# Appendix

The rates of change are defined by the following set of equations:

 $\frac{dDIN}{dt}=-V\_{phy}^{N}+X\_{zoo}^{N}$ (1)

 $\frac{dDIP}{dt}=-V\_{phy}^{P}+X\_{zoo}^{P}$ (2)

 $\frac{dC\_{phy}}{dt}=V\_{phy}^{C}-L\_{phy}^{C} $ (3)

 $ \frac{dN\_{phy}}{dt}=V\_{phy}^{N}-L\_{phy}^{C}Q\_{phy}^{N}$ (4)

 $\frac{dP\_{phy}}{dt}=V\_{phy}^{P}-L\_{phy}^{C}Q\_{phy}^{P}$ (5)

 $\frac{dChl}{dt}=\frac{dC\_{phy}}{dt}θ\_{phy}+\frac{dθ\_{phy}}{dt}C\_{phy}$ (6)

 $\frac{dC\_{zoo}}{dt}=V\_{zoo}^{C}-L\_{zoo}^{C}$ (7)

where DIN and DIP are dissolved inorganic nitrogen and phosphorus, C is carbon biomass (POC), N is particulate nitrogen (PON), P is particulate phosphorus (POP) and Chl is chlorophyll of the respective model compartments, *V* is net acquisition by the model compartment in the subscript of the element in the superscript, $X\_{zoo} $is excretion by all zooplankton compartments present, *L* is predation loss of the compartment in the subscript, $Q\_{phy}^{N}$ and $Q\_{phy}^{P}$ are phytoplankton N:C and P:C ratios, and $θ\_{phy}$ is the whole-cell phytoplankton Chl:C ratio. The NNP configuration is obtained by setting all zooplankton-related terms to 0 in Equations (1)-(6).

The change of the whole-cell Chl:C ratio over time is given by

 $\frac{dθ\_{phy}}{dt}=\frac{θ\_{phy}}{ζ^{Chl}}\frac{dV\_{phy}^{C}}{dθ\_{phy}}+\frac{dQ\_{phy}^{N}}{dt}\frac{∂θ\_{phy}}{∂Q\_{phy}^{N}}$ (8)

The first term in Eq. (8), $\frac{θ\_{phy}}{ζ^{Chl}}\frac{dV\_{phy}^{C}}{dθ\_{phy}}$, represents the light dependence of chlorophyll driven by the chloroplast, where $θ\_{phy}$ is the whole cell Chl:C. The second term, $\frac{dQ\_{phy}^{N}}{dt}\left.\frac{∂θ\_{phy}}{∂Q\_{phy}^{N}} \right.$, describes the nutrient-driven change of the whole-cell Chl:C ratio ($θ\_{phy}$) as a consequence of changes in the N:P ratio ($Q\_{phy}^{N}$). The whole-cell Chl:C ratio is a function of the chloroplast Chl:C ratio ($\hat{θ}\_{phy}$) and the N:C ratio:

 $θ\_{phy}=\hat{θ}\_{phy}\left(1- \frac{\frac{1}{2}Q\_{0}^{N}}{Q\_{phy}^{N}}-f\_{v}fv\right)$ (9)

where the optimal allocation factor for nutrient acquisition ($fv$) maximises net balanced growth rate:

 $f\_{v}=\frac{\frac{1}{2}Q\_{0}^{N}}{Q\_{phy}^{N}}-ζ^{Chl}\left(Q\_{phy}^{N}-Q\_{0}^{N}\right)$ (10)

The predation loss terms are defined by:

 $ L\_{x}^{C}=I\_{x}^{C}$, $x \in \left\{phy, zoo\right\}$ (11)

where *I* is ingestion of the compartment *x* by zooplankton.

The excretion terms for N and P are defined by:

 $X\_{zoo}^{N}=L\_{phy}^{C}Q\_{phy}^{N}+(L\_{zoo}^{C}-V\_{zoo}^{C})Q\_{zoo}^{N}$ (12)

 $X\_{zoo}^{P}=L\_{phy}^{C}Q\_{phy}^{P}+(L\_{zoo}^{C}-V\_{zoo}^{C})Q\_{zoo}^{P}$ (13)

The summed root mean square errors (RMSE) of the NNPZ simulations for 4 state variables (DIN, DIP, phytoplankton POC (phyto POC) and zooplankton POC (zoo POC)) of the PU1 and PU2 model simulations are defined by:

 $RMSE=\sqrt{\sum\_{t=1}^{n}\sum\_{i=1}^{r\_{i}}\left(\frac{\left(o^{x}-\overline{m}\_{t}^{x}\right)\_{i}^{2}}{r\_{i}}\right)}$, $ x \in \left\{DIN, DIP, phyto POC, zoo POC\right\}$ (14)

where *o* represents the mesocosm observations, *n* the number of days of the experiments and $r\_{i} $the number of replicates per treatment. $\overline{m}\_{t}^{x}$ is either the model simulation (PU1) or the mean of the 3 ensemble model simulations per treatment (PU2), calculated for the state variable (x) in consideration (see above).

We then normalised the RMSE with the mean of mesocosm observations ($\overline{o}$) of the PU1 and PU2 experiments, respectively, to obtain the coefficient of variation (CV) of the RMSE:

 $CV(RMSE)=\frac{RMSE}{\overline{o}}$