Supplemental material to " Seasonal and inter-annual variability of plankton chlorophyll and primary production in the Mediterranean Sea: a modelling approach"

P. Lazzari[1], C. Solidoro[1], V. Ibello[1,2], S. Salon[1], A. Teruzzi[1], K. Béranger[3], S. Colella[4] and A. Crise[1]

[1] Istituto Nazionale di Oceanografia e di Geofisica Sperimentale - OGS, Trieste, Italy

[2] Institute of Marine Sciences, Middle East Technical University, Erdemli, Turkey

[3] ENSTA-Paris Tech, Palaiseau, France

[4] CNR-ISAC UOS, Roma, Italy

Correspondence to: P. Lazzari (plazzari@ogs.trieste.it)

Equations of BFM Model

The translation of the computer routines of BFM v2.0 software into analytical expressions, is based on the following notation:

- $\frac{\partial A_B}{\partial t}\Big|_{C_B}^{D}$ 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 $\mu Em^{-2}day^{-1}$)
- $sunq$ (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})

$$\left.\frac{\partial P_c}{\partial t}\right|_{O^{(3)}}^{gpp} = p\_sum(P) * et * iN5s * \frac{sunq}{24} * eiPi * P_c \tag{6}$$

$$sum = Photo_{max} * eiPi \tag{7}$$

$$Photo_{max} = p\_sum(P) * et * iN5s * \frac{sunq}{24} \tag{8}$$

$$eiPi = 1 - exp\left(-Qchlc(P) * \frac{p\_alpha\_chl(P)}{Photo_{max}} * Irr\right) \tag{9}$$

$$iN5s = min\left(1, max\left(p_o, \frac{Qsc(P^{(1)}) - p\_qslc(P^{(1)})}{p\_qsRc(P^{(1)}) - p\_qslc(P^{(1)})}\right)\right) \tag{10}$$

$$et = p\_q10^{\frac{t-t_o}{t_o}} \tag{11}$$

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	0.007	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)

$$\frac{\partial P_c}{\partial t}\Big|_{O^{(3)}}^{rsp} = srt * P_c \tag{23}$$

$$srt = sra + srs \tag{24}$$

$$sra = (sum - set) * p\_pu\_ra(P) \tag{25}$$

$$srs = et * p\_srs(P) \tag{26}$$

$$et = p\_q10^{\frac{t-t_o}{t_o}} \tag{27}$$

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)

$$\frac{\partial P_c}{\partial t}\Big|_{R_c^{(2)}}^{npp} = max(0, (sum - slc) * P_c) \tag{28}$$

$$slc = set + srt + sdo \tag{29}$$

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

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

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

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

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

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

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)

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

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

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

- *sdo* (nutrient stress lysis)

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

1.3 Phosphorus component of phytoplankton functional group

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

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)

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

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)

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

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

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*	0.007	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

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

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}
- iN (nutrient intracellular limitation Liebig rule)
- sdo (nutrient stress lysis)
- sum (carbon maximum uptake)
- slc (specific carbon loss term)
- Irr (irradiance expressed in $\mu Em^{-2}day^{-1}$)

$$\begin{aligned}
\left.\frac{\partial P_i}{\partial t}\right|_{-}^{syn} &= iN * rho_{chl} * netgrowth - max(p_sdchl(P) * (1 - iN), sdo) * P_i + \\
&\quad + min(0, sum - slc + sdo) * max(0, P_i - p_qchl(P) * P_c) \qquad (70) \\
rho_{chl} &= p_qchlc(P) * \frac{sum}{p_alpha_chl(P) * Qchlc(P) * Irr} \qquad (71)
\end{aligned}$$

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)

$$
\begin{aligned}
\left.\frac{\partial P_s^{(1)}}{\partial t}\right|_{bio}^{-} &= +\left.\frac{\partial P_s^{(1)}}{\partial t}\right|_{N^{(5)}}^{upt} - \left.\frac{\partial P_s^{(1)}}{\partial t}\right|_{R^{(6)}}^{lys} + \\
& -\left\{\sum_{k=4,6}\left.\frac{\partial Z_c^{(k)}}{\partial t}\right|_{P_c^{(1)}}^{prd} * Qsc(P^{(1)})\right\} && (72)\\
\left.\frac{\partial N^{(5)}}{\partial t}\right|_{bio}^{-} &= -\left.\frac{\partial P_s^{(1)}}{\partial t}\right|_{N^{(5)}}^{upt} && (73)\\
\left.\frac{\partial R^{(6)}}{\partial t}\right|_{bio}^{-} &= +\left.\frac{\partial P_s^{(1)}}{\partial t}\right|_{R^{(6)}}^{lys} && (74)
\end{aligned}
$$

