



Supplement of

FABM-PCLake – linking aquatic ecology with hydrodynamics

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S1. FABM-PCLake modules description

FABM-PCLake consists of 9 individual modules, and a brief description of each module is provided here.

Supplemental Table S1 Modules overview for FABM-PCLake

Module	Nr. State	Processes
		variables
abiotic_water.F90	14	nitrification,denitrification,mineralisation,O ₂ dynamics in water column
abiotic_sediment.F90	9	diffusion,nitrification,denitrification,mineralisation,O ₂ demand in sediment
phytoplankton_water.F90	9	production, nutrient uptake, respiration, excretion, mortality
phytoplankton_sediment.F90	9	respiration, excretion, mortality
macrophytes.F90	3	production, nutrient uptake, respiration, excretion, mortality, migration, seasonality forcing, germination
Zooplankton.F90	10	consumption, assimilation, respiration, excretion, mortality
Fish.F90		migration, reproduction, assimilation, excretion, mortality, consumption, aging
zoobenthos.F90	3	consumption, assimilation, respiration, excretion, mortality
auxiliary.f90	0	resuspension, sedimentation, burial, conserved quantities, mass balance check

Detailed module descriptions are listed below and adhere to this general structure:

- Module description: relevant to corresponding F90 file.
- List of variables
 - List of local state variables

Local State variables: local state variables are state variables that are registered within this module and changed mainly in this module's processes

- List of diagnostic variables

Diagnostic variables are additional variables that can be output and analysed, and typically these will represent key system properties and provide a more in-depth understanding of the processes occurring in the modules.

- List of external dependencies

The external dependencies are the variables that are provided by other modules, either by the hydrodynamic models (physical drivers) or by other biogeochemical modules (and models) within FABM.

Additional information on the implementation of a biogeochemical model within FABM, e.g., defining state variables, diagnostic variables and external dependencies, is provided on the FABM website (www.fabm.net/wiki) under “Developing_a_new_biogeochemical_model”.

S1.1 Abiotic processes in the water column

- **File name:**

abiotic_water.F90

- **Module description:**

The abiotic_water module describes the state variables which are related to abiotic processes in the water column, including: inorganic matter (IM), organic matter (detritus), dissolved nutrients (ammonium, nitrate, phosphate and dissolved silica-dioxide), immobilized phosphorus (adsorbed phosphorus) and dissolved oxygen.

➤ **List of variables (in following tables):**

Supplemental Table S2 List of local state variables in abiotic water module

State variable	Description of state variables
sDDIMW	dry weight of inorg. matter in water column, mgDW/l
sDDetW	dry weight of detritus in water column, mgDW/l
sNDetW	nitrogen in detritus in water column, mgN/l
sPDetW	phosphorus in detritus in water column,mgP/l
sSiDetW	silica in detritus in water column,mgSi/l
sPO4W	phosphate in water column,mgP/l
sPAIMW	adsorbed phosphorus in water column,mgP/l
sNH4W	ammonium in water column,mgN/l
sNO3W	nitrate in water column,mgN/l
sSiO2W	dissolved silica in water column,mgSi/l
sO2W	oxygen in water column,mgO ₂ /l

Supplemental Table S3 List of local diagnostic variables in abiotic water module

Diagnostic variable	Description of diagnostic variable
afO2SatW	$afO2SatW = O_2\text{-concentration}/saturation\ O_2\text{-concentration} * 100$, oxygen saturation percentage,%
rNDDetW	$rNDDetW = sNDetW / sDDetW$, N/D ratio of detritus in water ,gN/gD
rPDDetW	$rPDDetW = sPDetW / sDDetW$, P/D ratio of detritus in water, gP/gD

Diagnostic variable	Description of diagnostic variable
extIM	$extIM = sDIMW * cExtSpIM$, extinction factor caused by inorganic matter, -
extDet	$extDet = sDDetW * cExtSpDet$, extinction factor caused by organic matter,-
tO2Aer	oxygen reaeration rate, mg/l/day

Supplemental Table S4 List of dependencies in abiotic water column module

dependencies	Description	Linked external module	Linked external variable
uTm	temperature	physical driver	temperature
uVWind	wind speed	physical driver	wind_speed

S1.2 Abiotic processes in the sediment

- **File name:** abiotic_sediment.F90

Module description: The abiotic_sediment module describes all the state variables which are related to abiotic processes in the sediment, including: inorganic matter (IM), organic matter (detritus), dissolved nutrients (ammonium, nitrate, and phosphate), immobilized phosphorus (adsorbed phosphorus) and humus.

- **List of variables (in following tables):**

Supplemental Table S5 List of local state variables in abiotic sediment module

State variable	Description of state variables
sDDIMS	dry weight of inorg. matter in sediment, gDW/m**2
sDDetS	dry weight of detritus in sediment, gDW/m**2
sNDetS	nitrogen in detritus in sediment, gN/m**2
sPDetS	phosphorus in detritus in sediment, gP/m**2

State variable	Description of state variables
sSiDetS	silica in detritus in sediment,gSi/m**2
sPO4S	phosphate in sediment,gP/m**2
sPAIMS	adsorbed phosphorus in sediment,gP/**2
sNH4S	ammonium in sediment, gN/**2
sNO3S	nitrate in sediment,gN/m**2
sDHumS	dry weight of humus in sediment, gDW/m**2
sNHumS	nitrogen of humus in sediment, gN/m**2
sPHumS	phosphorus of humus in sediment, gP/m**2

Supplemental Table S6 List of local diagnostic variables in abiotic water module

diagnostic variable	Description of diagnostic variable
afOxySed	$afOxySed = aDepthOxySed / cDepthS$,proportion aerobic sediment, -
rNDDetS	$rNDDetS = sNDetS / sDDetS$, N content of sediment detritus, gN/gDW
rPDDetS	$rPDDetS = sPDetS / sDDetS$, P content of sediment detritus, gP/gDW
aPEqIMS	$aPEqIMS = aPlsoAdsS * sDIMs$,equilibrium amount in sediment, gP/m**2

Supplemental Table S7 List of dependencies in abiotic sediment module

dependencies	Description	Linked external	Linked external
---------------------	--------------------	------------------------	------------------------

		module	variable
uTm	temperature	physical driver	temperature
SWNH4	ammonium_pool_in_water	abiotic_water	sNH4W
SWNO3	nitrate_pool_in_water	abiotic_water	sNO3W
SWPO4	phosphate_pool_in_water	abiotic_water	sPO4W
SWSiO2	siO2_release_to_water	abiotic_water	sSiO2W
O2Supply	oxygen_pool	abiotic_water	sO2W

S1.3 Phytoplankton in the water column

➤ **File name:** phytoplankton_water.F90

➤ **Module description:**

The phytoplankton_water module describes the processes related to phytoplankton in the water column. Three groups of phytoplankton are described here: diatoms, green algae and cyanobacteria (blue-green algae). Each group is described in three elements, dry weight, nitrogen and phosphorus. The silica concentration in diatoms is not a state variables here but instead defined as a diagnostic variable, since the model assumes that diatoms have a fixed Si/DW ratio, i.e., 0.1.

