)}$	$P^{(3)}$	$P^{(4)}$	
a_{08}	*p_qnlc*	0.00687	0.00687	0.00687	0.00687	minimum n quota
a_{09}	*p_qplc*	0.0004288	0.0004288	0.0004288	0.0004288	minimum p quota
a_{11}	*p_qnRc*	0.0126	0.0126	0.0126	0.0126	n uptake factor based on C as. quota
a_{12}	*p_qpRc*	0.0007862	0.0007862	0.0007862	0.0007862	p uptake factor based on C as. quota
a_{14}	*p_qun*	0.025	0.025	0.025	0.025	max. potential uptake of $N^{(3)}$, $N^{(4)}$
a_{15}	*p_qup*	0.0025	0.0025	0.0025	0.0025	max. potential uptake of p
a_{16}	*p_qus*	0.0025	0.0	0.0	0.0	max. potential uptake of s
a_{17}	*p_xqn*	2.0	2.0	2.0	2.0	n uptake factor based on C as. quota
a_{18}	*p_xqp*	2.0	2.0	2.0	2.0	p uptake factor based on C as. quota
a_{19}	*p_xqs*	1.5	0.0	0.0	0.0	s uptake factor based on C as. quota
a_{24}	*p_ln4*	1.0	0.5	0.1	1.0	specific affinity for nitrates vs ammonia
$P^{(1)}$ = diatoms, $P^{(2)}$ = flagellates, $P^{(3)}$ = picophytoplankton, $P^{(4)}$ = dinoflagellates						

1.2.2 Excretion of Nitrate ($\left.\frac{\partial P_n}{\partial t}\right|_{R_n^{(1)}}^{exc}$, $\left.\frac{\partial P_n}{\partial t}\right|_{R_n^{(6)}}^{exc}$)

- *sdo* (nutrient stress lysis)

$$
\begin{aligned}
\left.\frac{\partial P_n}{\partial t}\right|_{R_n^{(6)}}^{exc} &= pe_{R6} * sdo * P_n &(56)\\
\left.\frac{\partial P_n}{\partial t}\right|_{R_n^{(1)}}^{exc} &= sdo * P_n - \left.\frac{\partial P_n}{\partial t}\right|_{R_n^{(6)}}^{exc} &(57)
\end{aligned}
$$

1.3 Phosphorus component of phytoplankton functional group

$$\begin{aligned}
\left.\frac{\partial P_p}{\partial t}\right|_{bio}^{-} &= +\left.\frac{\partial P_p}{\partial t}\right|_{N^{(1)}}^{upt} - \left.\frac{\partial P_p}{\partial t}\right|_{R^{(1)}}^{exc} - \left.\frac{\partial P_p}{\partial t}\right|_{R^{(6)}}^{exc} + \\
&\quad - \left\{ \sum_{k=4,6} \left.\frac{\partial Z_c^{(k)}}{\partial t}\right|_{P_c}^{prd} * Qpc(P) \right\} \quad (58)\\
\left.\frac{\partial N^{(1)}}{\partial t}\right|_{bio}^{-} &= -\sum_{i=1,4} \left.\frac{\partial P_p^{(i)}}{\partial t}\right|_{N^{(1)}}^{upt} \quad (59)\\
\left.\frac{\partial R^{(1)}}{\partial t}\right|_{bio}^{-} &= +\sum_{i=1,4} \left.\frac{\partial P_p^{(i)}}{\partial t}\right|_{R^{(1)}}^{exc} \quad (60)\\
\left.\frac{\partial R^{(6)}}{\partial t}\right|_{bio}^{-} &= +\sum_{i=1,4} \left.\frac{\partial P_p^{(i)}}{\partial t}\right|_{R^{(6)}}^{exc} \quad (61)
\end{aligned}$$

Terms in curly parentheses are described respectively in Microzooplankton and Mesozooplankton sections.

1.3.1 Uptake of phosphorus ($\left.\frac{\partial P_p}{\partial t}\right|_{N^{(1)}}^{upt}$)

- *rupp* (phosphate uptake based on c uptake)
- *misp* (intracellular missing amount of phosphate)
- *rump* (max potential uptake)
- *sadap* (adaption rate with existing quota in cell)
- *sum* (carbon maximum uptake)
- *slc* (specific carbon loss term)

$$\begin{aligned}
\left.\frac{\partial P_p}{\partial t}\right|_{N^{(1)}}^{upt} &= min(rump, rupp + misp) \quad (62)\\
rupp &= p_qpRc(P) * p_xqp(P) * \left.\frac{\partial P_c}{\partial t}\right|_{O^{(3)},R_c^{(2)}}^{npp} \quad (63)\\
misp &= sadap * (p_xqp(P) * p_qpRc(P) * P_c - P_p) \quad (64)\\
sadap &= max(0.05, sum - slc) \quad (65)\\
rump &= p_qup(P) * N^{(1)} * P_c \quad (66)
\end{aligned}$$

Phytoplankton parameters						Details
		$P^{(1)}$	$P^{(2)}$	$P^{(3)}$	$P^{(4)}$	
a_{09}	*p_qplc*	0.0004288	0.0004288	0.0004288	0.0004288	minimum p quota
a_{12}	*p_qpRc*	0.0007862	0.0007862	0.0007862	0.0007862	p uptake factor based on C as. quota
a_{15}	*p_qup*	0.0025	0.0025	0.0025	0.0025	max. potential uptake of p
a_{18}	*p_xqp*	2.0	2.0	2.0	2.0	p uptake factor based on C as. quota
a_{24}	*p_ln4*	1.0	0.5	0.1	1.0	specific affinity for nitrates vs ammonia
$P^{(1)}$ = diatoms, $P^{(2)}$ = flagellates, $P^{(3)}$ = picophytoplankton, $P^{(4)}$ = dinoflagellates						

1.3.2 Excretion of phosphorus ($\frac{\partial P_p}{\partial t}\Big|^{exc}_{R^{(1)}}$, $\frac{\partial P_p}{\partial t}\Big|^{exc}_{R^{(6)}}$)

- $\frac{\partial P_c}{\partial t}\Big|^{lys}_{R_c^{(6)}}$ (apporting over POM)
- *sdo* (nutrient stress lysis)

$$\frac{\partial P_p}{\partial t}\Bigg|^{exc}_{R_c^{(6)}} = \frac{\partial P_c}{\partial t}\Bigg|^{lys}_{R_c^{(6)}} * sdo * P_p \quad (67)$$

$$\frac{\partial P_p}{\partial t}\Bigg|^{exc}_{R_c^{(1)}} = sdo * P_p - \frac{\partial P_p}{\partial t}\Bigg|^{exc}_{R_c^{(1)}} \quad (68)$$

Phytoplankton parameters						Details
		$P^{(1)}$	$P^{(2)}$	$P^{(3)}$	$P^{(4)}$	
a_{08}	*p_qnlc*	0.00687	0.00687	0.00687	0.00687	minimum n quota
a_{09}	*p_qplc*	0.0004288	0.0004288	0.0004288	0.0004288	minimum p quota
a_{10}	*p_qslc*	0.0054	0.0	0.0	0.0	minimum s quota
a_{11}	*p_qnRc*	0.0126	0.0126	0.0126	0.0126	n uptake factor based on C as. quota
a_{12}	*p_qpRc*	0.0007862	0.0007862	0.0007862	0.0007862	p uptake factor based on C as. quota
a_{14}	*p_qun*	0.025	0.025	0.025	0.025	max. potential uptake of $N^{(3)}$, $N^{(4)}$
a_{15}	*p_qup*	0.0025	0.0025	0.0025	0.0025	max. potential uptake of p
a_{17}	*p_xqn*	2.0	2.0	2.0	2.0	n uptake factor based on C as. quota
a_{18}	*p_xqp*	2.0	2.0	2.0	2.0	p uptake factor based on C as. quota
a_{19}	*p_xqs*	1.5	0.0	0.0	0.0	s uptake factor based on C as. quota
a_{24}	*p_ln4*	1.0	0.5	0.1	1.0	specific affinity for nitrates vs ammonia
$P^{(1)}$ = diatoms, $P^{(2)}$ = flagellates, $P^{(3)}$ = picophytoplankton, $P^{(4)}$ = dinoflagellates						

1.4 Chlorophyll component of phytoplankton functional group

$$\left.\frac{\partial P_i}{\partial t}\right|_{bio}^{-} = + \left.\frac{\partial P_i}{\partial t}\right|_{-}^{syn} - \left\{ \sum_{k=4,6} \left.\frac{\partial Z_c^{(k)}}{\partial t}\right|_{P_c}^{prd} * Qchlc(P) \right\} \tag{69}$$

Terms in curly parentheses are described respectively in microzooplankton and mesozooplankton sections.

total chlorophyll synthesis ($\left.\frac{\partial P_i}{\partial t}\right|_{-}^{syn}$)

- rho_{chl}
- $iN1n$ (nutrient intracellular limitation due to nitrate)
- sdo (nutrient stress lysis)
- sum (carbon maximum uptake)
- slc (specific carbon loss term)
- Irr (irradiance expressed in $\mu Em^{-2}day^{-1}$)

$$\begin{aligned} \left.\frac{\partial P_i}{\partial t}\right|_{-}^{syn} &= iNIn * rho_{chl} * netgrowth - max(p\_sdchl(P) * (1 - iNIn), sdo) * P_i + \\ &\quad + min(0, sum - slc + sdo) * max(0, P_i - p\_qchl(P) * P_c) \qquad (70) \\ rho_{chl} &= p\_qchlc(P) * \frac{sum}{p\_alpha\_chl(P) * Qchlc(P) * Irr} \qquad (71) \end{aligned}$$

Phytoplankton parameters						Details
		$P^{(1)}$	$P^{(2)}$	$P^{(3)}$	$P^{(4)}$	
a_{26}	*p_qchlc*	0.02	0.02	0.02	0.02	Maximum quotum Chla c
a_{27}	*p_alpha_chl*	1.38e-05	4.6e-06	1.52e-05	6.8e-06	initial slope PI curve
a_{28}	*p_sdchl*	0.2	0.2	0.2	0.2	specific turnover rate for chla
$P^{(1)}$ = diatoms, $P^{(2)}$ = flagellates, $P^{(3)}$ = picophytoplankton, $P^{(4)}$ = dinoflagellates						

1.5 Silicate component of phytoplankton functional group (only diatoms)

$$\left.\frac{\partial P_s^{(1)}}{\partial t}\right|_{bio}^{-} = +\left.\frac{\partial P_s^{(1)}}{\partial t}\right|_{N^{(5)}}^{upt} - \left.\frac{\partial P_s^{(1)}}{\partial t}\right|_{R^{(6)}}^{lys} + - \left\{\sum_{k=4,6}\left.\frac{\partial Z_c^{(k)}}{\partial t}\right|_{P_c^{(1)}}^{prd} * Qsc(P^{(1)})\right\} \tag{72}$$

$$\left.\frac{\partial N^{(5)}}{\partial t}\right|_{bio}^{-} = -\left.\frac{\partial P_s^{(1)}}{\partial t}\right|_{N^{(5)}}^{upt} \tag{73}$$

$$\left.\frac{\partial R^{(6)}}{\partial t}\right|_{bio}^{-} = +\left.\frac{\partial P_s^{(1)}}{\partial t}\right|_{R^{(6)}}^{lys} \tag{74}$$

Terms in curly parentheses are described respectively in microzooplankton and mesozooplankton sections.

