1. Organic Carbon

The present model has three state variables for organic carbon: refractory particulate, labile particulate, and dissolved.

1.1. RPOC and LPOC

Labile and refractory distinctions are based on the time scale of decomposition. Labile particulate organic carbon with a decomposition time scale of days to weeks decomposes rapidly in the water column or in the sediments. Refractory particulate organic carbon with a longer than- weeks decomposition time scale decomposes slowly, primarily in the sediments, and may contribute to sediment oxygen demand years after decomposition.

For labile and refractory particulate organic carbon, sources and sinks included in the model are:

- Algal predation
- Dissolution to dissolved organic carbon
- Settling
- External loads.

The governing equations for refractory and labile particulate organic carbons are:

$$\frac{\partial RPOC}{\partial t} = \sum_{x=c,d,g,m} FCRP_x \, PR_x \, B_x - K_{RPOC} \, RPOC + \frac{\partial}{\partial Z}(WS_{RP} \, RPOC) + \frac{WRPOC}{V}$$

$$\frac{\partial LPOC}{\partial t} = \sum_{x=c,d,g,m} FCLP_x \, PR_x \, B_x - K_{LPOC} \, LPOC + \frac{\partial}{\partial Z}(WS_{LP} \, LPOC) + \frac{WLPOC}{V}$$

Where

RPOC = concentration of refractory particulate organic carbon (g C m^{-3})

LPOC = concentration of labile particulate organic carbon (g C m^{-3})

FCRP = fraction of predated carbon produced as refractory particulate organic carbon

FCLP = fraction of predated carbon produced as labile particulate organic carbon

K_{RPOC} = dissolution rate of refractory particulate organic carbon (day^{-1})

KL_{POC} = dissolution rate of labile particulate organic carbon (day^{-1})

WS_{RP} = settling velocity of refractory particulate organic matter (m day^{-1})

WS_{LP} = settling velocity of labile particulate organic matter (m day^{-1})

WRPOC = external loads of refractory particulate organic carbon (g C day^{-1})

WLPOC = external loads of labile particulate organic carbon (g C day^{-1}).

1.2 DOC

Sources and sinks for dissolved organic carbon included in the model are:

- Algal excretion (exudation) and predation
- Dissolution from refractory and labile particulate organic carbon
- Heterotrophic respiration of dissolved organic carbon (decomposition)
- Denitrification
- External loads

The kinetic equation describing these processes is:

$$\frac{\partial DOC}{\partial t} = \sum_{x=c,d,g,m} \left(\left[FCD_x + (1 - FCD_x) \left(\frac{KHR_x}{KHR_x + DO} \right) \right] BM_x + FCDP_x PR_x \right) B_x$$

$$+ K_{RPOC}\, RPOC + K_{LPOC}\, LPOC - K_{HR}\, DOC - Denit\, DOC + \frac{WDOC}{V}$$

Where

DOC = concentration of dissolved organic carbon (g C m^{-3})

FCD_x = fraction of basal metabolism exuded as dissolved organic carbon at infinite dissolved oxygen concentration for algal group x

KHR_x = half-saturation constant of dissolved oxygen for algal dissolved organic carbon excretion for group x (g O2 m^{-3})

DO = dissolved oxygen concentration (g O2 m^{-3})

FCDP = fraction of predated carbon produced as dissolved organic carbon

K_{HR} = heterotrophic respiration rate of dissolved organic carbon (day^{-1})

Denit = denitrification rate (day^{-1})

BFDOC = benthic flux of dissolved organic carbon in bottom layer only (g C m^{-2} day^{-1})

WDOC = external loads of dissolved organic carbon (g C day^{-1}).

2. Nitrogen

The present model has five state variables for nitrogen: three organic forms (refractory particulate, labile particulate, and dissolved) and two inorganic forms (ammonium and nitrate).

The nitrate state variable in the model represents the sum of nitrate and nitrite.

2.1. RPON and LPON

For refractory and labile particulate organic nitrogen, sources and sinks included in the model are:

- Algal basal metabolism and predation
- Dissolution to dissolved organic nitrogen
- Settling
- External loads

The kinetic equations for refractory and labile particulate organic nitrogen are:

$$\frac{\partial RPON}{\partial t} = \sum_{x=c,d,g,m}(FNR_x\ BM_x + FNRP_x\ PR_x)\ ANC_x\ B_x - K_{RPON}\ RPON +$$

$$\frac{\partial}{\partial Z}(WS_{RP}\ RPON) + \frac{WRPON}{V}$$

$$\frac{\partial LPON}{\partial t} = \sum_{x=c,d,g,m}(FNL_x\ BM_x + FNLP_x\ PR_x)\ ANC_x\ B_x - K_{LPON}\ LPON +$$

$$\frac{\partial}{\partial Z}(WS_{LP}\ LPON) + \frac{WLPON}{V}$$

Where

RPON = concentration of refractory particulate organic nitrogen (g N m^{-3})