➤ **List of variables (in following tables):**

Supplemental Table S8 List of local state variables in phytoplankton water module

State variable	Description of state variables
sDDiatW	diatom concentration in dry weight, mgDW/l
sPDIatW	diatom concentration in phosphorus, mgP/l
sNDiatW	diatom concentration in nitrogen, mgN/l
sDGrenW	green algae concentration in dry weight, mgDW/l
sPGrenW	green algae concentration in phosphorus, mgP/l

sNGrenW	green algae concentration in nitrogen, mgN/l
sDBlueW	blue-green algae concentration in dry weight, mgDW/l
sPBlueW	blue-green algae concentration in phosphorus,mgP/l
sNBlueW	blue-green algae concentration in nitrogen, mgN/l

Supplemental Table S9 List of local diagnostic variables in phytoplankton water module

diagnostic variable	Description of diagnostic variable
oChlaBlue	blue-green algae chlorophyll-a concentration,ug/l
aLLimBlue	light limitation factor for blue-green algae,-
aNutLimBlue	nutrient limitation factor for blue-green algae
extBlue	$extBlue = sDBlueW * cExtSplM$, light extinction factor caused by blue-green algae,m-1
rNDBlueW	$rNDBlueW = sNBlueW / sDBlueW$, N content in blue-green algae,gN/gD
rPDBlueW	$rPDBlueW = sPBlueW / sDBlueW$, P content in blue-green algae,gP/gD
oChlaGren	green algae chlorophyll-a concentration,ug/l
aLLimGren	light limitation factor for green algae,-
aNutLimGren	nutrient limitation factor for green algae,-
extGren	$extGren = sDGrenW * cExtSplM$, light extinction factor caused by green algae,m-1
rNDGrenW	$rNDGrenW = sNGrenW / sDGrenW$, N content in green algae, gN/gD
rPDGrenW	$rPDGrenW = sPGrenW / sDGrenW$, P content in green algae, gP/gD
oChlaDiat	diatom chlorophyll-a concentration,ug/l
aLLimDiat	light limitation factor for diatoms,-
aNutLimDiat	nutrient limitation factor for diatoms,-

diagnostic variable	Description of diagnostic variable
extDiat	$extDiat = sDDiatW * cExtSpIM$, light extinction factor caused by diatoms, m^{-1}
rNDDiatW	$rNDDiatW = sNDiatW / sDDiatW$, N content in diatoms, gN/gDW
rPDDiatW	$rPDDiatW = sPDiadW / sDDiatW$, P content in diatoms, gP/gDW
oSiDiatW	$oSiDiatW = sDDiatW * cSiDDiatW$, diatom silica concentration, mgSi/l
aDPhytW	$aDPhytW = sDBlueW + sDGrenW + sDDiatW$, total algae biomass in the water column, mgDW/l
rNDPhytW	$rNDPhytW = (sNBlueW + sNGrenW + sNDiatW) / aDPhytW$, N content in phytoplankton in water column, gN/gDW
rPDPhytW	$rPDPhytW = (sPBlueW + sPGrenW + sPDiadW) / aDPhytW$, P content in phytoplankton in water column, gP/gDW
ParSurf	surface photosynthetically active radiation, W/m**2
phypar	local photosynthetically active radiation (layer center par), W/m**2
phytoextinction	local extinction factor used by phytoplankton light function, m^{-1}
wO2PrimW	oxygen production by phytoplankton, mgO2/l/d

Supplemental Table S10 List of dependencies in phytoplankton water module

dependencies	Description	Linked external module	Linked external variable
uTm	Temperature	physical driver	temperature
par	photosynthetically active radiation	physical driver	downwelling_photosynthetic_radiative_flux
Dz	cell_thickness	physical driver	cell_thickness
extc	attenuation coefficient	physical driver	attenuation_coefficient_of_photosynthetic_radiative_flux

dependencies	Description	Linked external module	Linked external variable
SiO2poolW	SiO ₂ _source_wat	abiotic_water	sSiO2W
PO4poolW	sPO4_source_wat	abiotic_water	sPO4W
NO3poolW	sNO3_source_wat	abiotic_water	sNO3S
NH4poolW	sNH4_source_wat	abiotic_water	sNH4W
O2poolW	oxygen_pool	abiotic_water	sO2W
DDetpoolW	detritus_DW_pool_wat	abiotic_water	sDDetW
NDetpoolW	detritus_N_pool_wat	abiotic_water	sNDetW
PDetpoolW	detritus_P_pool_wat	abiotic_water	sPDetW
SiDetpoolW	detritus_Si_pool_wat	abiotic_water	sSiDetW

S1.4 Phytoplankton in the sediment

➤ **File name:**

phytoplankton_sediment.F90

➤ **Module description:**

The phytoplankton_sediment module describes the processes related to the phytoplankton which has settled to the bottom sediments. Three groups of phytoplankton are described here: diatoms, green algae and cyanobacteria (blue-green algae). Each group is described in three elements, dry weight, nitrogen and phosphorus. The silica concentration in diatom is not a state variable here but instead a diagnostic variable, since the model assumes that diatoms have a fixed Si/DW ratio, i.e., 0.1

➤ **List of variables (in following tables):**

Supplemental Table S11 List of local state variables in phytoplankton sediment

module

State variable	Description of state variables
sDDiatS	diatom concentration in dry weight,gDW/m**2
sPDiats	diatom concentration in phosphorus,gP/m**2
sNDiatS	diatom concentration in nitrogen,gN/m**2
sDGrenS	green algae concentration in dry weight,gDW/m**2
sPGrenS	green algae concentration in phosphorus,gP/m**2
sNGrenS	green algae concentration in nitrogen,gN/m**2
sDBlueS	blue-green algae concentration in dry weight,gDW/m**2
sPBlueS	blue-green algae concentration in phosphorus,gP/m**2
sNBlueS	blue-green algae concentration in nitrogen,gN/m**2

Supplemental Table S12 List of local diagnostic variables in phytoplankton sediment module

Diagnostic variable	Description of diagnostic variable
oSiDiatS	sediment diatom concentration in silica, gSi/m**2
rNDPhytS	$rNDPhytS=(sNBlueS+sNGrenS+sNDiatS)/aDPhytS$, N content in phytoplankton in sediment,gN/gD
rPDPhytS	$rPDPhytS=(sPBlueS+sPGrenS+sPDiats)/aDPhytS$, P content in phytoplankton in sediment,gP/gD

Supplemental Table S13 List of dependencies in the phytoplankton sediment module

dependencie	Description	Linked external	Linked external

s		module	variable
uTm	temperature	physical driver	temperature
PO4poolS	sPO4_source_sed	abiotic_sediment	sPO4S
NO3poolS	sNO3_source_sed	abiotic_sediment	sNO3S
NH4poolS	sNH4_source_sed	abiotic_sediment	sNH4S
DDetpools	detritus_DW_pool_sed	abiotic_sediment	sDDetS
NDetpools	detritus_N_pool_sed	abiotic_sediment	sNDetS
PDetpools	detritus_P_pool_sed	abiotic_sediment	sPDetS
SiDetpools	detritus_Si_pool_sed	abiotic_sediment	sSiDetS
SiO2poolW	SiO ₂ _source_sed	abiotic_water	sSiO2W

S1.5 Macrophytes

➤ **File name:**

macrophytes.F90

➤ **Module description:**

This module describes the submerged macrophytes group, and is implemented as a benthic module. The state variables include: sDVeg, sNVeg, sPVeg (vegetation mass in dry weight, nitrogen and phosphorus, respectively). The related processes are: assimilation (only for sDVeg), nutrient uptake (only for sNVeg and sPVeg), respiration (only for sDVeg), excretion (only for sNVeg and sPVeg), mortality and migration.