1.5.1 Actual silicate uptake ($\left.\frac{\partial P_s^{(1)}}{\partial t}\right|_{N^{(5)}}^{upt}$)

- *rups* (silicate uptake based on C uptake)
- *miss* (intracellular missing silicate)
- *rums* (max silicate potential uptake)
- *sadap* (adaptation rate with existing quota in cell)

$$\left.\frac{\partial P_s^{(1)}}{\partial t}\right|_{N^{(5)}}^{upt} = min(rums, rups + miss) \tag{75}$$

$$rups = \left.\frac{\partial P_c^{(1)}}{\partial t}\right|_{R_c^{(2)}}^{npp} * p\_qsRc(P^{(1)}) \tag{76}$$

$$miss = sadap * (p\_qsRc(P^{(1)}) * P_c^{(1)} - P_s^{(1)}) \tag{77}$$

$$rums = p\_qus(P^{(1)}) * N^{(5)} * P_c^{(1)} \tag{78}$$

1.5.2 Losses of Si ($\left.\frac{\partial P_s^{(1)}}{\partial t}\right|_{R^{(6)}}^{lys}$)

- *sdo* (nutrient stress lysis)

Phytoplankton parameters						Details
		$P^{(1)}$	$P^{(2)}$	$P^{(3)}$	$P^{(4)}$	
a_{13}	*p_qsRc*	0.01	0.0	0.0	0.0	s uptake factor based on C as. quota
a_{16}	*p_qus*	0.0025	0.0	0.0	0.0	max. potential uptake of s
a_{19}	*p_xqs*	1.5	0.0	0.0	0.0	s uptake factor based on C as. quota
a_{23}	*p_chPs*	1.0	0.0	0.0	0.0	half value of SIO4_lim
a_{24}	*p_ln4*	1.0	0.5	0.1	1.0	specific affinity for nitrates vs ammonia
$P^{(1)}$ = diatoms, $P^{(2)}$ = flagellates, $P^{(3)}$ = picophytoplankton, $P^{(4)}$ = dinoflagellates						

$$\left.\frac{\partial P_s^{(1)}}{\partial t}\right|_{R^{(6)}}^{lys} = sdo * P_s^{(1)} \tag{79}$$

1.6 Sinking velocity (SediPI)

- tn (nutrient limitation)
- iN (nutrient limitation (Liebig Rule))
- $iN5s$ (nutrient limitation due to intra-extracellular silicate only diatoms)

$$sediPI = p\_res(P) * max(0, p\_esNI(P) - tn) \tag{80}$$

$$tn = \Delta_{i,1} * min(iN5s, iN) + (1 - \Delta_{i,1}) * iN \tag{81}$$

Phytoplankton parameters						Details
		$P^{(1)}$	$P^{(2)}$	$P^{(3)}$	$P^{(4)}$	
a_{20}	*p_esNI*	0.7	0.75	0.75	0.75	nutrient stress threshold for Sinking
a_{22}	*p_res*	5.0	0.0	0.0	2.5	sinking velocity
$P^{(1)}$ = diatoms, $P^{(2)}$ = flagellates, $P^{(3)}$ = picophytoplankton, $P^{(4)}$ = dinoflagellates						

Phytoplankton parameters						Details
		$P^{(1)}$	$P^{(2)}$	$P^{(3)}$	$P^{(4)}$	
a_{01}	$pq10$	2.0	2.0	2.0	2.0	parameter temperature limitation
a_{02}	*p_sum*	2.5	3.0	3.5	1.5	uptake parameter
a_{03}	*p_srs*	0.1	0.05	0.1	0.1	respiration rate 10 degrees C
a_{04}	*p_sdmo*	0.0	0.0	0.0	0.0	max. specific nutrient-stress lysis rate
a_{05}	*p_seo*	0.0	0.0	0.0	0.0	extra lysis rate for $P^{(4)}$
a_{06}	*p_pu_ea*	0.05	0.1	0.1	0.15	activity excretion
a_{07}	*p_pu_ra*	0.1	0.1	0.2	0.1	activity respiration rate
a_{08}	*p_qnlc*	0.00687	0.00687	0.00687	0.00687	minimum n quota
a_{09}	*p_qplc*	0.0004288	0.0004288	0.0004288	0.0004288	minimum p quota
a_{10}	*p_qslc*	0.0054	0.0	0.0	0.0	minimum s quota
a_{11}	*p_qnRc*	0.0126	0.0126	0.0126	0.0126	n uptake factor based on C as. quota
a_{12}	*p_qpRc*	0.0007862	0.0007862	0.0007862	0.0007862	p uptake factor based on C as. quota
a_{13}	*p_qsRc*	0.01	0.0	0.0	0.0	s uptake factor based on C as. quota
a_{14}	*p_qun*	0.025	0.025	0.025	0.025	max. potential uptake of $N^{(3)}$, $N^{(4)}$
a_{15}	*p_qup*	0.0025	0.0025	0.0025	0.0025	max. potential uptake of p
a_{16}	*p_qus*	0.0025	0.0	0.0	0.0	max. potential uptake of s
a_{17}	*p_xqn*	2.0	2.0	2.0	2.0	n uptake factor based on C as. quota
a_{18}	*p_xqp*	2.0	2.0	2.0	2.0	p uptake factor based on C as. quota
a_{19}	*p_xqs*	1.5	0.0	0.0	0.0	s uptake factor based on C as. quota
a_{20}	*p_esNI*	0.7	0.75	0.75	0.75	nutrient stress threshold for Sinking
a_{21}	*p_thdo*	0.0	0.0	0.0	0.0	half value for nutrient stress lysis
a_{22}	*p_res*	5.0	0.0	0.0	2.5	sinking velocity
a_{23}	*p_chPs*	1.0	0.0	0.0	0.0	half value of SIO4_lim
a_{24}	*p_ln4*	1.0	0.5	0.1	1.0	specific affinity for nitrates vs ammonia
a_{25}	*p_limnut*	1	1	1	1	liebig nutrient limitation (switch)
a_{26}	*p_qchlc*	0.02	0.02	0.02	0.02	Maximum quotum Chla c
a_{27}	*p_alpha_chl*	1.38e-05	4.6e-06	1.52e-05	6.8e-06	initial slope PI curve
a_{28}	*p_sdchl*	0.2	0.2	0.2	0.2	specific turnover rate for chla
$P^{(1)}$ = diatoms, $P^{(2)}$ = flagellates, $P^{(3)}$ = picophytoplankton, $P^{(4)}$ = dinoflagellates						

2 Bacteria

2.1 Carbon component of pelagic bacteria functional group

$$\left.\frac{\partial B_c}{\partial t}\right|_{bio}^{-} = -\left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(1)}}^{sub} + \left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(1)}}^{upt} + \left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(2)}}^{upt} + \left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(6)}}^{upt} + - \left.\frac{\partial B_c}{\partial t}\right|_{O^{(3)}}^{rsp} - \left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(7)}}^{cor} - \left\{ \sum_{k=5,6} \left.\frac{\partial Z_c^{(k)}}{\partial t}\right|_{B_c}^{prd} \right\} \quad (82)$$

$$\left.\frac{\partial R_c^{(1)}}{\partial t}\right|_{bio}^{-} = +\left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(1)}}^{sub} - \left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(1)}}^{upt} \quad (83)$$

$$\left.\frac{\partial R_c^{(2)}}{\partial t}\right|_{bio}^{-} = -\left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(2)}}^{upt} \quad (84)$$

$$\left.\frac{\partial R_c^{(6)}}{\partial t}\right|_{bio}^{-} = -\left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(6)}}^{upt} \quad (85)$$

$$\left.\frac{\partial R_c^{(7)}}{\partial t}\right|_{bio}^{-} = +\left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(7)}}^{cor} \quad (86)$$

$$\left.\frac{\partial O2o}{\partial t}\right|_{bio}^{-} = -eO2 * \frac{1}{12} * \left.\frac{\partial B_c}{\partial t}\right|_{O^{(3)}}^{rsp} \quad (87)$$

$$\left.\frac{\partial N6r}{\partial t}\right|_{bio}^{-} = (1 - eO2) * \frac{1}{12} * \left.\frac{\partial B_c}{\partial t}\right|_{O^{(3)}}^{rsp} * p\_qro \quad (88)$$

- definition of $eO2$, p_qro follows in this section
- terms in curly parentheses are described in microzooplankton section.

