Appendix 2. Main differential equations used in the Ecological sub-model. Part of these formulae have already been described in Cugier et al. (2005a), but changes and new equations have been introduced to account for the particularities of the estuary. Further details can be found online at the model webpage *[http://www.ifremer.fr/docmars/html/doc.module.biolo.html]*

1. Ammonium

$$\frac{dX_1}{dt} = (k_{Nminer} \cdot f_T \cdot X_{12}) - (k_{nitrif} \cdot X_1) - \left[\frac{f_{NH4diat}}{f_{Ndiat}} \cdot \mu_{maxdiat} \cdot f_T \cdot \min(f_{Ndiat}, f_{Sidiat}, f_{Pdiat}, f_{Ldiat}) \cdot X_6 + \frac{f_{NH4diatfresh}}{f_{Ndiatfresh}} \cdot \mu_{maxdiatfresh} \cdot f_T \cdot \min(f_{Ndiatfresh}, f_{Sidiatfresh}, f_{Pdiatfresh}, f_{Ldiatfresh}) \cdot X_7 + \frac{f_{NH4gra}}{f_{Ngra}} \cdot \mu_{maxgra} \cdot f_T \cdot \min(f_{Ngra}, f_{Pgra}, f_{Lgra}) \cdot X_9 + \frac{f_{NH4nano}}{f_{Nnano}} \cdot \mu_{maxnano} \cdot f_T \cdot \min(f_{Nnano}, f_{Pnano}, f_{Lnano}) \cdot X_{10} + \frac{f_{NH4dino}}{f_{Ndino}} \cdot \mu_{maxdino} \cdot f_T \cdot \min(f_{Ndino}, f_{Pdino}, f_{Ldino}) \cdot X_{11}\right] + excr_{meszoo} \cdot f_T \cdot G_{meszoo} \cdot X_{15} + excr_{miczoo} \cdot f_T \cdot G_{miczoo} \cdot X_{16} + excr_{miczoofresh} \cdot f_T \cdot G_{miczoofresh} \cdot X_{17}$$

2. Nitrate

$$\frac{dX_2}{dt} = (k_{nitrif} \cdot X_1) - \left[\frac{f_{NO3diat}}{f_{Ndiat}} \cdot \mu_{maxdiat} \cdot f_T \cdot \min(f_{Ndiat}, f_{Sidiat}, f_{Pdiat}, f_{Ldiat}) \cdot X_6 + \frac{f_{NO3diatfresh}}{f_{Ndiatfresh}} \cdot \mu_{maxdiatfresh} \cdot f_T \cdot \min(f_{Ndiatfresh}, f_{Sidiatfresh}, f_{Pdiatfresh}, f_{Ldiatfresh}) \cdot X_7 + \frac{f_{NO3gra}}{f_{Ngra}} \cdot \mu_{maxgra} \cdot f_T \cdot \min(f_{Ngra}, f_{Pgra}, f_{Lgra}) \cdot X_9 + \frac{f_{NO3nano}}{f_{Nnano}} \cdot \mu_{maxnano} \cdot f_T \cdot \min(f_{Nnano}, f_{Pnano}, f_{Lnano}) \cdot X_{10} + \frac{f_{NO3dino}}{f_{Ndino}} \cdot \mu_{maxdino} \cdot f_T \cdot \min(f_{Ndino}, f_{Pdino}, f_{Ldino}) \cdot X_{11}\right]$$

3. Dissolved silica

$$\frac{dX_3}{dt} = (k_{Sidiss} \cdot f_T \cdot X_{13}) - r_{SiN} \cdot [\mu_{maxdiat} \cdot f_T \cdot \min(f_{Ndiat}, f_{Sidiat}, f_{Pdiat}, f_{Ldiat}) \cdot X_6 + \mu_{maxdiatfresh} \cdot f_T \cdot \min(f_{Ndiatfresh}, f_{Sidiatfresh}, f_{Pdiatfresh}, f_{Ldiatfresh}) \cdot X_7]$$