➤ **List of variables (in following tables):**

Supplemental Table S14 List of local state variables in macrophytes module

State variable	Description of state variables
sDVeg	vegetation (shoots+roots) in dry weight,gDW/m**2

sNVeg	vegetation (shoots+roots) in nitrogen,gN/m**2
sPVeg	vegetation (shoots+roots) in phosphorus,gP/m**2

Supplemental Table S15 List of local diagnostic variables in macrophytes module

diagnostic variable	Description of diagnostic variable
aCovVeg	coverage of macrophytes, %
aDSubVeg	submerged macrophytes in dry weight,gDW/m**2
aLPAR1Veg	photosynthetically active radiation at top of vegetation layer, W/m**2
aLPAR2Veg	photosynthetically active radiation at bottom of vegetation layer, W/m**2
aNutLimVeg	nutrient limitation function for macrophytes,-
aLLimVeg	light limitation function for macrophytes,-
macroextinction	local extinction factor used by macrophytes light function, m-1

Supplemental Table S16 List of dependencies in macrophytes module

dependencie s	Description	Linked external module	Linked external variable
uTm	temperature	physical driver	temperature
par	photosynthetically active radiation	physical driver	downwelling_phot osynthetic_radiati ve_flux
dz	cell_thickness	physical driver	cell_thickness
sDepthW	water depth	physical driver	bottom_depth
extc	attenuation coefficient	physical driver	attenuation_coeffi cient_of_photosyn thetic_radiative_fl

dependencia s	Description	Linked external module	Linked external variable
day	number of days since start of the year	physical driver	number_of_days_since_start_of_the_year
NH4poolW	uptake_target_Ammonium_water	abiotic_water	sNH4W
NO3poolW	uptake_target_Nitrate_water	abiotic_water	sNO3W
PO4poolW	uptake_target_Phosphate_water	abiotic_water	sPO4W
DDetpoolW	detritus_DW_pool_water	abiotic_water	sDDetW
NDetpoolW	detritus_N_pool_water	abiotic_water	sNDetW
PDetpoolW	detritus_P_pool_water	abiotic_water	sPDetW
O2poolW	oxygen_pool	abiotic_water	sO2W
NH4poolS	uptake_target_Ammonium_sediment	abiotic_sediment	sNH4S
NO3poolS	uptake_target_Nitrate_sediment	abiotic_sediment	sNO3S
PO4poolS	uptake_target_Phosphate_sediment	abiotic_sediment	sPO4S
DDetpoolS	detritus_DW_pool_sediment	abiotic_sediment	sDDetS
NDetpoolS	detritus_N_pool_sediment	abiotic_sediment	sNDetS
PDetpoolS	detritus_P_pool_sediment	abiotic_sediment	sPDetS
afOxySed	fraction_aerobic_sediment	abiotic_sediment	afOxySed

S1.6 Zooplankton

- **File name:**

zooplankton.F90

➤ **Module description:**

The zooplankton module describes zooplankton behavior in the water column.

The local processes are:

Zooplankton: assimilation, respiration (only for sDZoo), excretion (only for sNZoo, sPZoo), mortality and consumption by juvenile fish.

➤ **List of variables (in following tables):**

Supplemental Table S17 List of local state variables in zooplankton module

State variable	Description of state variables
sDZoo	zooplankton in water column, dry weight,mgDW/l
sPZoo	zooplankton in water column,phosphorus,mgP/l
sNZoo	zooplankton in water column,nitrogen,mgN/l

Supplemental Table S18 List of local diagnostic variables in zooplankton module

Diagnostic variable	Description of diagnostic variable
None	None

Supplemental Table S19 List of dependencies in zooplankton module

dependencia	Description	Linked external module	Linked external variable
s			
uTm	temperature	physical driver	temperature
par	photosynthetically active radiation	physical driver	downwelling_photosynthetic_radiative_flux
dz	cell_thickness	physical driver	cell_thickness
day	number of days since start of the year	physical driver	number_of_days_since_start_of_the_year
DfoodDiat	diatom_as_food_DW	phytoplankton_water	sDDiatW
NfoodDiat	diatom_as_food_N	phytoplankton_water	sNDiatW
PfoodDiat	diatom_as_food_P	phytoplankton_water	sPDiатW
DfoodGren	green_as_food_DW	phytoplankton_water	sDGrenW
NfoodGren	green_as_food_N	phytoplankton_water	sNGrenW
PfoodGren	green_as_food_P	phytoplankton_water	sPGrenW
DfoodBlue	blue_as_food_DW	phytoplankton_water	sDBlueW
NfoodBlue	blue_as_food_N	phytoplankton_water	sNBlueW
PfoodBlue	blue_as_food_P	phytoplankton_water	sPBlueW
DDetpoolW	detritus_as_food_DW	abiotic_water	sDDetW
NDetpoolW	detritus_as_food_N	abiotic_water	sNDetW
PDetpoolW	detritus_as_food_P	abiotic_water	sPDetW
SiDetpoolW	detritus_as_food_Si	abiotic_water	sSiDetW
DfoodBent	benthos_as_food_DW	phytoplankton_sediment	sDBent
NH4poolW	NH4_pool_for_web	abiotic_water	sNH4W
NO3poolW	NO3_pool_for_web	abiotic_water	sNO3W
PO4poolW	PO4_pool_for_web	abiotic_water	sPO4W
aDSubVeg	submerged_macrophytes	macrophytes	aDSubVeg

dependencie	Description	Linked external module	Linked external variable
s			
tDEnvFiAd	environmental correction	zoobenthos	tDEnvFiAd
aDSatFiAd	Saturation concentration of adult fish	zoobenthos	aDSatFiAd

S1.7 Fish

➤ **File name:**

fish.F90

➤ **Module description:**

Fish module describes zooplanktivorous fish, zoobenthivorous fish and piscivorous fish behavior in the water column. The local processes include:

zooplanktivorous and benthivorous fish (represented by juvenile and adults, respectively) and piscivorous fish.

Juvenile fish: migration, reproduction (fraction of adult fish biomass become juvenile fish), assimilation (predation on zooplankton), respiration (only for sDFiJv), excretion (only for PFiJv, sNFiJv), mortality, consumption by piscivorous fish and aging (part of the juvenile fish become adult fish)

Adult fish: migration, reproduction (fraction of adult fish biomass become juvenile fish), respiration (only for sDFiAd), excretion (only for sPFiAd and sNFiAd), mortality, consumption by piscivorous fish, and aging (part of juvenile fish become adult fish), (note: the assimilation of adult fish occurs in the benthic module, where adult fish predating the zoobenthos).

Piscivorous fish: migration, assimilation, respiration and mortality (piscivorous fish have fixed N/D and P/D ratio).