2.1.1 Substrate availability ($\left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(1)}}^{sub}$)

- et (temperature limitation factor $t_o = 10^o$ C)

$$\left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(1)}}^{sub} = p\_sd * et * B_c \quad (89)$$

$$et = (p\_q10)^{\frac{t-t_o}{t_o}} \quad (90)$$

Bacteria parameters			Details
b_{02}	$pq10$	2.95	parameter temperature limitation
b_{04}	p_sd	0.0	independent specific mortality(1/d)

2.1.2 Rate uptake of carbon by bacteria ($\left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(1)}}^{upt}$, $\left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(2)}}^{upt}$, $\left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(6)}}^{upt}$)

- rug (actual uptake by bacteria)
- rut (total amount of substrate available)
- rum (potential uptake by bacteria)
- $iN, iN1p, iNIn$ (nutrient limitation intracellular: phosphorus, nitrogen)
- et (temperature limitation factor $t_o = 10^o$ C)

$$\left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(1)}}^{upt} = rug * \frac{p\_suR1 * R_c^{(1)}}{rut} \tag{91}$$

$$\left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(2)}}^{upt} = rug * \frac{p\_suR2 * R_c^{(2)}}{rut} \tag{92}$$

$$\left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(6)}}^{upt} = rug * \frac{p\_suR6 * min\left(min\left(1, \frac{Qpc(R^{(6)})}{p\_qpc}\right), min\left(1, \frac{Qnc(R^{(6)})}{p\_qnc}\right)\right) * R_c^{(6)}}{rut} \tag{93}$$

$$rug = min\,(rut, rum) \tag{94}$$

$$\begin{aligned} rut = {} & p\_suR1 * R_c^{(1)} + p\_suR2 * R_c^{(2)} + \\ & + p\_suR6 * min(min(1, \frac{Qpc(R^{(6)})}{p\_qpc}), min(1, \frac{Qnc(R^{(6)})}{p\_qnc})) \end{aligned} \tag{95}$$

$$rum = p\_sum * iN * et * B_c \tag{96}$$

$$iN = min\left(min\left(1, max\left(0, \frac{Qpc(B)}{p\_qpc}\right)\right), min\left(1, max\left(0, \frac{Qnc(B)}{p\_qnc}\right)\right)\right) \tag{97}$$

$$et = (p\_q10)^{\frac{t-t_o}{t_o}} \tag{98}$$

Bacteria parameters			Details
b_{02}	$pq10$	2.95	parameter temperature limitation
b_{05}	p_suR1	0.5	specific potential DOM availability (1/d)
b_{06}	p_suR2	0.25	specific potential DOM availability (1/d)
b_{07}	p_suR6	0.1	availability of POM (1/d)
b_{08}	p_sum	8.38	specific potential uptake (1/d)
b_{12}	p_qpc	0.0019	optimal P/C ratio (model units) P:C 1:45
b_{14}	p_qnc	0.017	optimal N/C ratio (model units) N:C 9:45

2.1.3 Respiration ($\frac{\partial B_c}{\partial t}\Big|_{O^{(3)}}^{rsp}$)

- $eO2$ (oxygen dependence)
- et (temperature limitation factor $t_o = 10^o$ C)

$$\frac{\partial B_c}{\partial t}\Big|_{O^{(3)}}^{rsp} = (1 - p\_pu + p\_puo * (1 - eO2)) * rug + p\_srs * B_c * et \quad (99)$$

$$eO2 = \frac{O2o^3}{O2o^3 + p\_chdo^3} \quad (100)$$

$$et = (p\_q10)^{\frac{t - t_o}{t_o}} \quad (101)$$

Bacteria parameters			Details
b_{02}	$pq10$	2.95	parameter temperature limitation
b_{03}	p_chdo	30.0	michaelis const for O2 dependence (mmol/m3)
b_{09}	p_pu	0.4	assimilation efficiency (ratio)
b_{10}	p_puo	0.2	decrease in ass. efficiency at low O2 conc.
b_{11}	p_srs	0.01	specific rest respiration (1/day)

2.1.4 Carbon correction ($\frac{\partial B_c}{\partial t}\Big|_{R_c^{(7)}}^{cor}$)

- run (production)
- rug (actual uptake by bacteria)
- $\frac{\partial B_n}{\partial t}\Big|_{R_n^{(1)}}^{upt}$, $\frac{\partial B_n}{\partial t}\Big|_{R_n^{(6)}}^{upt}$, $\frac{\partial B_n}{\partial t}\Big|_{N^{(4)}}^{rel}$, $\frac{\partial B_p}{\partial t}\Big|_{R_p^{(1)}}^{upt}$, $\frac{\partial B_p}{\partial t}\Big|_{R_p^{(6)}}^{upt}$, $\frac{\partial B_p}{\partial t}\Big|_{N^{(1)}}^{upt,rel}$ (described in nitrates and phosphorus dynamics)

$$\frac{\partial B_c}{\partial t}\Big|_{R_c^{(7)}}^{cor} = run - min(min(run, \frac{\frac{\partial B_n}{\partial t}\Big|_{R_n^{(1)}}^{upt} + \frac{\partial B_n}{\partial t}\Big|_{R_n^{(6)}}^{upt} + \frac{\partial B_n}{\partial t}\Big|_{N^{(4)}}^{rel}}{p\_qlnc}), \frac{\frac{\partial B_p}{\partial t}\Big|_{R_p^{(1)}}^{upt} + \frac{\partial B_p}{\partial t}\Big|_{R_p^{(6)}}^{upt} - \frac{\partial B_p}{\partial t}\Big|_{N^{(1)}}^{upt,rel}}{p\_qlpc}) \quad (102)$$

$$run = rug - \frac{\partial B_c}{\partial t}\Big|_{O^{(3)}}^{rsp} \quad (103)$$

2.2 Nitrate component of bacteria functional group

$$\left.\frac{\partial B_n}{\partial t}\right|_{bio}^{-} = -\left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(1)}}^{sub} * Qnc(B) + \left.\frac{\partial B_n}{\partial t}\right|_{N^{(3)}}^{upt} + \left.\frac{\partial B_n}{\partial t}\right|_{N^{(4)}}^{upt} + \left.\frac{\partial B_n}{\partial t}\right|_{N^{(4)}}^{rel} + + \left.\frac{\partial B_n}{\partial t}\right|_{R_n^{(1)}}^{upt} + \left.\frac{\partial B_n}{\partial t}\right|_{R_n^{(6)}}^{upt} - \left\{ \sum_{k=5,6} \left.\frac{\partial Z_c^{(k)}}{\partial t}\right|_{B_c}^{prd} * Qnc(B) \right\} \quad (104)$$

$$\left.\frac{\partial N_n^{(3)}}{\partial t}\right|_{bio}^{-} = +\left.\frac{\partial B_n}{\partial t}\right|_{N^{(3)}}^{-} \quad (105)$$

$$\left.\frac{\partial N_n^{(4)}}{\partial t}\right|_{bio}^{-} = +\left.\frac{\partial B_n}{\partial t}\right|_{N^{(4)}}^{rel} + \left.\frac{\partial B_n}{\partial t}\right|_{N^{(4)}}^{-} \quad (106)$$

$$\left.\frac{\partial R_n^{(1)}}{\partial t}\right|_{bio}^{-} = +\left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(1)}}^{sub} * Qnc(B) - \left.\frac{\partial B_n}{\partial t}\right|_{R_n^{(1)}}^{upt} \quad (107)$$

$$\left.\frac{\partial R_n^{(6)}}{\partial t}\right|_{bio}^{-} = -\left.\frac{\partial B_n}{\partial t}\right|_{R_n^{(6)}}^{upt} \quad (108)$$

Terms in curly parentheses are described in microzooplankton section.

2.2.1 Nitrogen dynamics ($\left.\frac{\partial B_n}{\partial t}\right|_{N^{(3)}}^{upt}$, $\left.\frac{\partial B_n}{\partial t}\right|_{N^{(4)}}^{upt}$, $\left.\frac{\partial B_n}{\partial t}\right|_{N^{(4)}}^{rel}$, $\left.\frac{\partial B_n}{\partial t}\right|_{R_n^{(1)}}^{upt}$, $\left.\frac{\partial B_n}{\partial t}\right|_{R_n^{(6)}}^{upt}$)

- $rumn3$ (Max potential Uptake of $N^{(3)}$)
- $rumn4$ (Max potential uptake of $N^{(4)}$)
- $H(x)$ is the function H(x) =1 if x > 0 and 0 otherwise

$$\left.\frac{\partial B_n}{\partial t}\right|_{N^{(3)}}^{upt} = \left.\frac{\partial B_n}{\partial t}\right|_{N^{(4)}}^{rel} * \frac{rumn3}{rumn} \quad (109)$$

$$\left.\frac{\partial B_n}{\partial t}\right|_{N^{(4)}}^{upt} = \left.\frac{\partial B_n}{\partial t}\right|_{N^{(4)}}^{rel} * \frac{rumn4}{rumn} \quad (110)$$

$$\left.\frac{\partial B_n}{\partial t}\right|_{N^{(4)}}^{rel} = -max\left(\frac{run}{B_c} * B_c * \left(\frac{\left.\frac{\partial B_n}{\partial t}\right|_{R_n^{(1)}}^{upt} + \left.\frac{\partial B_n}{\partial t}\right|_{R_n^{(6)}}^{upt}}{run} - p\_qnc\right), -rumn\right) * *H\left(\frac{run}{B_c} * \left(\frac{\left.\frac{\partial B_n}{\partial t}\right|_{R_n^{(1)}}^{upt} + \left.\frac{\partial B_n}{\partial t}\right|_{R_n^{(6)}}^{upt}}{run} - p\_qnc\right)\right) \quad (111)$$

$$\left.\frac{\partial B_n}{\partial t}\right|_{R_n^{(1)}}^{upt} = Qnc(R^{(1)}) * \left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(1)}}^{upt}$$

$$\left.\frac{\partial B_n}{\partial t}\right|_{R_n^{(6)}}^{upt} = Qnc(R^{(6)}) * \left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(6)}}^{upt}$$

$$rumn = rumn3 + rumn4$$

$$rumn3 = p\_qun * N^{(3)} * B_c * cqun3$$

$$rumn4 = p\_qun * N^{(4)} * B_c$$

$$cqun3 = \frac{p\_ln4}{p\_ln4 + N^{(4)}}$$

Bacteria parameters			Details
b_{14}	p_qnc	0.017	optimal N/C ratio (model units) N:C=9:45
b_{16}	p_qun	0.05	maximum uptake quotum N
b_{18}	p_lN4	0.05	specific affinity for nitrates vs ammonia

2.3 Phosphate component of bacteria functional group

$$
\begin{aligned}
\left.\frac{\partial B_p}{\partial t}\right|_{bio}^{-} &= -\left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(1)}}^{sub} * Qpc(B) - \left.\frac{\partial B_p}{\partial t}\right|_{N^{(1)}}^{upt,rel} + \left.\frac{\partial B_p}{\partial t}\right|_{R_p^{(1)}}^{upt} + \left.\frac{\partial B_p}{\partial t}\right|_{R_p^{(6)}}^{upt} + \\
&\quad -\left\{\sum_{k=5,6} \left.\frac{\partial Z_c^{(k)}}{\partial t}\right|_{B_c}^{prd} * Qpc(B)\right\} && (112)\\
\left.\frac{\partial N^{(1)}}{\partial t}\right|_{bio}^{-} &= +\left.\frac{\partial B_p}{\partial t}\right|_{N^{(1)}}^{upt,rel} && (113)\\
\left.\frac{\partial R^{(1)}}{\partial t}\right|_{bio}^{-} &= +\left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(1)}}^{sub} * Qpc(B) - \left.\frac{\partial B_p}{\partial t}\right|_{R_p(1)}^{upt} && (114)\\
\left.\frac{\partial R^{(6)}}{\partial t}\right|_{bio}^{-} &= -\left.\frac{\partial B_p}{\partial t}\right|_{R_p(6)}^{upt} && (115)
\end{aligned}
$$

Terms in curly parentheses , for $k = 4$, are described in microzooplankton section.