4. Dissolved phosphorus

$$\frac{dX_4}{dt} = (k_{Pminer} \cdot X_{14}) - r_{PN} \cdot [\mu_{maxdiat} \cdot f_T \cdot \min(f_{Ndiat}, f_{Sidiat}, f_{Pdiat}, f_{Ldiat}) \cdot X_6 + \mu_{maxdiatfresh} \cdot f_T \cdot \min(f_{Ndiatfresh}, f_{Sidiatfresh}, f_{Pdiatfresh}, f_{Ldiatfresh}) \cdot X_7 + \mu_{maxgra} \cdot f_T \cdot \min(f_{Ngra}, f_{Pgra}, f_{Lgra}) \cdot X_9 + \mu_{maxnano} \cdot f_T \cdot \min(f_{Nnano}, f_{Pnano}, f_{Lnano}) \cdot X_{10} + \mu_{maxdino} \cdot f_T \cdot \min(f_{Ndino}, f_{Pdino}, f_{Ldino}) \cdot X_{11}] + r_{PN} \cdot (excr_{meszoo} \cdot f_T \cdot G_{meszoo} \cdot X_{15} + excr_{miczoo} \cdot f_T \cdot G_{miczoo} \cdot X_{16} + excr_{miczoofresh} \cdot f_T \cdot G_{miczoofresh} \cdot X_{17}) - k_{adsorp} \cdot (Q_{adsorpmax} \cdot X_{SM} - X_5) \cdot X_4 + \frac{k_{desorp} \cdot X_5}{Q_{adsorpmax} \cdot X_{SM}} \cdot X_5$$

5. Particulate exchangeable phosphorus

$$\frac{dX_5}{dt} = k_{adsorp} \cdot (Q_{adsorpmax} \cdot X_{SM} - X_5) \cdot X_4 - \frac{k_{desorp} \cdot X_5}{Q_{adsorpmax} \cdot X_{SM}} \cdot X_5$$

6. Diatoms (in N units)

$$\frac{dX_6}{dt} = \left[\mu_{maxdiat} \cdot f_T \cdot \min(f_{Ndiat}, f_{Sidiat}, f_{Pdiat}, f_{Ldiat}) - m_{diat} \cdot f_T\right] \cdot X_6 - \left[\frac{\mu_{maxmeszoo} \cdot f_T \cdot G_{meszoo} \cdot Mesz_{captdiato} \cdot X_6}{Mesz_{captdiato} \cdot X_6 + Mesz_{captdino} \cdot X_{11} + Mesz_{captmicz} \cdot X_{16}}\right] \cdot X_{15} - \left[\frac{\mu_{maxmiczoo} \cdot f_T \cdot G_{miczoo} \cdot Micz_{captdiato} \cdot X_6}{Micz_{captdiato} \cdot X_6 + Micz_{captnano} \cdot X_{10} + Micz_{captdet} \cdot \min\left(X_{12}, \frac{1}{r_{PN}} X_{14}\right)}\right] \cdot X_{16}$$

and for the bottom water layer only, benthic grazing, falling and resuspension:

$$\frac{dX_6}{dt} = \frac{dX_6}{dt} - \frac{filtbenth_{max} \cdot f_{SINUS}}{D_{bottom}} \cdot X_6 - v_{falldiato} \cdot X_6 + flx_{eros} \cdot \left(\frac{u_{bottom}}{vcrit_{eros}} - 1\right)$$

7. Freshwater diatoms (in N units)

$$\frac{dX_7}{dt} = \left[\mu_{maxdiatfresh} \cdot f_T \cdot \min(f_{Ndiatfresh}, f_{Sidiatfresh}, f_{Pdiatfresh}, f_{Ldiatfresh}) - m_{diatfresh} \cdot f_T\right] \cdot X_7 - \left[\frac{\mu_{maxmiczoofresh} \cdot f_T \cdot G_{miczoofresh} \cdot Miczfresh_{captdiato} \cdot X_7}{Miczfresh_{captdiato} \cdot X_7 + Miczfresh_{captchlo} \cdot X_9 + Miczfresh_{captdet} \cdot \min\left(X_{12}, \frac{1}{r_{PN}} X_{14}\right)}\right] \cdot X_{17}$$

and for the bottom water layer only, benthic grazing, falling and resuspension:

$$\frac{dX_7}{dt} = \frac{dX_7}{dt} - \frac{filtbenth_{max} \cdot f_{SINUS}}{D_{bottom}} \cdot X_7 - v_{falldiato} \cdot X_7 + flx_{eros} \cdot \left(\frac{u_{bottom}}{vcrit_{eros}} - 1\right)$$