➤ **List of variables (in following tables):**

Supplemental Table S20 List of local state variables in fish module

State variable	Description of state variables
sDFiJv	young fish in water,dry weight,mgDW/l
sPFIJv	young fish in water,phosphorus,mgP/l
sNFIJv	young fish in water,nitrogen,mgN/l
sDFiAd	adult fish in water, dry weight,mgDW/l
sPFIAd	adult fish in water, phosphorus,mgP/l
sNFIAd	adult fish in water, nitrogen,mgN/l
sDPisc	piscivorous fish in water, dry weight,mgDW/l

Supplemental Table S21 List of local diagnostic variables in fish module

Diagnostic variable	Description of diagnostic variable
aNPisc	piscivorous fish in nitrogen, mgN/l
aPPisc	piscivorous fish in phosphorus, mgP/l

Supplemental Table S22 List of dependencies in fish module

dependencie	Description	Linked external module	Linked external variable
s			
uTm	temperature	physical driver	temperature
par	photosynthetically active radiation	physical driver	downwelling_photosynthetic_radiative_flux
dz	cell_thickness	physical driver	cell_thickness
day	number of days since start of the year	physical driver	number_of_days_since_start_of_the_year
NH4poolW	NH4_pool_for_web	abiotic_water	sNH4W

dependencie	Description	Linked external module	Linked external variable
s			
NO3poolW	NO3_pool_for_web	abiotic_water	sNO3W
PO4poolW	PO4_pool_for_web	abiotic_water	sPO4W
aDSubVeg	submerged_macrophytes	macrophytes	aDSubVeg
tDEnvFiAd	environmental correction	zoobenthos	tDEnvFiAd
aDSatFiAd	Saturation concentration of adult fish	zoobenthos	aDSatFiAd

S1.8 Zoobenthos

➤ **File name:**

zoobenthos.F90

➤ **Module description:**

The zoobenthos module describes the state variables relating to zoobenthos, thus sDBent, sPBent and sNBent. Local processes include consumption, migration, assimilation, and respiration (only for sDBent), excretion (only for sNBent and sPBent) and mortality. This module also describes the process of benthivorous fish (adult fish) preying on zoobenthos.

➤ **List of variables (in following tables):**

Supplemental Table S23 List of local state variables in zoobenthos module

State variable	Description of state variables
sDBent	zoobenthos, in dry weight,gDW/m**2
sPBent	zoobenthos, in phosphorus,gP/m**2
sNBent	zoobenthos, in nitrogen,gN/m**2

Supplemental Table S24 List of local diagnostic variables in zoobenthos module

diagnostic variable	Description of diagnostic variable
None	

Supplemental Table S25 List of dependencies in zoobenthos module

dependencie	Description	Linked external module	Linked external variable
uTm	temperature	physical_driver	temperature
sDepthW	water_depth	physical_driver	bottom_depth
DDetpoolS	detritus_as_food_DW	abiotic_sediment	sDDetS
PDetpoolS	detritus_as_food_P	abiotic_sediment	sPDetS
NDetpoolS	detritus_as_food_N	abiotic_sediment	sNDetS
SiDetpoolS	detritus_as_food_Si	abiotic_sediment	sSiDetS
PO4poolS	PO4_pool_web_sed	abiotic_sediment	sPO4S
NH4poolS	NH4_pool_web_sed	abiotic_sediment	sNH4S
NO3poolS	NO3_pool_web_sed	abiotic_sediment	sNO3S
DfoodDiatS	diatom_as_food_DW	phytoplankton_sediment	sDDiatS
PfoodDiatS	diatom_as_food_P	phytoplankton_sediment	sPDiats
NfoodDiatS	diatom_as_food_N	phytoplankton_sediment	sNDiatS
DfoodGrenS	green_as_food_DW	phytoplankton_sediment	sDGrenS
PfoodGrenS	green_as_food_P	phytoplankton_sediment	sPGrenS
NfoodGrenS	green_as_food_N	phytoplankton_sediment	sNGrenS
DfoodBlueS	blue_as_food_DW	phytoplankton_sediment	sDBlueS
PfoodBlueS	blue_as_food_P	phytoplankton_sediment	sPBlueS
NfoodBlueS	blue_as_food_N	phytoplankton_sediment	sNBlueS
DAdFish	adult_fish_DW	Fish	sDFiAd
NAdFish	adult_fish_N	Fish	sNFiAd
PAdFish	adult_fish_P	Fish	sPFIJv

dependencie	Description	Linked external module	Linked external variable
s			
DJvFish	young_fish_DW	fish	sDFiJv
aCovVeg	macrophytes_coverage	macrophytes	aCovVeg

S1.9 Auxiliary module

➤ **File name:**

auxiliary.F90

➤ **Module description:**

The auxiliary module is created for the purpose of computing resuspension and sedimentation, erosion and sediment burial processes (that influence several other modules).

➤ **List of variables (in following tables):**

Supplemental Table S26 List of dependencies in auxiliary module

dependencie	Description	Linked external module	Linked external variable
s			
uTm	temperature	physical driver	temperature
sDepthW	water depth	physical driver	bottom_depth
SWNH4	ammonium pool in water column	abiotic_water	sNH4W
SWNO3	nitrate_pool_in_water	abiotic_water	sNO3W
SWPO4	phosphate_pool_in_water	abiotic_water	sPO4W
SWPAIM	adsorbed_phosphorus_in_water	abiotic_water	sPAIMW
SWDIM	inorg_pool_in_water	abiotic_water	sIMW

dependencia	Description	Linked external module	Linked external variable
s			
SWSiO2	SiO2_release_to_water	abiotic_water	sSiO2W
SWO2	oxygen_pool	abiotic_water	sO2W
SWDDet	detritus_DW_in_water	abiotic_water	sDDetW
SWNDet	detritus_N_in_water	abiotic_water	sNDetW
SWPDet	detritus_P_in_water	abiotic_water	sPDetW
SWSiDet	detritus_Si_in_water	abiotic_water	sSiDetW
SWDDiat	diatom_DW_in_water	phytoplankton_water	sDDiatW
SWNDiat	diatom_N_in_water	phytoplankton_water	sNDiatW
SWPDiат	diatom_P_in_water	phytoplankton_water	sPDiатW
SWDGren	green_DW_in_water	phytoplankton_water	sDGrenW
SWNGren	green_N_in_water	phytoplankton_water	sNGrenW
SWPGren	green_P_in_water	phytoplankton_water	sPGrenW
SWDBlue	blue_DW_in_water	phytoplankton_water	sDBlueW
SWNBlue	blue_N_in_water	phytoplankton_water	sNBlueW
SWPBlue	blue_P_in_water	phytoplankton_water	sPBlueW
WSDDiatS	diatom_DW_in_sediment	phytoplankton_sediment	sDDiatS
WSNDiatS	diatom_N_in_sediment	phytoplankton_sediment	sNDiatS
WSPDiатS	diatom_P_in_sediment	phytoplankton_sediment	sPDiатS
WSDGrenS	green_DW_in_sediment	phytoplankton_sediment	sDGrenS
WSNGrenS	green_N_in_sediment	phytoplankton_sediment	sNGrenS
WSPGrenS	green_P_in_sediment	phytoplankton_sediment	sPGrenS
WSDBlueS	blue_DW_in_sediment	phytoplankton_sediment	sDBlueS
WSNBlueS	blue_N_in_sediment	phytoplankton_sediment	sNBlueS
WSPBlueS	blue_P_in_sediment	phytoplankton_sediment	sPBlueS
DragVeg	vegetation_biomass	macrophytes	sDVege

dependencia	Description	Linked external module	Linked external variable
s			
TurbFish	adult_fish_biomass	fish	aDFish
tDAbioDetS	detritus_abiotic_update	zoobenthos	tDAbioDetS
tDAbioHumS	humus_abiotic_update	zoobenthos	
tDPrimDetS	detritus_from_algae	phytoplankton_sediment	tDPrimDetS
tDWebDetS	detritus_from_zoobenthos	zoobenthos	tDBenDetS
tDBedDetS	detritus_from_vegetation	macrophytes	tDBedDetS

S2. List of FABM-PCLake biogeochemical sink and source terms

This section provides a full list of the derivatives (and the processes in these) for the state variables implemented in FABM-PCLake. In order to distinguish the processes' modular location, different symbols are introduced to mark the processes (adopted from (Janse 2005)), see table S27 for the symbols representing the various modules.