2.3.1 Phosphorus dynamics ($\left.\frac{\partial B_p}{\partial t}\right|_{N^{(1)}}^{upt,rel}$, $\left.\frac{\partial B_p}{\partial t}\right|_{R_p^{(1)}}^{upt}$, $\left.\frac{\partial B_p}{\partial t}\right|_{R_p^{(6)}}^{upt}$)

- $rump$ (max potential uptake)
- run (production)

$$
\left(\begin{array}{llll}
if \quad hulp > 0 & then & \left.\frac{\partial B_p}{\partial t}\right|_{N^{(1)}}^{upt,rel} & = hulp * Bc \\
 & else & \left.\frac{\partial B_p}{\partial t}\right|_{N^{(1)}}^{upt,rel} & = max(hulp * Bc, -rump)
\end{array}\right)
$$

$$
\begin{aligned}
hulp &= \frac{run}{Bc} * \left(\frac{\left.\frac{\partial B_p}{\partial t}\right|_{R_p^{(1)}}^{upt} + \left.\frac{\partial B_p}{\partial t}\right|_{R_p^{(6)}}^{upt}}{run} - p\_qpc\right) && (116)\\
\left.\frac{\partial B_p}{\partial t}\right|_{R_p^{(1)}}^{upt} &= Qpc(R^{(1)}) * \left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(1)}}^{upt} && (117)\\
\left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(6)}}^{upt} &= Qpc(R^{(6)}) * \left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(6)}}^{upt} && (118)\\
rump &= p\_qup * N^{(1)} * B_c && (119)
\end{aligned}
$$

Bacteria parameters			Details
b_{01}	$p\_controlR1$	2	parameter temperature limitation
b_{02}	$pq10$	2.95	parameter temperature limitation
b_{03}	p_chdo	30.0	michaelis const for O2 dependence (mmol/m3)
b_{04}	p_sd	0.0	independent specific mortality(1/d)
b_{05}	p_suR1	0.5	specific potential DOM availability (1/d)
b_{06}	p_suR2	0.25	specific potential DOM availability (1/d)
b_{07}	p_suR6	0.1	availability of POM (1/d)
b_{08}	p_sum	8.38	specific potential uptake (1/d)
b_{09}	p_pu	0.4	assimilation efficiency (ratio)
b_{10}	p_puo	0.2	decrease in ass. efficiency at low O2 conc.
b_{11}	p_srs	0.01	specific rest respiration (1/day)
b_{12}	p_qpc	0.0019	optimal P/C ratio (model units) P:C=1:45
b_{13}	p_qlpc	0.00095	minimum P/C ratio (model units) P:C = 1:87
b_{14}	p_qnc	0.017	optimal N/C ratio (model units) N:C=9:45
b_{15}	p_qlnc	0.0085	minimum N/C ratio (model units) N:C = 8.9:87
b_{16}	p_qun	0.05	maximum uptake quotum N
b_{17}	p_qup	0.005	maximum uptake quotum P
b_{18}	p_lN4	0.05	specific affinity for nitrates vs ammonia

3 Microzooplankton

3.1 Carbon component of microzooplankton functional group

$$
\begin{aligned}
\left.\frac{\partial Z_c}{\partial t}\right|_{bio}^{-} &= + \sum_{X=P,B,Z} \left.\frac{\partial Z_c}{\partial t}\right|_{X_c}^{prd} - \left.\frac{\partial Z_c}{\partial t}\right|_{O^{(3)}}^{rsp} - \left.\frac{\partial Z_c}{\partial t}\right|_{R_c^{(1)}}^{rel} - \left.\frac{\partial Z_c}{\partial t}\right|_{R_c^{(6)}}^{rel} + \\
& - \left\{ \sum_{k=4,5,6} \left.\frac{\partial Z_c}{\partial t}\right|_{Z_c^{(k)}}^{prd} \right\} \qquad (120) \\
\left.\frac{\partial R_c^{(1)}}{\partial t}\right|_{bio}^{-} &= + \sum_{i=5,6} \left.\frac{\partial Z_c^{(i)}}{\partial t}\right|_{R^{(1)}}^{rel} \qquad (121) \\
\left.\frac{\partial R_c^{(6)}}{\partial t}\right|_{bio}^{-} &= + \sum_{i=5,6} \left.\frac{\partial Z_c^{(i)}}{\partial t}\right|_{R^{(6)}}^{rel} \qquad (122) \\
\left.\frac{\partial O2o}{\partial t}\right|_{bio}^{-} &= - \sum_{i=5,6} \frac{1}{12} * \left.\frac{\partial Z_c^{(i)}}{\partial t}\right|_{O^{(3)}}^{rsp} \qquad (123)
\end{aligned}
$$

Terms in curly parentheses, for $k = 4$, are described in mesozooplankton section.

3.1.1 Carbon fluxes in microzooplankton ($\left.\frac{\partial Z_c}{\partial t}\right|_{B_c}^{prd}$, $\left.\frac{\partial Z_c}{\partial t}\right|_{P_c^{(j)}}^{prd}$, $\left.\frac{\partial Z_c}{\partial t}\right|_{Z_c^{(j)}}^{prd}$)

- put_u (average uptake)
- $rugc$ (rate uptake gross, carbon)
- $efood$
- $rumc$ (total food available)
- $rumB_c$, $rumP_c$, $rumZ_c$
- et (temperature limitation factor $t_o = 10^o$ C)

$$
\begin{aligned}
\left.\frac{\partial Z_c}{\partial t}\right|_{B_c}^{prd} &= put\_u * rumB \qquad (124) \\
\left.\frac{\partial Z_c}{\partial t}\right|_{P_c^{(j)}}^{prd} &= put\_u * rumP_{(j)} \qquad (125) \\
\left.\frac{\partial Z_c}{\partial t}\right|_{Z_c^{(j)}}^{prd} &= put\_u * rumZ_{(j)} \qquad (126) \\
put\_u &= \frac{rugc}{rumc} \qquad (127)
\end{aligned}
$$

$$
\begin{aligned}
rugc &= p\_sum(Z) * et * Z_c * efood & (128)\\
efood &= \frac{rumc}{rumc + p\_chuc(Z)} & (129)\\
rumc &= rumB + \sum_{j=1,4} rumP_{(j)} + \sum_{j=5,6} rumZ_{(j)} & (130)\\
rumB &= p\_suB(Z) * \frac{(B_c)^2}{B_c + p\_minfood(Z)} & (131)\\
rumP_{(j)} &= p\_suPj(Z) * \frac{(P_c^{(j)})^2}{P_c^{(j)} + p\_minfood(Z)} & (132)\\
rumZ_{(j)} &= p\_suZj(Z) * \frac{(Z_c^{(j)})^2}{Z_c^{(j)} + p\_minfood(Z)} & (133)\\
et &= (p\_q10)^{\frac{t-t_o}{t_o}} & (134)
\end{aligned}
$$

Microzooplankton parameters				Details
		$Z^{(5)}$	$Z^{(6)}$	
c_{01}	$pq10$	2.0	2.0	parameter temperature limitation
c_{03}	p_sum	2.0	5.0	maximal productivity at 10 degrees C
c_{10}	p_chuc	30.0	100.0	food concentration where total uptake rate is 0.5
c_{11}	$p\_minfood$	50.0	50.0	conc below which feeding a particular foodsource depressed
c_{12}	p_suP1	0.7	0.0	relative $P^{(1)}$ uptake by zoo
c_{13}	p_suP2	1.0	0.2	relative $P^{(2)}$ uptake by zoo
c_{14}	p_suP3	0.1	1.0	relative $P^{(3)}$ uptake by zoo
c_{15}	p_suP4	0.1	0.0	relative $P^{(4)}$ uptake by zoo
c_{16}	p_suZ5	1.0	0.0	relative $Z^{(5)}$ uptake by zoo
c_{17}	p_suZ6	1.0	0.2	relative $Z^{(6)}$ uptake by zoo
c_{18}	p_suB1	0.1	1.0	relative B uptake by zoo
$Z^{(5)}$ = Microzooplankton, $Z^{(6)}$ = Heterotrophyc nanoflagellates				

3.1.2 Total respiration ($\frac{\partial Z_c}{\partial t}\Big|_{O^{(3)}}^{rsp}$)

- $rrsc$ (rest respiration)
- $rrac$ (activity respiration)

$$
\begin{aligned}
\frac{\partial Z_c}{\partial t}\Big|_{O^{(3)}}^{rsp} &= rrsc + rrac\\
rrsc &= p\_srs(Z) * et * Z_c\\
rrac &= rugc * (1 - p\_pu(Z)) * (1 - p\_pu\_ea(Z))
\end{aligned}
$$

Microzooplankton parameters				Details
		$Z^{(5)}$	$Z^{(6)}$	
c_{01}	$pq10$	2.0	2.0	parameter temperature limitation
c_{02}	p_srs	0.02	0.02	respiration rate 10 degrees C
c_{06}	p_pu	0.5	0.3	assimilation efficiency (ratio)
c_{07}	p_pu_ea	0.5	0.5	activity excretion
$Z^{(5)}$ = Microzooplankton, $Z^{(6)}$ = Heterotrophyc nanoflagellates				

3.1.3 rate apporting over R_c^1 and R_c^6 ($\frac{\partial Z_c}{\partial t}\Big|_{R^{(1)}}^{rel}$, $\frac{\partial Z_c}{\partial t}\Big|_{R^{(6)}}^{rel}$)