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)

$$
\begin{aligned}
\left.\frac{\partial P_s^{(1)}}{\partial t}\right|_{N^{(5)}}^{upt} &= min(rums, rups + miss) && (75)\\
rups &= \left.\frac{\partial P_c^{(1)}}{\partial t}\right|_{R_c^{(2)}}^{npp} * p\_qsRc(P^{(1)}) && (76)\\
miss &= sadap * (p\_qsRc(P^{(1)}) * P_c^{(1)} - P_s^{(1)}) && (77)\\
rums &= p\_qus(P^{(1)}) * N^{(5)} * P_c^{(1)} && (78)
\end{aligned}
$$

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	0.007	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)

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

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

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

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

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

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

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

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

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 ($\left.\frac{\partial B_c}{\partial t}\right|_{O^{(3)}}^{rsp}$)

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

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

$$eO2 = \frac{O2o^3}{O2o^3 + p\_chdo^3} \tag{100}$$

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

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 ($\left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(7)}}^{cor}$)

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

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

$$run = rug - \left.\frac{\partial B_c}{\partial t}\right|_{O^{(3)}}^{rsp} \tag{103}$$

2.2 Nitrate component of bacteria functional group

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

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

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

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

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

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

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

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

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

$$
\begin{aligned}
\left.\frac{\partial B_n}{\partial t}\right|_{R_n^{(1)}}^{upt} &= Qnc(R^{(1)}) * \left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(1)}}^{upt} \\
\left.\frac{\partial B_n}{\partial t}\right|_{R_n^{(6)}}^{upt} &= Qnc(R^{(6)}) * \left.\frac{\partial B_c}{\partial t}\right|_{R_c^{(6)}}^{upt} \\
rumn &= rumn3 + rumn4 \\
rumn3 &= p\_qun * N^{(3)} * B_c * cqun3 \\
rumn4 &= p\_qun * N^{(4)} * B_c \\
cqun3 &= \frac{p\_ln4}{p\_ln4 + N^{(4)}}
\end{aligned}
$$

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

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

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)

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

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

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

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

$$\left.\frac{\partial N^{(4)}}{\partial t}\right|_{bio}^{-} = +\sum_{j=5,6}\left.\frac{\partial Z_n^{(j)}}{\partial t}\right|_{N^{(4)}}^{rel} \tag{143}$$

$$\left.\frac{\partial R_n^{(1)}}{\partial t}\right|_{bio}^{-} = +\sum_{j=5,6}\left.\frac{\partial Z_n^{(j)}}{\partial t}\right|_{R^{(1)}}^{rel} \tag{144}$$

$$\left.\frac{\partial R_n^{(6)}}{\partial t}\right|_{bio}^{-} = +\sum_{j=5,6}\left.\frac{\partial Z_n^{(j)}}{\partial t}\right|_{R^{(6)}}^{rel} \tag{145}$$

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

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

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

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 ($\left.\frac{\partial Z_n}{\partial t}\right|_{R^{(1)}}^{rel}$, $\left.\frac{\partial Z_n}{\partial t}\right|_{R^{(6)}}^{rel}$)