Supplemental Table S27 Symbols of different FABM-PCLake module processes

Modules	Module mark	Example
abiotic water	()	(-wDMinDetW)
abiotic sediment	(_)	(-tDMinDetS)
phytoplankton water	[]	[+ wDMortPhytW]
phytoplankton sediment	[]	[+ tPMortPhytDetS]
macrophytes	< >	<+ tDMortVegW>
zooplankton	{ }	{-wDConsDetZoo}
fish	< >	
zoobenthos	{_}	{- tDConsDetBent}
auxiliary module		- tDSetIM + tDResusIM

S 2.1 Abiotic water column module

1) inorg. matter in water [mgD/l/s]

$$dDIMW = -tDSetIM + tDResusIM + uDErosIMW$$

= - settling + resuspension+erosion

2) detritus in water [mgD/l/s]

$dDDetW = \boxed{-tDSetDet + tDResusDet}$ (-wDMinDetW) [+ wDMortPhytW] $\leq + tDMortVegW$
 {-wDConsDetZoo + wDEgesZoo + wDMortZoo} <+ tDEgesFish + tDMortFishDet
 +tDEgesPisc + tDMortPiscDet>

3) detritus in water [mgP/l/s]

$dPDetW = \boxed{-tPSetDet + tPResusDet}$ (-wPMInDetW) [+ wPMortPhytDetW] $\leq + tPMortVegDetW$
 $\leq + tPMortVegDetW$ {-wPConsDetZoo + wPEgesZooDet + wPMortZooDet} <+ tPEgesFishDet
 + tPMortFishDet +tPEgesPiscDet + tPMortPiscDet>

4) detritus in water [mgN/l/s]

$dNDetW = \boxed{-tNSetDet + tNResusDet}$ (-wNMinDetW) [+ wNMortPhytDetW] $\leq + tNMortVegDetW$
 $\leq + tNMortVegDetW$ {-wNConsDetZoo + wNEgesZooDet + wNMortZooDet} <+ tNEgesFishDet
 + tNMortFishDet+ tNEgesPiscDet + tNMortPiscDet>
 = $\boxed{- settling + resuspension}$ (- mineralisation) [+ algal mortality] $\leq + part of macrophyte$
 $mortality in water$ {- zooplankton detritus consumption +zooplankton egestion and mortality}
 <+ whitefish egestion and mortality + pred.fish egestion and mortality>

5) detritus [mgSi/ l/s]

$dSiDetW = \boxed{-tSiSetDet + tSiResusDet}$ (- wSiMinDetW) [+ wSiMortDiatW] {+
 wSiConsDiatZoo}
 = $\boxed{- settling + resuspension}$ (- mineralisation) [+ diatoms mortality] {+zooplankton diatoms
 consumption}

6) PO4 in water [mgP/l/s]

$dPO4W = (wPMInDetW - wPSorpIMW + tPDifPO4) + \boxed{tPResusPO4}$ [- wPUptPhyt +
 wPEcrPhytW +wPMortPhytPO4W] < - tPUptVegW + tPEcrVegW + tPMortVegPO4W> {+

$wPExcrZoo + wPEgesZooPO4 + wPMortZooPO4} <+ tPExcrFiJv + tPExcrFiAd +$
 $tPEgesFishPO4 + tPMortFishPO4 + tPExcrPisc + tPEgesPiscPO4 + tPMortPiscPO4>$
 $= (\text{mineralisation} - \text{sorption} + \text{diffusion from sediment}) + \boxed{\text{resuspension}} [- \text{algal uptake} +$
 $\text{algal excretion} + \text{part of algal mortality}] \underline{- \text{macrophyte uptake from water} + \text{macrophyte}}$
 $\underline{\text{excretion in water} + \text{part of macrophyte mortality}} \{ + \text{zooplankton excretion and part of}$
 $\text{egestion and mortality}\} <+ \text{whitefish excretion and part of egestion and mortality} + \text{pred.fish}$
 $\text{excretion and part of egestion and mortality} >$

7) adsorbed P in water [mgP/l/s]

$$dPAIMW = \boxed{tPResusAIM - tPSetAIM} (+wPSorpIMW)$$
 $= \boxed{\text{resuspension} - \text{settling}} (+ \text{sorption})$

8) ammonium in water [mgN/l/s]

$$dNH4W = (wNMinDetW - wNNitrW - tNDifNH4) + \boxed{tNResusNH4} [- wNUptNH4Phyt +$$
 $wNExcrPhytW + wNMortPhytNH4W] \underline{- tNUptNH4VegW + tNExcrVegW + tNMortVegNH4W}$
 $\{ + wNExcrZoo + wNEgesZooNH4 + wNMortZooNH4 + tNExcrFiJv + tNExcrFiAd +$
 $tNEgesFishNH4 + tNMortFishNH4 + tNExcrPisc + tNEgesPiscNH4 + tNMortPiscNH4\}$
 $= (\text{mineralisation} - \text{nitrification in water} - \text{diffusion from sediment}) + \boxed{\text{resuspension}} [- \text{algal}$
 $\text{uptake} + \text{algal excretion} + \text{part of algal mortality} - \text{macrophyte uptake from water}] \underline{- \text{macrophyte}}$
 $\underline{\text{excretion in water} + \text{part of macrophyte mortality}} \{ + \text{zooplankton excretion and}$
 $\text{part of egestion and mortality}\} <+ \text{whitefish excretion and part of egestion and mortality} +$
 $\text{pred.fish excretion and part of egestion and mortality}>$

9) nitrate in water [mgN/l/s]

$$dNO3W = (wNNitrW - wNDenitW + tNDifNO3) + \boxed{tNResusNO3} [- wNUptNO3Phyt] \underline{- tNUptNO3VegW}$$

= (nitrification in water – denitrif. in water + diffusion from sediment) + resuspension [-
algal uptake] <- macrophyte uptake>.

10) oxygen in water [mgO₂/l/s]

$dO_2W = (tO_2Aer - wO_2MinDetW - wO_2NitrW) (- tO_2MinDetS + tO_2NitrS) [+ wO_2ProdPhyt - wO_2RespPhytW + wO_2UptNO3Phyt] <+ tO_2ProdVegW - tO_2RespVegW + tO_2UptNO3VegW>$
=(reaeration - mineralisation – nitrification) - sediment oxygen demand [+algal production - algal respiration + nitrate uptake by algae] <+ macrophyte production - macrophyte respiration + nitrate uptake by macrophytes>

11) dissolved silicon dioxide in water [mgSi/ l/ s]

$dSiO_2W = (wSiMinDetW) (+ (1.0 - fRefrDetS) * tSiMinDetS) [- wSiUptDiat + wSiExcrDiatW] [+ tSiExcrDiatS]$
= (mineralisation in water) (+ mineralisation in sediment) [- diatoms uptake + diatoms excretion in water] [+ diatoms excretion in sed.]