- $rric$ (excrection)
- rdc (mortality)
- $eO2$ (Oxygen limitation)
- $eO2mO2$ (Oxygen Saturation)
- $cxoO2$ (Oxygen Saturation see Chemical)

$$\left.\frac{\partial Z_c}{\partial t}\right|_{R^{(1)}}^{rel} = rric * p\_pe\_R1(Z) \tag{135}$$

$$\left.\frac{\partial Z_c}{\partial t}\right|_{R^{(6)}}^{rel} = rric * (1 - p\_pe\_R1(Z)) \tag{136}$$

$$rric = rugc * (1 - p\_pu(Z)) * p\_pu\_ea(Z) + rdc \tag{137}$$

$$rdc = ((1 - eO2) * p\_sdo(Z) + p\_sd(Z)) * Z_c \tag{138}$$

$$eO2 = min\left(1, (1 - p\_chro(Z)) * \frac{eO2mO2}{eO2mO2 + p\_chro(Z)}\right)$$

$$eO2mO2 = \frac{O2o}{cxoO2}$$

3.2 Chlorophyll fluxes to the sink

$$\left.\frac{\partial P_i}{\partial t}\right|_{bio}^{-} = -\sum_{j=5,6} \left.\frac{\partial Z_c^{(j)}}{\partial t}\right|_{P_c}^{prd} * Qchlc(P) \tag{139}$$

3.3 Silicates fluxes to particulate (only diatoms)

$$\left.\frac{\partial P_s^{(1)}}{\partial t}\right|_{bio}^{-} = -\sum_{j=5,6} \left.\frac{\partial Z_c^{(j)}}{\partial t}\right|_{P_c^{(1)}}^{prd} * Qsc(P^{(1)}) \tag{140}$$

Microzooplankton parameters				Details
		$Z^{(5)}$	$Z^{(6)}$	
c_{01}	$pq10$	2.0	2.0	parameter temperature limitation
c_{04}	p_sdo	0.05	0.05	mortality due Oxygen limitaiton
c_{05}	p_sd	0.0	0.0	independent specific mortality
c_{06}	p_pu	0.5	0.3	assimilation efficiency (ratio)
c_{07}	p_pu_ea	0.5	0.5	activity excretion
c_{08}	p_pe_R1	0.7	0.7	fraction of excretion going to PLOC
c_{09}	p_chro	7.8	7.8	oxygen saturation where respiration is 0.5
$Z^{(5)}$ = Microzooplankton, $Z^{(6)}$ = Heterotrophyc nanoflagellates				

$$\left.\frac{\partial R_s^{(6)}}{\partial t}\right|_{bio}^{-} = + \sum_{j=5,6} \left.\frac{\partial Z_c^{(j)}}{\partial t}\right|_{P_c^{(1)}}^{prd} * Qsc(P^{(1)}) \tag{141}$$

3.4 Nitrate component of microzooplankton functional group

$$
\begin{aligned}
\left.\frac{\partial Z_n}{\partial t}\right|_{bio}^{-} &= +\sum_{X=P,B,Z}\left(\left.\frac{\partial Z_c}{\partial t}\right|_{X_c}^{prd} * Qnc(X)\right) + \\
&\quad - \left.\frac{\partial Z_n}{\partial t}\right|_{N^{(4)}}^{rel} - \left.\frac{\partial Z_n}{\partial t}\right|_{R^{(1)}}^{rel} - \left.\frac{\partial Z_n}{\partial t}\right|_{R^{(6)}}^{rel} + \\
&\quad - \left\{\sum_{k=4,5,6}\left.\frac{\partial Z_c}{\partial t}\right|_{Z_c^{(k)}}^{prd} * Qnc(Z^{(k)})\right\} \quad (142) \\
\left.\frac{\partial N^{(4)}}{\partial t}\right|_{bio}^{-} &= +\sum_{j=5,6}\left.\frac{\partial Z_n^{(j)}}{\partial t}\right|_{N^{(4)}}^{rel} \quad (143) \\
\left.\frac{\partial R_n^{(1)}}{\partial t}\right|_{bio}^{-} &= +\sum_{j=5,6}\left.\frac{\partial Z_n^{(j)}}{\partial t}\right|_{R^{(1)}}^{rel} \quad (144) \\
\left.\frac{\partial R_n^{(6)}}{\partial t}\right|_{bio}^{-} &= +\sum_{j=5,6}\left.\frac{\partial Z_n^{(j)}}{\partial t}\right|_{R^{(6)}}^{rel} \quad (145)
\end{aligned}
$$

Terms in curly parentheses, for $k = 4$, are described in mesozooplankton section.

3.4.1 Nutrient regeneration, ammonia ($\left.\frac{\partial Z_n}{\partial t}\right|_{N^{(4)}}^{rel}$)

$$
\left.\frac{\partial Z_n}{\partial t}\right|_{N^4}^{rel} = max(0.0, Qnc(Z) - p\_qn\_mz(Z)) * Z_c * p\_stemp(Z) \quad (146)
$$

Microzooplankton parameters				Details
		$Z^{(5)}$	$Z^{(6)}$	
c_{20}	*p_qn_mz*	0.0167	0.0167	maximum quotum N
c_{21}	*p_stemp*	0.5	0.5	
$Z^{(5)}$ = Microzooplankton, $Z^{(6)}$ = Heterotrophyc nanoflagellates				

3.4.2 Excretion of nitrate to PON p_xR1n = 1.2 ($\left.\frac{\partial Z_n}{\partial t}\right|_{R^{(1)}}^{rel}$, $\left.\frac{\partial Z_n}{\partial t}\right|_{R^{(6)}}^{rel}$)

$$
\left.\frac{\partial Z_n}{\partial t}\right|_{R^{(6)}}^{rel} = rrin - \left.\frac{\partial Z_n}{\partial t}\right|_{R^{(1)}}^{rel} \quad (147)
$$

$$\left.\frac{\partial Z_n}{\partial t}\right|_{R^{(1)}}^{rel} = min\,(rrin, rr1c * Qnc(Z) * p\_xR1n) \tag{148}$$

$$rrin = rric * Qnc(Z) \tag{149}$$

3.5 Phosphorus component of microzooplankton functional group

$$\left.\frac{\partial Z_p}{\partial t}\right|_{bio}^{-} = + \sum_{X=P,B,Z} \left(\left.\frac{\partial Z_c}{\partial t}\right|_{X_c}^{prd} * Qpc(X) \right) + - \left.\frac{\partial Z_p}{\partial t}\right|_{N^{(1)}}^{rel} - \left.\frac{\partial Z_p}{\partial t}\right|_{R_p^{(1)}}^{rel} - \left.\frac{\partial Z_p}{\partial t}\right|_{R_p^{(6)}}^{rel} + - \left\{ \sum_{k=4,5,6} \left.\frac{\partial Z_c}{\partial t}\right|_{Z_c^{(k)}}^{prd} * Qpc(Z^{(k)}) \right\} \tag{150}$$

$$\left.\frac{\partial N^{(1)}}{\partial t}\right|_{bio}^{-} = + \sum_{j=5,6} \left.\frac{\partial Z_p^{(j)}}{\partial t}\right|_{N^{(1)}}^{rel} \tag{151}$$

$$\left.\frac{\partial R_p^{(1)}}{\partial t}\right|_{bio}^{-} = + \sum_{j=5,6} \left.\frac{\partial Z_p^{(j)}}{\partial t}\right|_{R_p^{(1)}}^{rel} \tag{152}$$

$$\left.\frac{\partial R_p^{(6)}}{\partial t}\right|_{bio}^{-} = + \sum_{j=5,6} \left.\frac{\partial Z_p^{(j)}}{\partial t}\right|_{R_p^{(6)}}^{rel} \tag{153}$$

Terms in curly parentheses, for $k = 4$, are described in mesozooplankton section.

3.5.1 Nutrient regeneration, phosphorus ($\left.\frac{\partial Z_p^{(j)}}{\partial t}\right|_{N^{(1)}}^{rel}$)

$$\left.\frac{\partial Z_p}{\partial t}\right|_{N^{(1)}}^{rel} = max(0.0, Qpc(Z) - p\_qp\_mz(Z)) * Z_c * p\_stemp(Z) \tag{154}$$

Microzooplankton parameters				Details
		$Z^{(5)}$	$Z^{(6)}$	
c_{19}	*p_qp_mz*	0.00185	0.00185	maximum quotum P
c_{21}	*p_stemp*	0.5	0.5	
$Z^{(5)}$ = Microzooplankton, $Z^{(6)}$ = Heterotrophyc nanoflagellates				

3.5.2 Excretion of phosphate to PON p_xR1p = 1.2 ($\frac{\partial Z_p}{\partial t}\Big|_{R_p^{(1)}}^{rel}$, $\frac{\partial Z_p}{\partial t}\Big|_{R_p^{(6)}}^{rel}$)

$$\frac{\partial Z_p}{\partial t}\Big|_{R_p^{(6)}}^{rel} = rrip - \frac{\partial Z_p}{\partial t}\Big|_{R_p^{(1)}}^{rel} \tag{155}$$

$$\frac{\partial Z_p}{\partial t}\Big|_{R_p^{(1)}}^{rel} = min\,(rrip, rr1c * Qpc(Z) * p\_xR1p) \tag{156}$$

$$rrip = rric * Qpc(Z) \tag{157}$$

Microzooplankton parameters				Details
		$Z^{(5)}$	$Z^{(6)}$	
c_{01}	$pq10$	2.0	2.0	parameter temperature limitation
c_{02}	p_srs	0.02	0.02	respiration rate 10 degrees C
c_{03}	p_sum	2.0	5.0	maximal productivity at 10 degrees C
c_{04}	p_sdo	0.05	0.05	mortality due Oxygen limitaiton
c_{05}	p_sd	0.0	0.0	independent specific mortality
c_{06}	p_pu	0.5	0.3	assimilation efficiency (ratio)
c_{07}	p_pu_ea	0.5	0.5	activity excretion
c_{08}	p_pe_R1	0.7	0.7	fraction of excretion going to PLOC
c_{09}	p_chro	7.8	7.8	oxygen saturation where respiration is 0.5
c_{10}	p_chuc	30.0	100.0	food concentration where total uptake rate is 0.5
c_{11}	$p\_minfood$	50.0	50.0	conc below which feeding a particular foodsource depressed
c_{12}	p_suP1	0.7	0.0	relative $P^{(1)}$ uptake by zoo
c_{13}	p_suP2	1.0	0.2	relative $P^{(2)}$ uptake by zoo
c_{14}	p_suP3	0.1	1.0	relative $P^{(3)}$ uptake by zoo
c_{15}	p_suP4	0.1	0.0	relative $P^{(4)}$ uptake by zoo
c_{16}	p_suZ5	1.0	0.0	relative $Z^{(5)}$ uptake by zoo
c_{17}	p_suZ6	1.0	0.2	relative $Z^{(6)}$ uptake by zoo
c_{18}	p_suB1	0.1	1.0	relative B uptake by zoo
c_{19}	p_qp_mz	0.00185	0.00185	maximum quotum P
c_{20}	p_qn_mz	0.0167	0.0167	maximum quotum N
c_{21}	p_stemp	0.5	0.5	
$Z^{(5)}$ = Microzooplankton, $Z^{(6)}$ = Heterotrophyc nanoflagellates				