LPON = concentration of labile particulate organic nitrogen (g N m^{-3})

FNR_x = fraction metabolized nitrogen by algal group x as refractory particulate

organic nitrogen

FNL_x = fraction of metabolized nitrogen by algal group x produced as labile particulate organic nitrogen

FNRP = fraction of predated nitrogen produced as refractory particulate organic nitrogen

FNLP = fraction of predated nitrogen produced as labile particulate organic nitrogen

ANC_x = nitrogen-to-carbon ratio in algal group x (g N per g C)

K_{RPON} = hydrolysis rate of refractory particulate organic nitrogen (day^{-1})

K_{LPON} = hydrolysis rate of labile particulate organic nitrogen (day^{-1})

WRPON = external loads of refractory particulate organic nitrogen (g N day^{-1})

WLPON = external loads of labile particulate organic nitrogen (g N day^{-1})

2.2. DON

Sources and sinks for dissolved organic nitrogen included in the model are:

- Algal basal metabolism and predation
- Dissolution from refractory and labile particulate organic nitrogen
- Mineralization to ammonium
- External loads.

The kinetic equation describing these processes is:

$$\frac{\partial DON}{\partial t} = \sum_{x=c,d,g,m}(FND_x\ BM_x + FNDP_x\ PR_x)\ ANC_x\ B_x + K_{RPON}\ RPON +$$

$$K_{LPON}\ LPON - K_{DON}\ DON + \frac{BFDON}{\Delta Z} + \frac{WDON}{V}$$

Where

DON = concentration of dissolved organic nitrogen (g N m^{-3})

FND_x = fraction of metabolized nitrogen by algal group x produced as dissolved organic nitrogen

FNDP = fraction of predated nitrogen produced as dissolved organic nitrogen

K_{DON} = mineralization rate of dissolved organic nitrogen (day^{-1})

BFDON = benthic flux of dissolved organic nitrogen in bottom layer only (g C m^{-2} day^{-1}).

WDON = external loads of dissolved organic nitrogen (g N day^{-1}).

2.3. NH4

Sources and sinks for ammonia nitrogen included in the model are:

- Algal basal metabolism, predation, and uptake
- Mineralization from dissolved organic nitrogen
- Nitrification to nitrate
- Sediment-water exchange for the bottom layer only
- External loads

$$\frac{\partial NH4}{\partial t} = \sum_{x=c,d,g,m}(FNI_x\ BM_x + FNIP_x\ PR_x - PN_x\ P_x)\ ANC_x\ B_x + K_{DON}\ DON -$$

$$KNit\ NH4 + \frac{BFNH4}{\Delta Z} + \frac{WNH4}{V}$$

Where

FNI_x = fraction of metabolized nitrogen by algal group x produced as inorganic nitrogen

FNIP = fraction of predated nitrogen produced as inorganic nitrogen

PN_x = preference for ammonium uptake by algal group x ($0 \leq PNx \leq 1$)

KNit = nitrification rate (day^{-1})

BFNH4 = sediment-water exchange flux of ammonium (g N m^{-2} day^{-1}), applied to the bottom layer only

WNH4 = external loads of ammonium (g N day^{-1})

2.4. NO3

Sources and sinks for nitrate nitrogen included in the model are (Figure 2.1):

- Algal uptake

• Nitrification from ammonium

• Denitrification to nitrogen gas

• Sediment-water exchange for the bottom layer only

• External loads

The kinetic equation describing these processes is:

$$\frac{\partial NO3}{\partial t} = \sum_{x=c,d,g,m}(PN_x - 1)\, P_x\, ANC_x\, B_x + KNit\, NH4 - ANDC\, Denit\, DOC + \frac{BFNO3}{\Delta Z} + \frac{WNO3}{V}$$

Where

ANDC = mass of nitrate nitrogen reduced per mass of dissolved organic carbon oxidized (0.933 g N per g C)

BFNO3 = sediment-water exchange flux of nitrate (g N m^{-2} day^{-1}), applied to the bottom layer only

WNO3 = external loads of nitrate (g N day^{-1})

3. Phosphorus

The present model has four state variables for phosphorus: three organic forms (refractory particulate, labile particulate, and dissolved) and one inorganic form representing the sum of dissolved and particulate phosphate in the water phase, but exclude phosphate in algae cells.