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

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

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

3.5 Phosphorus component of microzooplankton functional group

$$
\begin{aligned}
\left.\frac{\partial Z_p}{\partial t}\right|_{bio}^{-} &= +\sum_{X=P,B,Z}\left(\left.\frac{\partial Z_c}{\partial t}\right|_{X_c}^{prd} * Qpc(X)\right) + \\
&\quad -\left.\frac{\partial Z_p}{\partial t}\right|_{N^{(1)}}^{rel} - \left.\frac{\partial Z_p}{\partial t}\right|_{R_p^{(1)}}^{rel} - \left.\frac{\partial Z_p}{\partial t}\right|_{R_p^{(6)}}^{rel} + \\
&\quad -\left\{\sum_{k=4,5,6}\left.\frac{\partial Z_c}{\partial t}\right|_{Z_c^{(k)}}^{prd} * Qpc(Z^{(k)})\right\} \qquad (150)\\
\left.\frac{\partial N^{(1)}}{\partial t}\right|_{bio}^{-} &= +\sum_{j=5,6}\left.\frac{\partial Z_p^{(j)}}{\partial t}\right|_{N^{(1)}}^{rel} \qquad (151)\\
\left.\frac{\partial R_p^{(1)}}{\partial t}\right|_{bio}^{-} &= +\sum_{j=5,6}\left.\frac{\partial Z_p^{(j)}}{\partial t}\right|_{R_p^{(1)}}^{rel} \qquad (152)\\
\left.\frac{\partial R_p^{(6)}}{\partial t}\right|_{bio}^{-} &= +\sum_{j=5,6}\left.\frac{\partial Z_p^{(j)}}{\partial t}\right|_{R_p^{(6)}}^{rel} \qquad (153)
\end{aligned}
$$

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

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

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

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 ($\left.\frac{\partial Z_p}{\partial t}\right|^{rel}_{R_p^{(1)}}$, $\left.\frac{\partial Z_p}{\partial t}\right|^{rel}_{R_p^{(6)}}$)

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

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

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

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)

$$\begin{aligned}
\left.\frac{\partial Z_c^{(3)}}{\partial t}\right|_{Z_c^{(4)}}^{prd} &= rum * \frac{Z_c^{(4)}}{ZIm} \\
\left.\frac{\partial Z_c^{(3)}}{\partial t}\right|_{Z_c^{(3)}}^{prd} &= rum * \frac{Z_c^{(3)}}{ZIm} \\
rum &= et * p_sum(Z^{(3)}) * \frac{p_vum(Z^{(3)}) * ZIm}{p_vum(Z^{(3)}) * ZIm + p_sum(Z^{(3)})} * Z_c^{(3)} \\
ZIm &= Z_c^{(3)} + Z_c^{(4)} \\
et &= (p_q10)^{\frac{t-t_o}{t_o}}
\end{aligned}$$

Mesozooplankton parameters				Details
		$Z^{(3)}$	$Z^{(4)}$	
d_{01}	$pq10$	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)

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

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

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				

$$\left.\frac{\partial Z_c}{\partial t}\right|_{O^{(3)}}^{rsp} = rra\_c + rrs\_c \tag{163}$$
$$rra\_c = prI\_R6 * rut\_c \tag{164}$$
$$rrs\_c = p\_srs(Z) * et * Z_c \tag{165}$$
$$prI\_R6 = 1 - p\_puI\_u(Z) - p\_peI\_R6(Z) \tag{166}$$

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

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_{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 $n\_l = 1$)

$$\frac{\partial Z_c}{\partial t}\Big|_{R_c^{(6)}}^{rel} = rd\_c + ret\_c + rdo\_c + pe\_R6c * rut\_c \tag{167}$$
$$rd\_c = p\_sd(Z) * et * Z_c \tag{168}$$
$$ret\_c = p\_peI\_R6(Z) * rut\_c \tag{169}$$
$$rdo\_c = p\_sdo(Z) * (Z_c)^{p\_sds(Z)} * Z_c \tag{170}$$
$$\tag{171}$$

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

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

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

$$temp\_n = \frac{pu\_e\_n}{Qnc(Z)} \tag{172}$$
$$temp\_p = \frac{pu\_e\_p}{Qpc(Z)} \tag{173}$$
$$pu\_e\_n = \frac{ru\_n}{p\_zero + ru\_c} \tag{174}$$
$$pu\_e\_p = \frac{ru\_p}{p\_zero + ru\_c} \tag{175}$$
$$ru\_c = p\_puI\_u(Z) * rut\_c \tag{176}$$
$$ru\_n = [p\_puI\_u(Z) + prI\_R6_i] * rut\_n \tag{177}$$
$$ru\_p = [p\_puI\_u(Z) + prI\_R6_i] * rut\_p \tag{178}$$
$$\tag{179}$$

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

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)

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

$$rd\_n = p\_sd(Z) * et * Z_n \tag{193}$$

$$ret\_n = p\_peI\_R6(Z) * rut\_n \tag{194}$$

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

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