4 Mesozooplankton

4.1 Carbon component of mesozooplankton functional group

$$\left.\frac{\partial Z_c}{\partial t}\right|_{bio}^{-} = +\sum_{X=P,Z} \left.\frac{\partial Z_c}{\partial t}\right|_{X_c}^{prd} - \left.\frac{\partial Z_c}{\partial t}\right|_{O^{(3)}}^{rsp} - \left.\frac{\partial Z_c}{\partial t}\right|_{R_c^{(1)}}^{rel} - \left.\frac{\partial Z_c}{\partial t}\right|_{R_c^{(6)}}^{rel} \tag{158}$$

$$\left.\frac{\partial R_c^{(1)}}{\partial t}\right|_{bio}^{-} = +\sum_{k=3,4} \left.\frac{\partial Z_c^{(k)}}{\partial t}\right|_{R^{(1)}}^{rel} \tag{159}$$

$$\left.\frac{\partial R_c^{(6)}}{\partial t}\right|_{bio}^{-} = +\sum_{k=3,4} \left.\frac{\partial Z_c^{(k)}}{\partial t}\right|_{R_c^{(6)}}^{rel} \tag{160}$$

$$\left.\frac{\partial O2o}{\partial t}\right|_{bio}^{-} = -\sum_{k=3,4} \frac{\left.\frac{\partial Z_c^{(k)}}{\partial t}\right|_{O^{(3)}}^{rsp}}{12} \tag{161}$$

4.1.1 Total gross uptake carbon fluxes from omnivorous mesoplankton -$Z^{(4)}$- to carnivorous mesozooplankton -$Z^{(3)}$- ($\left.\frac{\partial Z_c^{(3)}}{\partial t}\right|_{Z_c^{(4)}}^{prd}$, $\left.\frac{\partial Z_c^{(3)}}{\partial t}\right|_{Z_c^{(3)}}^{prd}$)

- rum (total carbon consumption)
- ZIm (total food available)
- et (temperature limitation factor $t_o = 10^o$ C)

$$\left.\frac{\partial Z_c^{(3)}}{\partial t}\right|_{Z_c^{(4)}}^{prd} = rum * \frac{Z_c^{(4)}}{ZIm}$$

$$\left.\frac{\partial Z_c^{(3)}}{\partial t}\right|_{Z_c^{(3)}}^{prd} = rum * \frac{Z_c^{(3)}}{ZIm}$$

$$rum = et * p\_sum(Z^{(3)}) * \frac{p\_vum(Z^{(3)}) * ZIm}{p\_vum(Z^{(3)}) * ZIm + p\_sum(Z^{(3)})} * Z_c^{(3)}$$

$$ZIm = Z_c^{(3)} + Z_c^{(4)}$$

$$et = (p\_q10)^{\frac{t-t_o}{t_o}}$$

Mesozooplankton parameters				Details
		$Z^{(3)}$	$Z^{(4)}$	
d_{01}	*pq*10	2.0	2.0	parameter temperature limitation
d_{06}	*p_sum*	2.0	2.0	maximal productivity at 10 degrees C
d_{07}	*p_vum*	0.008	0.02	specific search volume
$Z^{(3)}$ = carnivorous mesozooplankton, $Z^{(4)}$ = omnivorous mesozooplnkton				

4.1.2 Total gross uptake Carbon fluxes from phytoplankton, microzooplankton and mesozooplankton ($\frac{\partial Z_c}{\partial t}\Big|_{P_c}^{prd}$, $\frac{\partial Z_c^{(4)}}{\partial t}\Big|_{Z_c^{(4)}}^{prd}$, $\frac{\partial Z_c^{(4)}}{\partial t}\Big|_{Z_c^{(5)}}^{prd}$)

- *rum* (total carbon consumption)
- *ZIm* (total food available)
- *et* (temperature limitation factor $t_o = 10^o$ C)

$$\begin{pmatrix} \frac{\partial Z_c^{(4)}}{\partial t}\Big|_{P_c^{(1)}}^{prd} & = & rum * \frac{P_c^{(1)}}{ZIm} & \frac{\partial Z_c^{(4)}}{\partial t}\Big|_{P_c^{(2)}}^{prd} & = & rum * \frac{p\_pu\_P2 * P_c^{(2)}}{ZIm} \\ \frac{\partial Z_c^{(4)}}{\partial t}\Big|_{P_c^{(3)}}^{prd} & = & 0 & \frac{\partial Z_c^{(4)}}{\partial t}\Big|_{P_c^{(4)}}^{prd} & = & rum * \frac{p\_pu\_P4 * P_c^{(4)}}{ZIm} \\ \frac{\partial Z_c^{(4)}}{\partial t}\Big|_{Z_c^{(4)}}^{prd} & = & rum * \frac{Z_c^{(4)}}{ZIm} & \frac{\partial Z_c^{(4)}}{\partial t}\Big|_{Z_c^{(5)}}^{prd} & = & rum * \frac{Z_c^{(5)}}{ZIm} \end{pmatrix}$$

$$\begin{aligned} rum &= et * p\_sum(Z^{(4)}) * \frac{p\_vum(Z^{(4)}) * ZIm}{p\_vum(Z^{(4)}) * ZIm + p\_sum(Z^{(4)})} * Z_c^{(4)} \qquad (162) \\ ZIm &= P_c^{(1)} + p\_pu\_P2 * P_c^{(2)} + p\_pu\_P4 * P_c^{(4)} + Z_c^{(4)} + Z_c^{(5)} \\ et &= (p\_q10)^{\frac{t-t_o}{t_o}} \end{aligned}$$

4.1.3 Total respiration activity + basal metabolism ($\frac{\partial Z_c}{\partial t}\Big|_{O^{(3)}}^{rsp}$)

- *rra_c* (respiration)
- *rrs_c* (basal metabolism)
- *rut_c* (rate uptake carbon for transpiration)

Mesozooplankton parameters				Details
		$Z^{(3)}$	$Z^{(4)}$	
d_{01}	$pq10$	2.0	2.0	parameter temperature limitation
d_{03}	p_puP2	0.0	0.75	availability of P2 to Z4
d_{04}	p_puP4	1.0	1.0	availability of $P^{(4)}$
d_{06}	p_sum	2.0	2.0	maximal productivity at 10 degrees C
d_{07}	p_vum	0.008	0.02	specific search volume
$Z^{(3)}$ = carnivorous mesozooplankton, $Z^{(4)}$ = omnivorous mesozooplnkton				

$$\left.\frac{\partial Z_c}{\partial t}\right|_{O^{(3)}}^{rsp} = rra\_c + rrs\_c \tag{163}$$

$$rra\_c = prI\_R6 * rut\_c \tag{164}$$

$$rrs\_c = p\_srs(Z) * et * Z_c \tag{165}$$

$$prI\_R6 = 1 - p\_puI\_u(Z) - p\_peI\_R6(Z) \tag{166}$$

$$\left(\begin{array}{lll} rut\_c & = & \left.\frac{\partial Z_c^{(3)}}{\partial t}\right|_{Z_c^{(4)}}^{prd} + \left.\frac{\partial Z_c^{(3)}}{\partial t}\right|_{Z_c^{(3)}}^{prd} \quad for \quad Z^{(3)} \\ rut\_c & = & \sum_{j=1,2,4} \left.\frac{\partial Z_c^{(4)}}{\partial t}\right|_{P_c^{(j)}}^{prd} + \left.\frac{\partial Z_c^{(4)}}{\partial t}\right|_{Z_c^{(4)}}^{prd} + \left.\frac{\partial Z_c^{(4)}}{\partial t}\right|_{Z_c^{(5)}}^{prd} \quad for \quad Z^{(4)} \end{array}\right)$$

Mesozooplankton parameters				Details
		$Z^{(3)}$	$Z^{(4)}$	
d_{01}	$pq10$	2.0	2.0	parameter temperature limitation
d_{02}	p_srs	0.01	0.02	respiration rate 10 degrees C
d_{08}	p_puI_u	0.6	0.6	assimilation efficiency
d_{09}	p_peI_R6	0.3	0.35	faeces production
$Z^{(3)}$ = carnivorous mesozooplankton, $Z^{(4)}$ = omnivorous mesozooplnkton				

4.1.4 Fluxes for eliminated excess nutrients ($\left.\frac{\partial Z_c}{\partial t}\right|_{R_c^{(6)}}^{rel}$)

- rd_c (natural mortality)
- ret_c (defecation)
- rdo_c (density dependent mortality)
- pu_e_n, pu_e_p (P:C and N:C in assimilate Nitrogen and Phosphorus)
- ru_c, ru_n, ru_p (Assimilated material respectively carbon, nitrogen, phosphorus)

- n_l (Nutrient type of limitation, default $n\_l = 1$)

$$\left.\frac{\partial Z_c}{\partial t}\right|_{R_c^{(6)}}^{rel} = rd\_c + ret\_c + rdo\_c + pe\_R6c * rut\_c \quad (167)$$

$$rd\_c = p\_sd(Z) * et * Z_c \quad (168)$$

$$ret\_c = p\_peI\_R6(Z) * rut\_c \quad (169)$$

$$rdo\_c = p\_sdo(Z) * (Z_c)^{p\_sds(Z)} * Z_c \quad (170)$$

$$(171)$$

$$\begin{pmatrix} pe\_R6c & = & 0. & if \quad n\_l = 1 \\ pe\_R6c & = & \frac{(p\_qpc(Z)*ru\_c)-(1-p\_peI\_R6(Z))*rut\_p}{p\_zero+p\_qpc(Z)*rut\_c} & if \quad n\_l = 2 \\ pe\_R6c & = & \frac{(p\_qnc(Z)*ru\_c)-(1-p\_peI\_R6(Z))*rut\_p}{p\_zero+p\_qnc(Z)*rut\_c} & if \quad n\_l = 3 \end{pmatrix}$$

$$if\ (temp\_p < temp\_n)\ or\ (abs(temp\_p - temp\_n)) < p\_zero)\ then$$

$$\begin{pmatrix} if \quad (pu\_e\_p < Qpc(Z)) \quad then \quad n\_l = 2 \\ else \\ if \quad (pu\_e\_n < Qnc(Z)) \quad then \quad n\_l = 3 \end{pmatrix}$$