S2.2 Abiotic sediment module

12) sediment inorg. matter [gD/m²/s]

$dDIMS = \boxed{tDSetIM - tDResusIM - tDBurIM + uDErosIMS}$
= settling – resuspension – burial+erosion

13) sediment detritus [gD/m²/s]

$dDDetS = \boxed{tDSetDet - tDResusDet - tDBurDet} (- tDMinDetS) [+ tDMortPhytS]
<+tDMortVegS> \{- tDConsDetBent + tDEgesBent + tDMortBent\}$

14) sediment detritus P [gP/m²/s]

$$dPDetS = [tPSetDet - tPResusDet - tPBurDet] (- tPMinDetS) [+ tPMortPhytDetS] <+ \\ tPMortVegDetS > \{ - tPConsDetBent + tPEgesBent + tPMortBent \}$$

15) sediment detritus N [gN/m²/s]

$$dNDetS = [tNSetDet - tNResusDet - tNBurDet] (- tNMinDetS) [+ tNMortPhytDetS] <+ \\ tNMortVegDetS > \{ - tNConsDetBent + tNEgesBent + tNMortBent \} \\ = [settling - resuspension - burial] (- mineralisation) [+ sed. algal mortality] <+ macrophyte \\ mortality in sed > \{ - zoobenthos detritus consumption + zoobenthos egestion and mortality \}$$

16) sediment detritus Si [gSi/m²/s]

$$dSiDetS = [tSiSetDet - tSiResusDet - tSiBurDet] (- tSiMinDetS) [+ tSiMortDiatS] \\ \{ + tSiConsDiatBent \} \\ = [settling - resuspension - burial] (- mineralisation) [+ sed. diatoms mortality] \{ - \\ zoobenthos diatoms consumption \}$$

17) phosphate in pore water [gP/m²/s]

$$dPO4S = (tPMinDetS * (1.0 - fRefrDetS) - tPSorpIMS - tPDifPO4 - tPChemPO4) \\ [tPResusPO4 - tPBurPO4] [+ tPEcrPhytS + tPMortPhytPO4S] <- tPUptVegS + tPEcrVegS \\ + tPMortVegPO4S > \{ + tPEcrBent + tPEgesBentPO4 + tPMortBentPO4 \} \\ = (detritus and humus mineralisation - sorption - diffusion to/from water - immobilisation) \\ - resuspension - burial [+ excretion and part of mortality of sed. algae] <- macrophyte uptake \\ from sediment + macrophyte excretion in sediment + part of macrophyte mortality > \{ + \\ excretion and part of egestion and mortality of zoobenthos \}$$

18) adsorbed P in sediment [gP/m²/s]

$$dPAIMS = [tPSetAIM - tPResusAIM - tPBurAIM] (+ tPSorpIMS) \\ = (sorption) + settling - resuspension - burial$$

19) pore water ammonium [gN/m²/s]

$$\begin{aligned} dNH4S = & (tNMinDetS * (1.0 - fRefrDetS) - tNDifNH4 - tNNitrS) - tNResusNH4 - tNBurNH4 \quad [+ \\ & tNExcrPhytS + tNMortPhytNH4S - tNUptNH4VegS] \quad <+ tNExcrVegS + tNMortVegNH4S > \quad [+ \\ & tNExcrBent + tNEgesBentNH4 + tNMortBentNH4] \\ = & (\text{detritus and humus mineralisation} - \text{diffusion to/from water-nitrification in sediment}) \quad [- \\ & \text{resuspension} - \text{burial}] \quad [+ \text{excretion and part of mortality of sed. algae}] \quad <- \text{macrophyte uptake} \\ & \text{from sediment} + \text{macrophyte excretion in sediment} + \text{part of macrophyte mortality} > \quad \{+ \\ & \text{excretion and part of egestion and mortality of zoobenthos}\} \end{aligned}$$

20) pore water nitrate [gN/m²/s]

$$\begin{aligned} dNO3S = & (tNNitrS - tNDenitS - tNDifNO3) - tNResusNO3 - tNBurNO3 \quad <- tNUptNO3VegS > \\ = & (\text{nitrification in sed.} - \text{denitrification in sed.} - \text{diffusion to/from water}) \quad [- \text{resuspension} - \\ & \text{burial}] \quad <- \text{macrophyte uptake from sediment}\> \end{aligned}$$

21) Sediment humus [gD /m² /s]

$$dDHumS = uDErosOM - tDBurHum \quad (+ fRefrDetS * tDMinDetS - tDMinHumS)$$

22) Sediment humus [gN /m² /s]

$$dNHumS = uNErosOM - tNBurHum \quad (+ fRefrDetS * tDMinDetS - tDMinHumS)$$

23) Sediment humus [gP /m² /s]

$$\begin{aligned} dPHumS = & uPErosOM - tPBurHum \quad (+ fRefrDetS * tPMinDetS - tPMinHumS) \\ = & \text{erosion} - \text{burial} \quad (+ \text{humification} - \text{mineralisation}) \end{aligned}$$

S2.3 Phytoplankton water column module

24) diatom dry weight in water column [mgD/l/s]

$$dDDiatW = [wDAssDiat - wDRespDiatW - wDMortDiatW] - tDSetDiat + tDResusDiat \{ - wDConsDiatZoo \}$$

25) green algae dry weight in water column [mgD/l /s]

$$dDGrenW = [wDAssGren - wDRespGrenW - wDMortGrenW] - tDSetGren + tDResusGren \{ - wDConsGrenZoo \}$$

26) cyanobacteria (blue-green algae) dry weight in water column [mgD/l /s]

$$dDBlueW = [wDAssBlue - wDRespBlueW - wDMortBlueW] - tDSetBlue + tDResusBlue \{ - wDConsBlueZoo \} = [production - respiration - mortality] - settling + resuspension \{ - grazing \}$$

27) diatom P in water column [mgP/l /s]

$$dPDiatW = [wPUptDiat - wPExcrDiatW - wPMortDiatW] - tPSetDiat + tPResusDiat \{ - wPConsDiatZoo \}$$

28) green algae P in water column [mgP/l /s]

$$dPGrenW = [wPUptGren - wPExcrGrenW - wPMortGrenW] - tPSetGren + tPResusGren \{ - wPConsGrenZoo \}$$

29) cyanobacteria (blue-green algae) P in water column [mgP/l /s]

$$dPBlueW = [wPUptBlue - wPExcrBlueW - wPMortBlueW] - tPSetBlue + tPResusBlue \{ - wPConsBlueZoo \} = [uptake - excretion - mortality] - settling + resuspension \{ - grazing \}$$

30) diatom N in water column [mgN/l /s]

$$dNDiatW = [wNUptDiat - wNExcrDiatW - wNMortDiatW] \boxed{- tNSetDiat + tNResusDiat} \{ - \\ wNConsDiatZoo \}$$

31) green algae N in water column [mgN/l /s]

$$dNGrenW = [wNUptGren - wNExcrGrenW - wNMortGrenW] \boxed{- tNSetGren + \\ tNResusGren} \{ - wNConsGrenZoo \}$$

32) cyanobacteria (blue-green algae) N in water column [mgN/l /s]

$$dNBlueW = [wNUptBlue - wNExcrBlueW - wNMortBlueW] \boxed{- tNSetBlue + tNResusBlue} \{ - \\ wNConsBlueZoo \} \\ = [uptake - excretion - mortality] \boxed{- settling + resuspension} \{ - grazing \}$$

S2.4 Phytoplankton sediment module

33) sediment diatom dry weight [gD/m²/s]

$$dDDiatS = \boxed{tDSetDiat - tDResusDiat} \boxed{- tDMortDiatS - tDRespDiatS} \{ - tDConsDiatBent \}$$