3.1. RPOP and LPOP

For refractory and labile particulate organic phosphorus, sources and sinks included in the model are:

• Algal basal metabolism and predation

• Dissolution to dissolved organic phosphorus

• Settling

• External loads.

The kinetic equations for refractory and labile particulate organic phosphorus are:

$$\frac{\partial RPOP}{\partial t} = \sum_{x=c,d,g,m}(FPR_x\, BM_x + FPRP_x\, PR_x)\, APC_x\, B_x - K_{RPOP}\, RPOP +$$

$$\frac{\partial}{\partial Z}(WS_{RP}\ RPOP) + \frac{WRPOP}{V}$$

$$\frac{\partial LPOP}{\partial t} = \sum_{x=c,d,g,m}(FPL_x\ BM_x + FPLP_x\ PR_x)\ APC_x\ B_x - K_{LPOP}\ LPOP +$$

$$\frac{\partial}{\partial Z}(WS_{RP}\ LPOP) + \frac{WLPOP}{V}$$

Where
RPOP = concentration of refractory particulate organic phosphorus (g P m^{-3})

LPOP = concentration of labile particulate organic phosphorus (g P m^{-3})

FPR_x = fraction of metabolized phosphorus by algal group x produced as refractory particulate organic phosphorus

FPL_x = fraction of metabolized phosphorus by algal group x produced as labile particulate organic phosphorus

FPRP = fraction of predated phosphorus produced as refractory particulate organic phosphorus

FPLP = fraction of predated phosphorus produced as labile particulate organic phosphorus

APC = mean algal phosphorus-to-carbon ratio for all algal groups (g P per g C)

K_{RPOP} = hydrolysis rate of refractory particulate organic phosphorus (day^{-1})

K_{LPOP} = hydrolysis rate of labile particulate organic phosphorus (day^{-1})

WRPOP = external loads of refractory particulate organic phosphorus (g P day^{-1})

WLPOP = external loads of labile particulate organic phosphorus (g P day^{-1}).

3.2. DOP

Sources and sinks for dissolved organic phosphorus included in the model are:

- Algal basal metabolism and predation
- Dissolution from refractory and labile particulate organic phosphorus
- Mineralization to phosphate phosphorus
- External loads.

The kinetic equation describing these processes is:

$$\frac{\partial DOP}{\partial t} = \sum_{x=c,d,g,m}(FPD_x\ BM_x + FPDP_x\ PR_x)\ APC_x\ B_x + K_{RPOP}\ RPOP + K_{LPOP}\ LPOP -$$

$$K_{DOP}\ DOP + \frac{WDOP}{V}$$

Where

DOP = concentration of dissolved organic phosphorus (g P m^{-3})

FPD_x = fraction of metabolized phosphorus by algal group x produced as dissolved organic phosphorus

$FPDP_x$ = fraction of predated phosphorus produced as dissolved organic phosphorus

K_{DOP} = mineralization rate of dissolved organic phosphorus (day^{-1})

WDOP = external loads of dissolved organic phosphorus (g P day^{-1})

3.3. PO4

For total phosphate that includes both dissolved and sorbed phosphate in the water phase, sources and sinks included in the model are:

- Algal basal metabolism, predation, and uptake
- Mineralization from dissolved organic phosphorus
- Settling of sorbed phosphate
- Sediment-water exchange of dissolved phosphate for the bottom layer only
- External loads

The kinetic equation describing these processes is:

$$\frac{\partial}{\partial t}(PO4p + PO4d)$$

$$= \sum_{x=c,d,g,m}(FPI_x\ BM_x + FPIP_x\ PR_x - P_x)\ APC_x\ B_x + K_{DOP}\ DOP$$

$$+ \frac{\partial}{\partial Z}(WS_{TSS}\ PO4p) + \frac{BFPO4d}{\Delta Z} + \frac{WPO4p}{V} + \frac{WPO4d}{V}$$

Where

PO4t = total phosphate (g P m^{-3}) = PO4d + PO4p

PO4d = dissolved phosphate (g P m^{-3})

PO4p = particulate (sorbed) phosphate (g P m^{-3})

FPI_x = fraction of metabolized phosphorus by algal group x produced as inorganic phosphorus

FPIP = fraction of predated phosphorus produced as inorganic phosphorus

WS_{TSS} = settling velocity of suspended solid (m day^{-1}), provided by the hydrodynamic model

BFPO4d = sediment-water exchange flux of phosphate (g P m^{-2} day^{-1}), applied to the bottom layer only

WPO4t = external loads of total phosphate (g P day^{-1}).