8. Benthic diatoms (in N units)

$$\frac{dX_8}{dt} = v_{falldiato} \cdot (X_6 + X_7) - flx_{eros} \cdot \left(\frac{u_{bottom}}{vcrit_{eros}} - 1\right) - m_{diatsed} \cdot f_T \cdot X_8$$

9. Green algae (in N units)

$$\frac{dX_9}{dt} = \left[\mu_{maxgra} \cdot f_T \cdot \min\left(f_{Ngra}, f_{Pgra}, f_{Lgra}\right) - m_{gra} \cdot f_T\right] \cdot X_9 - \left[\frac{\mu_{maxmiczoofresh} \cdot f_T \cdot G_{miczoofresh} \cdot Miczfresh_{captchlo} \cdot X_9}{Miczfresh_{captdiato} \cdot X_7 + Miczfresh_{captchlo} \cdot X_9 + Miczfresh_{captdet} \cdot \min\left(X_{12}, \frac{1}{r_{PN}} X_{14}\right)}\right] \cdot X_{17}$$

and for the bottom water layer only, benthic grazing:

$$\frac{dX_9}{dt} = \frac{dX_9}{dt} - \frac{filtbenth_{max} \cdot f_{SINUS}}{D_{bottom}} \cdot X_9$$

10. Nanophytoplankton (in N units)

$$\frac{dX_{10}}{dt} = \left[\mu_{maxnano} \cdot f_T \cdot \min(f_{Nnano}, f_{Pnano}, f_{Lnano}) - m_{nano} \cdot f_T\right] \cdot X_{10} - \left[\frac{\mu_{maxmiczoo} \cdot f_T \cdot G_{miczoo} \cdot Micz_{captnano} \cdot X_{10}}{Micz_{captdiato} \cdot X_6 + Micz_{captnano} \cdot X_{10} + Micz_{captdet} \cdot \min\left(X_{12}, \frac{1}{r_{PN}} X_{14}\right)}\right] \cdot X_{16}$$

and for the bottom water layer only, benthic grazing:

$$\frac{dX_{10}}{dt} = \frac{dX_{10}}{dt} - \frac{filtbenth_{max} \cdot f_{SINUS}}{D_{bottom}} \cdot X_{10}$$

11. Dinoflagellates (in N units)

$$\frac{dX_{11}}{dt} = \left[\mu_{maxdino} \cdot f_T \cdot \min(f_{Ndino}, f_{Pdino}, f_{Ldino}) - m_{dino} \cdot f_T\right] \cdot X_{11} - \left[\frac{\mu_{maxmeszoo} \cdot f_T \cdot G_{meszoo} \cdot Mesz_{captdino} \cdot X_{11}}{Mesz_{captdiato} \cdot X_6 + Mesz_{captdino} \cdot X_{11} + Mesz_{captmicz} \cdot X_{16}}\right] \cdot X_{15}$$

and for the bottom water layer only, benthic grazing:

$$\frac{dX_{11}}{dt} = \frac{dX_{11}}{dt} - \frac{filtbenth_{max} \cdot f_{SINUS}}{D_{bottom}} \cdot X_{11}$$