34) sediment green algae dry weight [gD/m²/s]

$$dDGrenS = \boxed{tDSetGren - tDResusGren} \boxed{- tDMortGrenS - tDRespGrenS} \{ - \\ tDConsGrenBent \}$$

35) sediment cyanobacteria (blue-green algae) dry weight [gD/m²/s]

$$dDBlueS = \boxed{tDSetBlue - tDResusBlue} \boxed{- tDMortBlueS - tDRespBlueS} \{ - \\ tDConsBlueBent \} \\ = \boxed{\text{settling} - \text{resuspension}} \boxed{- \text{mortality} - \text{respiration}} \{ - \text{zoobenthos consumption} \}$$

36) sediment diatom phosphorus [gP/m²/s]

$$dPDiatS = [tPSetDiat - tPResusDiat] [- tPMortDiatS - tPExcrDiatS] \{- tPConsDiatBent\}$$

37) sediment green algae phosphorus [gP/m²/s]

$$dPGrenS = [tPSetGren - tPResusGren] [- tPMortGrenS - tPExcrGrenS] \{- tPConsGrenBent\}$$

38) sediment cyanobacteria (blue-green algae) phosphorus [gP/m²/s]

$$dPBlueS = [tPSetBlue - tPResusBlue] [- tPMortBlueS - tPExcrBlueS] \{- tPConsBlueBent\}$$
$$= [settling - resuspension] [- mortality - excretion] \{- zoobenthos consumption\}$$

39) sediment diatom nitrogen [gN/m²/s]

$$dNDiatS = [tNSetDiat - tNResusDiat] [- tNMortDiatS - tNExcrDiatS] \{- tNConsDiatBent\}$$

40) sediment green algae nitrogen [gN/m²/s]

$$dNGrenS = [tNSetGren - tNResusGren] [- tNMortGrenS - tNExcrGrenS] \{- tNConsGrenBent\}$$

41) sediment cyanobacteria (blue-green algae) nitrogen [gN/m²/s]

$$dNBlueS = tNSetBlue - tNResusBlue - tNMortBlueS - tNExcrBlueS - tNConsBlueBent$$
$$= [settling - resuspension] [- mortality - excretion] \{- zoobenthos consumption\}$$

S2.5 Macrophytes module

42) macrophytes dry weight [gD/m²/s]

$$dDVeg = <tDProdVeg - tDRespVeg - tDMortVeg + tDMigrVeg>$$

= <production - respiration - mortality + migrationz>

43) macrophytes phosphorus [gP/m²/s]

dPVeg = <tPUptVeg - tPExcrVeg - tPMortVeg + tPMigrVeg>

= <uptake – excretion - mortality + migration>

44) macrophytes nitrogen [gN/m²/s]

dNVeg = <tNUptVeg - tNExcrVeg - tNMortVeg + tNMigrVeg>

= <uptake – excretion - mortality + migration>

S2.6 Zooplankton Module

45) zooplankton dry weight [mgD/l/s]

dDZoo = {wDAssZoo - wDRespZoo – wDMortZoo} <- tDConsFiJv>

= {assimilation - respiration – mortality} <- fish predation>

46) zooplankton phosphorus [mgP/l/s]

dPZoo = {wPAssZoo - wPExcrZoo – wPMortZoo} <- tPConsFiJv>

= {assimilation - excretion – mortality} <- fish predation>

47) zooplankton phosphorus [mgN/l/s]

dNZoo = {wNAssZoo - wNExcrZoo - wNMortZoo – tNConsFiJv}

= {assimilation - excretion – mortality} <- fish predation>

S2.7 Fish module

48) juvenile whitefish dry weight[mgD/l/s]

$dDFiJv = < tDMigrFiJv + tDReprFish - tDAgeFish + tDAssFiJv - tDRespFiJv - tDMortFiJv - tDConsFiJvPisc >$

49) juvenile whitefish phosphorus [mgP/l/s]

$dPFiJv = < tPMigrFiJv + tPReprFish - tPAgeFish + tPAssFiJv - tPRespFiJv - tPMortFiJv - tPConsFiJvPisc >$

50) juvenile whitefish nitrogen [mgN/l/s]

$dDFiJv = < tDMigrFiJv + tDReprFish - tDAgeFish + tDAssFiJv - tDRespFiJv - tDMortFiJv - tDConsFiJvPisc >$
= <migration + reproduction – ageing + assimilation - respiration – mortality – predation>

51) adult whitefish dry weight[mgD/l/s]

$dDFiAd = < tDMigrFiAd - tDReprFish + tDAgeFish - tDRespFiAd - tDMortFiAd - tDConsFiAdPisc - tDHavFish > \{ + tDAssFiAd \}$

52) adult whitefish phosphorus [mgP/l/s]

$dPFiAd = < tPMigrFiAd - tPReprFish + tPAgeFish - tPRespFiAd - tPMortFiAd - tPConsFiAdPisc > \{ + tPAssFiAd \}$

53) adult whitefish nitrogen [mgN/l/s]

$dNFiAd = < tNMigrFiAd - tNReprFish + tNAgeFish - tNRespFiAd - tNMortFiAd - tNConsFiAdPisc > \{ + tNAssFiAd \}$
= <migration - reproduction + ageing - respiration – mortality – predation> {+ assimilation}

54) piscivorous fish dry weight[mgD/l/s]

$dDPisc = < tDMigrPisc + tDAssPisc - tDRespPisc - tDMortPisc >$
= <migration + assimilation - respiration – mortality >

S2.8 Zoobenthos module

55) zoobenthos dry weight[gD/m²/s]

$$dDBent = \{tDMigrBent + tDAssBent - tDRespBent - tDMortBent - tDConsFiAd\}$$

56) zoobenthos phosphorus[gP/m²/s]

$$dPBent = \{tPMigrBent + tPAssBent - tPRespBent - tPMortBent - tPConsFiAd\}$$

57) zoobenthos nitrogen[gN/m²/s]

$$dNBent = \{tNMigrBent + tNAssBent - tNRespBent - tNMortBent - tNConsFiAd\}$$

$$= \{\text{migration} + \text{assimilation} - \text{respiration} - \text{mortality} - \text{fish predation}\}$$

S3. FABM-PCLake parameter list (input file in .yaml format) in modular structure

The input file can be downloaded from www.fabm.net and use of the template provided here is recommended as a basis for parameter adaptation, as the yaml file format includes a strict indentation standard.