$$temp\_n = \frac{pu\_e\_n}{Qnc(Z)} \quad (172)$$

$$temp\_p = \frac{pu\_e\_p}{Qpc(Z)} \quad (173)$$

$$pu\_e\_n = \frac{ru\_n}{p\_zero + ru\_c} \quad (174)$$

$$pu\_e\_p = \frac{ru\_p}{p\_zero + ru\_c} \quad (175)$$

$$ru\_c = p\_puI\_u(Z) * rut\_c \quad (176)$$

$$ru\_n = [p\_puI\_u(Z) + prI\_R6_i] * rut\_n \quad (177)$$

$$ru\_p = [p\_puI\_u(Z) + prI\_R6_i] * rut\_p \quad (178)$$

$$(179)$$

$$\begin{pmatrix} for & & Z^{(3)} \\ rut\_n & = & \left.\frac{\partial Z_c^{(3)}}{\partial t}\right|_{Z_c^{(4)}}^{prd} * Qnc(Z^{(4)}) + \left.\frac{\partial Z_c^{(3)}}{\partial t}\right|_{Z_c^{(3)}}^{prd} * Qnc(Z^{(3)}) \\ rut\_p & = & \left.\frac{\partial Z_c^{(3)}}{\partial t}\right|_{Z_c^{(4)}}^{prd} * Qpc(Z^{(4)}) + \left.\frac{\partial Z_c^{(3)}}{\partial t}\right|_{Z_c^{(3)}}^{prd} * Qpc(Z^{(3)}) \\ for & & Z^{(4)} \\ rut\_n & = & \sum_{j=1,2,4} \left.\frac{\partial Z_c^{(4)}}{\partial t}\right|_{P_c^{(j)}}^{prd} * Qnc(P^{(j)}) + \left.\frac{\partial Z_c^{(4)}}{\partial t}\right|_{Z_c^{(4)}}^{prd} * Qnc(Z^{(4)}) + \left.\frac{\partial Z_c^{(4)}}{\partial t}\right|_{Z_c^{(5)}}^{prd} * Qnc(Z^{(5)}) \\ rut\_p & = & \sum_{j=1,2,4} \left.\frac{\partial Z_c^{(4)}}{\partial t}\right|_{P_c^{(j)}}^{prd} * Qpc(P^{(j)}) + \left.\frac{\partial Z_c^{(4)}}{\partial t}\right|_{Z_c^{(4)}}^{prd} * Qpc(Z^{(4)}) + \left.\frac{\partial Z_c^{(4)}}{\partial t}\right|_{Z_c^{(5)}}^{prd} * Qpc(Z^{(5)}) \end{pmatrix}$$

Mesozooplankton parameters				Details
		$Z^{(3)}$	$Z^{(4)}$	
d_{01}	$pq10$	2.0	2.0	parameter temperature limitation
d_{02}	p_srs	0.01	0.02	respiration rate 10 degrees C
d_{05}	p_sd	0.01	0.01	independent specific mortality
d_{08}	p_puI_u	0.6	0.6	assimilation efficiency
d_{09}	p_peI_R6	0.3	0.35	faeces production
d_{10}	p_sdo	0.0004	0.0004	fractional density-dependent mortality
d_{11}	p_sds	2	2	density dependent mortality
d_{12}	p_qpc	0.00167	0.00167	maximum quotum P
d_{13}	p_qnc	0.015	0.015	maximum quotum N
$Z^{(3)}$ = carnivorous mesozooplankton, $Z^{(4)}$ = omnivorous mesozooplnkton				

4.2 Chlorophyll fluxes to the sink

$$\left.\frac{\partial P_i}{\partial t}\right|_{bio}^{-} = -\left.\frac{\partial Z_c^{(4)}}{\partial t}\right|_{P_c}^{prd} * Qchlc(P) \tag{180}$$

4.3 Silicates fluxes to particulate(only diatoms)

$$\left.\frac{\partial P_s^{(1)}}{\partial t}\right|_{bio}^{-} = -\left.\frac{\partial Z_c^{(4)}}{\partial t}\right|_{P_c^{(1)}}^{prd} * Qsc(P^{(1)}) \tag{181}$$

$$\left.\frac{\partial N^{(5)}}{\partial t}\right|_{bio}^{-} = +\left.\frac{\partial Z_c^{(4)}}{\partial t}\right|_{P_c^{(1)}}^{prd} * Qsc(P^{(1)}) \tag{182}$$

4.4 Nitrate component of mesozooplankton functional group

$$\left.\frac{\partial Z_n^{(3)}}{\partial t}\right|_{bio}^{-} = + \left.\frac{\partial Z_c^{(3)}}{\partial t}\right|_{Z_c^{(4)}}^{prd} * Qnc(Z^{(4)}) - \left.\frac{\partial Z_n^{(3)}}{\partial t}\right|_{N^{(4)}}^{rel} - \left.\frac{\partial Z_c^{(3)}}{\partial t}\right|_{R_c^{(6)}}^{rel} \quad (183)$$

$$\left.\frac{\partial Z_n^{(4)}}{\partial t}\right|_{bio}^{-} = - \left.\frac{\partial Z_c^{(3)}}{\partial t}\right|_{Z_c^{(4)}}^{prd} * Qnc(Z^{(4)}) + \sum_{X=P,Z} \left.\frac{\partial Z_c^{(4)}}{\partial t}\right|_{X_c}^{prd} * Qnc(X) + - \left.\frac{\partial Z_n^{(4)}}{\partial t}\right|_{N^{(4)}}^{rel} - \left.\frac{\partial Z_c^{(4)}}{\partial t}\right|_{R_c^{(6)}}^{rel} \quad (184)$$

$$\left.\frac{\partial P_n}{\partial t}\right|_{bio}^{-} = - \left.\frac{\partial Z_c^{(2)}}{\partial t}\right|_{P_c}^{prd} * Qnc(P) \quad (185)$$

$$\left.\frac{\partial Z_n^{(5)}}{\partial t}\right|_{bio}^{-} = - \left.\frac{\partial Z_c^{(2)}}{\partial t}\right|_{Z_c^{(5)}}^{prd} * Qnc(Z^{(5)}) \quad (186)$$

$$\left.\frac{\partial N^{(4)}}{\partial t}\right|_{bio}^{-} = + \sum_{k=3,4} \left.\frac{\partial Z_n^{(k)}}{\partial t}\right|_{N^{(4)}}^{rel} \quad (187)$$

$$\left.\frac{\partial R_n^{(6)}}{\partial t}\right|_{bio}^{-} = + \sum_{k=3,4} \left.\frac{\partial Z_n^{(k)}}{\partial t}\right|_{R_n^{(6)}}^{rel} \quad (188)$$

4.4.1 Excretion: activity + basal metabolism + excess nonlimiting nutrients ($\left.\frac{\partial Z_n^{(2)}}{\partial t}\right|_{N^{(4)}}^{rel}$)

- rra_n
- rrs_n
- rut_n

$$\left.\frac{\partial Z_n}{\partial t}\right|_{N^{(4)}}^{rel} = rra\_n + rrs\_n + pe\_N4n * rut\_n \quad (189)$$

$$rra\_n = 0 \quad (190)$$

$$rrs\_n = p\_srs(Z) * et * Z_n \quad (191)$$

$$\begin{pmatrix} pe\_N4n & = & \frac{(1-p\_peI\_R6(Z))*rut\_n-p\_qnc(Z)*ru\_c}{p_o+rut\_n} & if \quad n\_l=1 \\ pe\_N4n & = & \frac{(1-p\_peI\_R6(Z))*rut\_n-p\_qnc(Z)*(ru\_c-pe\_R6c*rut\_c)}{p\_zero+rut\_n} & if \quad n\_l=2 \\ pe\_N4n & = & 0. & if \quad n\_l=3 \end{pmatrix}$$

Mesozooplankton parameters				Details
		$Z^{(1)}$	$Z^{(2)}$	
d_{01}	$pq10$	2.0	2.0	parameter temperature limitation
d_{02}	p_srs	0.01	0.02	respiration rate 10 degrees C
d_{05}	p_sd	0.01	0.01	independent specific mortality
d_{08}	p_puI_u	0.6	0.6	assimilation efficiency
d_{09}	p_peI_R6	0.3	0.35	faeces production
d_{10}	p_sdo	0.0004	0.0004	fractional density-dependent mortality
d_{12}	p_qpc	0.00167	0.00167	maximum quotum P
d_{13}	p_qnc	0.015	0.015	maximum quotum N
$Z^{(1)}$ = carnivorous mesozooplankton, $Z^{(2)}$ = omnivorous mesozooplnkton				

4.4.2 Fluxes for eliminated excess of nutrients ($\frac{\partial Z_n}{\partial t}\Big|_{R_n^{(6)}}^{rel}$)

- rd_n (Natural mortality)
- ret_n (Defecation)
- rdo_n (Density dependent mortality)
- rut_n (Total Gross Uptake)

$$\frac{\partial Z_n}{\partial t}\Big|_{R_n^{(6)}}^{rel} = rd\_n + ret\_n + rdo\_n \quad (192)$$

$$rd\_n = p\_sd(Z) * et * Z_n \quad (193)$$

$$ret\_n = p\_peI\_R6(Z) * rut\_n \quad (194)$$

$$rdo\_n = p\_sdo(Z) * (Z_c)^{p\_sds(Z)} * Z_n \quad (195)$$

4.5 Phosphate component of mesozooplankton functional group

$$\left.\frac{\partial Z_p^{(3)}}{\partial t}\right|_{bio}^{-} = + \left.\frac{\partial Z_c^{(3)}}{\partial t}\right|_{Z_c^{(4)}}^{prd} * Qpc(Z^{(4)}) - \left.\frac{\partial Z_p^{(3)}}{\partial t}\right|_{N^{(1)}}^{rel} - \left.\frac{\partial Z_p^{(3)}}{\partial t}\right|_{R_p^{(6)}}^{rel} \quad (196)$$

$$\left.\frac{\partial Z_p^{(4)}}{\partial t}\right|_{bio}^{-} = - \left.\frac{\partial Z_c^{(3)}}{\partial t}\right|_{Z_c^{(4)}}^{prd} * Qpc(Z^{(4)}) + \sum_{X=P,Z} \left.\frac{\partial Z_c^{(4)}}{\partial t}\right|_{X_c}^{prd} * Qpc(X) + - \left.\frac{\partial Z_p^{(4)}}{\partial t}\right|_{N^{(1)}}^{rel} - \left.\frac{\partial Z_p^{(4)}}{\partial t}\right|_{R_p^{(6)}}^{rel} \quad (197)$$

$$\left.\frac{\partial P_p}{\partial t}\right|_{bio}^{-} = - \left.\frac{\partial Z_c^{(2)}}{\partial t}\right|_{P_c}^{prd} * Qpc(P) \quad (198)$$

$$\left.\frac{\partial Z_p^{(5)}}{\partial t}\right|_{bio}^{-} = - \left.\frac{\partial Z_c^{(2)}}{\partial t}\right|_{Z_c^{(5)}}^{prd} * Qpc(Z^{(5)}) \quad (199)$$

$$\left.\frac{\partial N^{(1)}}{\partial t}\right|_{bio}^{-} = + \sum_{k=3,4} \left.\frac{\partial Z_p^{(k)}}{\partial t}\right|_{N^{(1)}}^{rel} \quad (200)$$

$$\left.\frac{\partial R_p^{(6)}}{\partial t}\right|_{bio}^{-} = + \sum_{k=3,4} \left.\frac{\partial Z_p^{(k)}}{\partial t}\right|_{R_p^{(6)}}^{rel} \quad (201)$$