12. Detrital organic nitrogen

$$\frac{dX_{12}}{dt} = -(k_{Nminer} \cdot f_T \cdot X_{12}) + (m_{diat} \cdot f_T \cdot X_6) + (m_{diatfresh} \cdot f_T \cdot X_7) + \left(m_{gra} \cdot f_T \cdot X_9\right) + (m_{nano} \cdot f_T \cdot X_{10}) + (m_{dino} \cdot f_T \cdot X_{11}) + [(m_{meszoo} + m_{fzoo} \cdot X_{15} \cdot f_T) + (1 - Assim_{meszoo}) \cdot \mu_{maxmeszoo} \cdot f_T \cdot G_{meszoo}] \cdot X_{15} + \left[(m_{miczoo} + m_{fzoo} \cdot X_{16} \cdot f_T) + (1 - Assim_{miczoo}) \cdot \mu_{maxmiczoo} \cdot f_T \cdot G_{miczoo} - \frac{\mu_{maxmiczoo} \cdot f_T \cdot G_{miczoo} \cdot Micz_{captdet} \cdot \min\left(X_{12}, \frac{1}{r_{PN}} X_{14}\right)}{Micz_{captdiato} \cdot X_6 + Micz_{captnano} \cdot X_{10} + Micz_{captdet} \cdot \min\left(X_{12}, \frac{1}{r_{PN}} X_{14}\right)}\right] \cdot X_{16} + \left[(m_{miczoofresh} + m_{fzoo} \cdot X_{17} \cdot f_T) + (1 - Assim_{miczoofresh}) \cdot \mu_{maxmiczoofresh} \cdot f_T \cdot G_{miczoofresh} - \frac{\mu_{maxmiczoofresh} \cdot f_T \cdot G_{miczoofresh} \cdot Miczfresh_{captdet} \cdot \min\left(X_{12}, \frac{1}{r_{PN}} X_{14}\right)}{Micz_{captdiato} \cdot X_6 + Micz_{captnano} \cdot X_{10} + Micz_{captdet} \cdot \min\left(X_{12}, \frac{1}{r_{PN}} X_{14}\right)}\right] \cdot X_{17}$$

and for the bottom water layer only, benthic grazing, falling and resuspension:

$$\frac{dX_{12}}{dt} = \frac{dX_{12}}{dt} + \frac{filtbenth_{max} \cdot f_{SINUS}}{D_{bottom}} \cdot (X_6 + X_7 + X_9 + X_{10} + X_{11}) - v_{falldet} \cdot X_{12} + flx_{eros} \cdot \left(\frac{u_{bottom}}{vcrit_{eros}} - 1\right)$$

13. Detrital biogenic Silica

$$\frac{dX_{13}}{dt} = -(k_{Sidiss} \cdot f_T \cdot X_{13}) + (m_{diat} \cdot f_T \cdot r_{SiN} \cdot X_6) + (m_{diatfresh} \cdot f_T \cdot r_{SiN} \cdot X_7) + \left[\frac{\mu_{maxmeszoo} \cdot f_T \cdot G_{meszoo} \cdot Mesz_{captdiato} \cdot X_6}{Mesz_{captdiato} \cdot X_6 + Mesz_{captdino} \cdot X_{11} + Mesz_{captmicz} \cdot X_{16}}\right] \cdot X_{15} \cdot r_{SiN} + \left[\frac{\mu_{maxmiczoo} \cdot f_T \cdot G_{miczoo} \cdot Micz_{captdiato} \cdot X_6}{Micz_{captdiato} \cdot X_6 + Micz_{captnano} \cdot X_{10} + Micz_{captdet} \cdot \min\left(X_{12}, \frac{1}{r_{PN}} X_{14}\right)}\right] \cdot X_{16} \cdot r_{SiN} + \left[\frac{\mu_{maxmiczoofresh} \cdot f_T \cdot G_{miczoofresh} \cdot Miczfresh_{captdiato} \cdot X_7}{Miczfresh_{captdiato} \cdot X_7 + Miczfresh_{captchlo} \cdot X_9 + Miczfresh_{captdet} \cdot \min\left(X_{12}, \frac{1}{r_{PN}} X_{14}\right)}\right] \cdot X_{17} \cdot r_{SiN}$$

and for the bottom water layer only, benthic grazing, falling and resuspension:

$$\frac{dX_{13}}{dt} = \frac{dX_{13}}{dt} + \frac{filtbenth_{max} \cdot f_{SINUS}}{D_{bottom}} \cdot (X_6 + X_7) \cdot r_{SiN} - v_{falldet} \cdot X_{13} + flx_{eros} \cdot \left(\frac{u_{bottom}}{vcrit_{eros}} - 1\right) \cdot r_{SiN}$$