4.5.1 Excretion: activity + basal metabolism + excess non limiting nutrients ($\left.\frac{\partial Z_p^{(4)}}{\partial t}\right|_{N^{(1)}}^{rel}$)

- rra_p
- rrs_p
- rut_p

$$\left.\frac{\partial Z_p}{\partial t}\right|_{N^{(1)}}^{rel} = rra\_p + rrs\_p + pe\_N1p * rut\_p \quad (202)$$

$$rra\_p = 0 \quad (203)$$

$$rrs\_p = p\_srs(Z) * et * Z_p \quad (204)$$

$$\begin{pmatrix} pe\_N1p & = & \frac{(1-p\_peI\_R6(Z))*rut\_p-p\_qpc(Z)*ru\_c}{p\_zero+rut\_p} & if \quad n\_l = 1 \\ pe\_N1p & = & 0. & if \quad n\_l = 2 \\ pe\_N1p & = & \frac{(1-p\_peI\_R6(Z))*rut\_p-p\_qpc(Z)*(ru\_c-pe\_R6c*rut\_p)}{p\_zero+rut\_p} & if \quad n\_l = 3 \end{pmatrix}$$

4.5.2 Fluxes for eliminated excess of nutrients ($\frac{\partial Z_p}{\partial t}\Big|_{R_p^{(6)}}^{rel}$)

- rd_p (Natural mortality)
- ret_p (Defecation)
- rdo_p (Density dependent mortality)
- rut_p (Total Gross Uptake)

$$\frac{\partial Z_p}{\partial t}\Big|_{R_p^{(6)}}^{rel} = rd\_p + ret\_p + rdo\_p \quad (205)$$

$$rd\_p = p\_sd(Z) * et * Z_p \quad (206)$$

$$ret\_p = p\_peI\_R6(Z) * rut\_p \quad (207)$$

$$rdo\_p = p\_sdo(Z) * (Z_c)^{p\_sds(Z)} * Z_p \quad (208)$$

Mesozooplankton parameters				Details
		$Z^{(1)}$	$Z^{(2)}$	
d_{01}	$pq10$	2.0	2.0	parameter temperature limitation
d_{02}	p_srs	0.01	0.02	respiration rate 10 degrees C
d_{03}	p_puP2	0.0	0.75	availability of P2 to Z4
d_{04}	p_puP4	1.0	1.0	availability of $P^{(4)}$
d_{05}	p_sd	0.01	0.01	independent specific mortality
d_{06}	p_sum	2.0	2.0	maximal productivity at 10 degrees C
d_{07}	p_vum	0.008	0.02	specific search volume
d_{08}	p_puI_u	0.6	0.6	assimilation efficiency
d_{09}	p_peI_R6	0.3	0.35	faeces production
d_{10}	p_sdo	0.0004	0.0004	fractional density-dependent mortality
d_{11}	p_sds	2.0	2.0	density dependent mortality
d_{12}	p_qpc	0.00167	0.00167	maximum quotum P
d_{13}	p_qnc	0.015	0.015	maximum quotum N
$Z^{(1)}$ = carnivorous mesozooplankton, $Z^{(2)}$ = omnivorous mesozooplnkton				

5 Chemical reactions

5.1 Nitrate component of pelagic chemical compartment

$$\left.\frac{\partial N^{(4)}}{\partial t}\right|_{bio}^{-} = -\left.\frac{\partial N^{(3)}}{\partial t}\right|_{N^{(4)}}^{nit} \tag{209}$$

$$\left.\frac{\partial N^{(3)}}{\partial t}\right|_{bio}^{-} = +\left.\frac{\partial N^{(3)}}{\partial t}\right|_{N^{(4)}}^{nit} - \left.\frac{\partial O4n}{\partial t}\right|_{N^{(3)}}^{-} \tag{210}$$

5.1.1 Nitrification in the water ($\left.\frac{\partial N^{(3)}}{\partial t}\right|_{N^{(4)}}^{nit}$)

- eo (regulating factor)

$$\left.\frac{\partial N^{(3)}}{\partial t}\right|_{N^{(4)}}^{nit} = p\_sN4N3 * N^{(4)} * (p\_q10N4N3)^{\frac{t-t_o}{t_o}} * eo$$

$$eo = \frac{O2o}{O2o + p\_clO2o}$$

5.1.2 Denitrification in the water ($\left.\frac{\partial O4n}{\partial t}\right|_{N^{(3)}}^{-}$)

- er (regulating factor)
- p_qro ($O2S2$ conversion factor p_qro=0.5)

$$\left.\frac{\partial O4n}{\partial t}\right|_{N^{(3)}}^{-} = p\_sN3O4n * (p\_q10N4N3)^{\frac{t-t_o}{t_o}} * er * \frac{rPAo}{p\_rPAo} * N^{(4)} \tag{211}$$

$$er = \frac{N^{(6)}}{N^{(6)} + p\_clN6r} \tag{212}$$

$$rPAo = \frac{\partial_t N^{(6)}}{p\_qro} \tag{213}$$

5.1.3 Reoxidation of reduction equivalent ($\left.\frac{\partial O2r}{\partial t}\right|_{N6}^{-}$)

$$\left.\frac{\partial O2r}{\partial t}\right|_{N^{(6)}}^{-} = p\_rOS * N^{(6)} * eo \tag{214}$$

5.2 Oxygen component of pelagic chemical compartment

- p_qon_nitri ((mN/nO) proportion between $O2$ and N, $p\_qon\_nitri = 2.0$)
- p_qon_dentri (proportion between $O2$ and N produced, $p\_qon\_dentri = 1.25$)

$$\left.\frac{\partial O2o}{\partial t}\right|_{bio}^{-} = -\left.\frac{\partial N^{(3)}}{\partial t}\right|_{N^{(4)}}^{nit} * p\_qon\_nitri - \frac{\left.\frac{\partial O2r}{\partial t}\right|_{N^{(6)}}^{-}}{p\_qro} \tag{215}$$

$$\left.\frac{\partial N^{(6)}}{\partial t}\right|_{bio}^{-} = -p\_qro * \left.\frac{\partial O4n}{\partial t}\right|_{N^{(3)}}^{-} * p\_qon\_dentri * H(-\frac{O2o - N^{(6)}}{p\_qro}) - \left.\frac{\partial O2r}{\partial t}\right|_{N^{(6)}}^{-} \tag{216}$$

5.3 Silicates component of pelagic chemical compartment

$$\left.\frac{\partial R_s^{(6)}}{\partial t}\right|_{bio}^{-} = -\left.\frac{\partial R_s^{(6)}}{\partial t}\right|_{N^{(5)}}^{rem} \tag{217}$$

$$\left.\frac{\partial N^{(5)}}{\partial t}\right|_{bio}^{-} = \left.\frac{\partial R_s^{(6)}}{\partial t}\right|_{N^{(5)}}^{rem} \tag{218}$$

5.3.1 Regeneration of dissolved silica ($\left.\frac{\partial R_s^{(5)}}{\partial t}\right|_{N^{(5)}}^{rem}$)

$$\left.\frac{\partial R_s^{(6)}}{\partial t}\right|_{N^{(5)}}^{rem} = p\_sR6N5 * (p\_q10R6N5)^{\frac{t-t_o}{t_o}} * R_s^{(6)}$$

5.4 Oxigen reareation

$$\left.\frac{\partial O2o}{\partial t}\right|_{wnd}^{-} = + \left.\frac{\partial O2o}{\partial t}\right|_{atm}^{wnd}$$

5.4.1 Wind reareation factor ($\left.\frac{\partial O2o}{\partial t}\right|_{atm}^{wnd}$)

- $reacon$ (wind dependency reareation factor)
- $Wind$ (wind speed $\frac{m}{s}$)
- $Schmidt$ (Schmidt oxygenation number)
- $Temp$ (temperature in Celsius degrees)

- *abt* (absolute temperature divided by 100)
- *Salt* (salinity PSU)
- $cxoO2$ (oxygen saturation)
- *depth* (layer depth)

$$
\begin{aligned}
\left.\frac{\partial O2o}{\partial t}\right|_{atm}^{wnd} &= reacon * \frac{cxoO2 - O2o}{Depth} \\
reacon &= 0.074 * Wind^{\sqrt[2]{\frac{schmidt}{660}}} \\
Schmidt &= 1953.4 - t * (128.00 - t * (3.9918 - t * 0.050091))) \\
cxoO2 &= \frac{-173.4292 + \frac{249.6339}{abt} + 143.3483 * log(abt) - 21.8492 * abt}{24.4665^{-3}} + \\
&+ \frac{Salt * (-0.033096 + 0.014259 * abt - 0.0017 * abt^2)}{24.4665^{-3}} \\
abt &= \frac{t + 273.3}{100.0}
\end{aligned}
$$

Chemical reaction parameters			Details
e_{01}	p_sN4N3	0.01	nitrification in the water factor
e_{02}	$p\_q10N4N3$	2.367	nitrification in the water temperature limitation
e_{03}	$p\_q10R6N5$	1.49	regeneration of dissolved silica temperature limitation
e_{04}	p_rOS	0.05	reoxidation of reduction equivalents factor
e_{05}	p_clO2o	10.0	regulating factors Oxygen
e_{06}	p_clN6r	1.0	regulating factors denitrification
e_{07}	p_sN3O4n	0.35	denitrification in the water factor
e_{08}	p_rPAo	1.0	denitrification in the water
e_{09}	p_sR6N5	0.1	regeneration of dissolved silica