14. Detrital organic phosphorus

$$\frac{dX_{14}}{dt} = -(k_{Pminer} \cdot f_T \cdot X_{14}) + r_{PN} \cdot f_T \cdot \left[(m_{diat} \cdot X_6) + (m_{diatfresh} \cdot X_7) + \left(m_{gra} \cdot X_9\right) + (m_{nano} \cdot X_{10}) + (m_{dino} \cdot X_{11})\right] + \left[(m_{meszoo} + m_{fzoo} \cdot X_{15} \cdot f_T) + (1 - Assim_{meszoo}) \cdot \mu_{maxmeszoo} \cdot f_T \cdot G_{meszoo}\right] \cdot X_{15} \cdot r_{PN} + \left[(m_{miczoo} + m_{fzoo} \cdot X_{16} \cdot f_T) + (1 - Assim_{miczoo}) \cdot \mu_{maxmiczoo} \cdot f_T \cdot G_{miczoo} - \frac{\mu_{maxmiczoo} \cdot f_T \cdot G_{miczoo} \cdot Micz_{captdet} \cdot \min\left(X_{12}, \frac{1}{r_{PN}} X_{14}\right)}{Micz_{captdiato} \cdot X_6 + Micz_{captnano} \cdot X_{10} + Micz_{captdet} \cdot \min\left(X_{12}, \frac{1}{r_{PN}} X_{14}\right)}\right] \cdot X_{16} \cdot r_{PN} + \left[(m_{miczoofresh} + m_{fzoo} \cdot X_{17} \cdot f_T) + (1 - Assim_{miczoofresh}) \cdot \mu_{maxmiczoofresh} \cdot f_T \cdot G_{miczoofresh} - \frac{\mu_{maxmiczoofresh} \cdot f_T \cdot G_{miczoofresh} \cdot Miczfresh_{captdet} \cdot \min\left(X_{12}, \frac{1}{r_{PN}} X_{14}\right)}{Micz_{captdiato} \cdot X_6 + Micz_{captnano} \cdot X_{10} + Micz_{captdet} \cdot \min\left(X_{12}, \frac{1}{r_{PN}} X_{14}\right)}\right] \cdot X_{17} \cdot r_{PN}$$

and for the bottom water layer only, benthic grazing, falling and resuspension:

$$\frac{dX_{14}}{dt} = \frac{dX_{14}}{dt} + \frac{filtbenth_{max} \cdot f_{SINUS}}{D_{bottom}} \cdot (X_6 + X_7 + X_9 + X_{10} + X_{11}) \cdot r_{PN} - v_{falldet} \cdot X_{14} + flx_{eros} \cdot \left(\frac{u_{bottom}}{vcrit_{eros}} - 1\right) \cdot r_{PN}$$

15. Mesozooplankton (in N units)

$$\frac{dX_{15}}{dt} = \left[(\mu_{maxmeszoo} \cdot Assim_{meszoo} \cdot f_T \cdot G_{meszoo}) - (excr_{meszoo} \cdot f_T \cdot X_{15}) - (m_{meszoo} + m_{fzoo} \cdot X_{15} \cdot f_T)\right] \cdot X_{15}$$

16. Microzooplankton (in N units)

$$\frac{dX_{16}}{dt} = [(\mu_{maxmiczoo} \cdot Assim_{miczoo} \cdot f_T \cdot G_{miczoo}) - (excr_{miczoo} \cdot f_T \cdot X_{16}) - (m_{miczoo} + m_{fzoo} \cdot X_{16} \cdot f_T)] \cdot X_{16} - \left[\frac{\mu_{maxmeszoo} \cdot f_T \cdot G_{meszoo} \cdot Mesz_{captmicz} \cdot X_{16}}{Mesz_{captdiato} \cdot X_6 + Mesz_{captdino} \cdot X_{11} + Mesz_{captmicz} \cdot X_{16}}\right] \cdot X_{15}$$

17. Freshwater microzooplankton (in N units)

$$\frac{dX_{17}}{dt} = \left[\left(\mu_{maxmiczoofresh} \cdot Assim_{miczoofresh} \cdot f_T \cdot G_{miczoofresh}\right) - (excr_{miczoofresh} \cdot f_T \cdot X_{17}) - (m_{miczoofresh} + m_{fzoo} \cdot X_{17} \cdot f_T)\right] \cdot X_{17}$$

18. Oxygen

$$\frac{dX_{18}}{dt} = r_{PS} \cdot r_{O2N} \cdot \left[\mu_{maxdiat} \cdot f_T \cdot \min(f_{Ndiat}, f_{Sidiat}, f_{Pdiat}, f_{Ldiat}) \cdot X_6 + \mu_{maxdiatfresh} \cdot f_T \cdot \min(f_{Ndiatfresh}, f_{Sidiatfresh}, f_{Pdiatfresh}, f_{Ldiatfresh}) \cdot X_7 + \mu_{maxgra} \cdot f_T \cdot \min(f_{Ngra}, f_{Pgra}, f_{Lgra}) \cdot X_9 + \mu_{maxnano} \cdot f_T \cdot \min(f_{Nnano}, f_{Pnano}, f_{Lnano}) \cdot X_{10} + \mu_{maxdino} \cdot f_T \cdot \min(f_{Ndino}, f_{Pdino}, f_{Ldino}) \cdot X_{11}\right] - r_{O2N} \cdot f_T \cdot \left[\theta_{respphyto} \cdot \left((1 - f_{Ldiat}) \cdot X_6 + (1 - f_{Ldino}) \cdot X_{11} + (1 - f_{Lnano}) \cdot X_{10} + (1 - f_{Lfreshdiat}) \cdot X_7 + \left(1 - f_{Lfreshgra}\right) \cdot X_9\right) + \theta_{respzoo} \cdot (X_{15} + X_{16} + X_{17})\right] - K_{O2reminer} \cdot r_{O2N} \cdot X_{12} - K_{nitrif} \cdot r_{O2nitrif} \cdot X_1$$

and for the surface water layer only:

$$\frac{dX_{18}}{dt} = \frac{dX_{18}}{dt} + \frac{0.64 + 0.0256 \cdot \left(\frac{Wind}{0.447}\right)^2}{D_{surface}} \cdot (X_{SatO2} - X_{18})$$

19. Additional specifications

$$G_{meszoo} = 1 - \exp\left(-\gamma_{meszoo}\left(Mesz_{captdiat} \cdot X_6 + Mesz_{captdino} \cdot X_{11} + Mesz_{captmicz} \cdot X_{16} - Pr_{thresmeszoo}\right)\right)$$

$$G_{miczoo} = \frac{Micz_{captdiato} \cdot X_6 + Micz_{captnano} \cdot X_{10} + Micz_{captdet} \cdot \min\left(X_{12}, \frac{1}{r_{PN}} X_{14}\right) - Pr_{thresmiczoo}}{K_{miczoo} + Micz_{captdiato} \cdot X_6 + Micz_{captnano} \cdot X_{10} + Micz_{captdet} \cdot \min\left(X_{12}, \frac{1}{r_{PN}} X_{14}\right) - Pr_{thresmiczoo}}$$

$$G_{miczoofresh} = \frac{Miczfresh_{captdiato} \cdot X_7 + Miczfresh_{captchlo} \cdot X_9 + Miczfresh_{captdet} \cdot \min\left(X_{12}, \frac{1}{r_{PN}} X_{14}\right) - Pr_{thresmiczoofresh}}{K_{miczoofresh} + Miczfresh_{captdiato} \cdot X_7 + Miczfresh_{captchlo} \cdot X_9 + Miczfresh_{captdet} \cdot \min\left(X_{12}, \frac{1}{r_{PN}} X_{14}\right) - Pr_{thresmiczoofresh}}$$

where:

f_{SINUS} = sinusoidal function for seasonal variability of benthic filtration

f_{NH4}, f_{NO3}, f_N, f_P, f_{Si} = phytoplankton limiting effect of nutrients
f_L = phytoplankton limiting effect of light
X_{SM} = total suspended particulate matter concentration ($g \cdot l^{-1}$)
D_{bottom} = thickness of the bottom water layer (m)
$D_{surface}$ = thickness of the surface water layer (m)
$v_{falldiato}$ = falling velocity of diatoms
u_{bottom} = mean current in the bottom water layer
$wind$ = wind velocity ($m \cdot s^{-1}$)