S3.1 FABM-PCLake_abiotic_water

model: pclake_abiotic_water

long_name: abiotic_process_in_water

initialization:

sNH4W: 0.1 # mgN/l, ammonium in water

sNO3W: 0.1 # mgN/l, nitrite in water

sPO4W: 0.01 #mgP/l, phosphate in water

sPAIMW: 0.0 # mgP/l, adsorbed phosphorus on inorg. matter in water

sSiO2W: 3.0 # mgSi/l, dissolved silicon dioxide in water

sO2W: 10.0 # mgO2/l, oxygen in water

sDIMW: 5.0 # mgDW/l, inorg.matter in water

sDDetW: 2.0 # mgDW/l, water detritus in dry weight

sPDetW: 0.005 # mgP/l, water detritus in phosphorus

sNDetW: 0.05 # mgN/l, water detritus in nitrogen

sSiDetW: 0.02# mgSi/l, water detritus in silica

parameters:

cCPerDW: 0.4# gC/gDW, C content of organic matter

cExtSpDet: 0.15 # m2/gDW,specific_extinction_detritus

cExtSpIM: 0.05 # 0.05m2/gDW specific_extinction_inert_matter

cExtWat: 0.5 # background_extinction"

cKPAdsOx: 0.6 # m3/gP, P adsorption affinity at oxidized conditions

cRelPAdsAl: 0.134 # gP/gAl, max. P adsorption per g Al

cRelPAdsD: 0.00003 # gP/gD, max. P adsorption per g DW

cRelPAdsFe: 0.065 # gP/gFe, max. P adsorption per g Fe
 cThetaAer: 1.024 # 1/e^oC, temperature coeff. for reaeration
 cThetaMinW: 1.07 # exponantional temperature constant of mineralisation in water
 cThetaNitr: 1.08 # temperature coefficient for nitrification
 fAlDIM: 0.01 # gAl/gD, Al content of inorg. matter
 fFeDIM: 0.01 # gFe/gD, Fe content of inorg. matter
 fRedMax: 0.9 # max. reduction factor of P adsorption affinity
 hNO3Denit: 2 # mgN/l, quadratic half-sat. NO3 conc. for denitrification
 hO2BOD: 1 # mgO2/l, half-sat. oxygen conc. for BOD
 hO2Nitr: 2 # mgO2/l ,half-sat_O2_conc_for_nitrification_in_water
 kDMinDetW: 0.01 # day-1, decomposition constant of detritus
 kNitrW: 0.1 # day-1, nitrification rate constant in water
 kPSorp: 0.05 # day-1, P sorption rate constant not too high -> model speed day
 NO3PerC: 0.8 # mol NO3 denitrified per mol C mineralised
 O2PerNH4: 2 # mol O2 used per mol NH4+ nitrified

Sinking

cVSetIM: -1.0 # m/day, max. sedimentation velocity of inert org. matter
 cVSetDet: -0.25 # m/day, max. sedimentation velocity of detritus

S3.2 FABM-PCLake_abiotic_sediment

model: pclake_abiotic_sediment

long_name: abiotic_process_in_sediment

initialization:

sNH4S: 0.02 # gN/m2, dissolved N-NH4 in interstitial water
 sNO3S: 0.002 # gN/m2, dissolved N-NO3 in interstitial water
 sPO4S: 0.181703 # gP/m2, dissolved P-PO4 in interstitial water
 sPAIMS: 17.9886 # gP/m2, adsorbed P in sediment
 sDIMS: 32706.5 # gDW/m2; Inorg matter in sediment

sDDetS: 181.703 # gDW/m², detritus in sediment
sNDetS: 4.54258 # gN/m², detritus in sediment
sPDetS: 0.454258 # gP/m², detritus in sediment
sSiDetS: 1.81703 # gSi/m², detritus in sediment
sDHumS: 3452.36 # gDW/m², humus in sediment,
sNHumS: 172.618 # gN/m², humus in sediment, initial N fraction in humus
sPHumS: 17.2618 # gP/m², humus in sediment, initial P fraction in humus

parameters:

bPorS: 0.847947 # porosity [m³ water m⁻³ sediment]
bPorCorS: 0.737275 # sediment porosity, corrected for tortuosity
cCPerDW: 0.4 # gC/gDW, C content of organic matter
cDepthS: 0.1 # sediment depth [m]
cKPAdsOx: 0.6 # m³/gP, P adsorption affinity at oxidized conditions
coPO4Max: 1.0 # mgP/l, max. PO₄ conc. in pore water
cRelPAdsAl: 0.134 # gP/gAl, max. P adsorption per g Al
cRelPAdsD: 0.00003 # gP/gD, max. P adsorption per g DW
cRelPAdsFe: 0.065 # gP/gFe, max. P adsorption per g Fe
cThetaDif: 1.02 # Temperature coefficient for diffusion
cThetaMinS: 1.07 # -, exponential Temperature constant of sediment mineralisation
cThetaNitr: 1.08 # Temperature coefficient for nitrification
cTurbDifNut: 5.0 # bioturbation factor for diffusion
cTurbDifO2: 5.0 # -, bioturbation factor for diffusion
fAlDIM: 0.01 # gAl/gD, Al content of inorg. matter
fDepthDifS: 0.5 # utrrient diffusion distance as fraction of sediment depth
fFeDIM: 0.01 # gFe/gD, Fe content of inorg. matter
fRedMax: 0.9 # max. reduction factor of P adsorption affinity
fRefrDetS: 0.15 # -, refractory fraction of sed. detritus
hNO3Denit: 2.0 # mgN/l, quadratic half-sat. NO₃ conc. for denitrification

```

kDMinDetS: 0.002 # "day-1, decomposition constant of sediment detritus

kNDifNH4: 0.000112 # m2/day, mol. NH4 diffusion constant

kNDifNO3: 0.000086 # m2/day, mol. NO3 diffusion constant

kNitrS: 1.0      # day-1,nitrification rate constant in sediment

kO2Dif: 0.000026 # m2/day, mol. O2 diffusion constant

kPChemPO4: 0.03  # day-1, chem. PO4 loss rate

kPDifPO4: 0.000072 # m2/day, mol. PO4 diffusion constant

kPSorp: 0.05    # day-1, P sorption rate constant not too high -> model speed

NO3PerC: 0.8    # mol NO3 denitrified per mol C mineralised

O2PerNH4: 2.0   # mol O2 used per mol NH4+ nitrified

kDMinHum: 0.00001 # day-1 ,maximum_decomposition_constant_of_humic_material_(1D-5)

```

coupling:

```

oxygen_pool_water: abiotic_water/sO2W

SiO2_generated_by_mineralisation: abiotic_water/sSiO2W

NH4_diffusion_flux: abiotic_water/sNH4W

NO3_diffusion_flux: abiotic_water/sNO3W

PO4_diffusion_flux: abiotic_water/sPO4W

```

S3.3 FABM-PCLake_phytoplankton_water

model: pclake_phytoplankton_water

long_name: phytoplankton_in_water

initialization:

```

sDDiatW: 0.5    # diatoms_DW_in_lake_water

sPDiadW: 0.005  # diatoms_P_in_lake_water

sNDiatW: 0.05   # diatoms_N_in_lake_water

sDGrenW: 0.5   # green_algae_DW_in_lake_water

sPGrenW: 0.005  # green_algae_P_in_lake_water

```

sNGrenW: 0.05 # green_algae_N_in_lake_water

sDBlueW: 3.0 # blue-greens_DW_in_lake_water

sPBlueW: 0.03 # blue-greens_P_in_lake_water

sNBlueW: 0.3 # blue-greens_N_in_lake_water

parameters:

cAffNUptBlue: 0.2 # l/mgDW/day, initial N uptake affinity bluegreens

cAffNUptDiat: 0.2 # l/mgDW/day, initial N uptake affinity diatoms

cAffNUptGren: 0.2 # l/mgDW/day, initial N uptake affinity greens:

cAffPUptBlue: 0.8 # l/mgDW/day, initial P uptake affinity bluegreens

cAffPUptDiat: 0.2 # l/mgDW/day, initial P uptake affinity diatoms

cAffPUptGren: 0.2 # l/mgDW/day, initial P uptake affinity greens

cChDBlueMax: 0.015 # mgChl/mgDW,max._chlorophyll/C_ratio_bluegreens

cChDBlueMin: 0.005 # mgChl/mgDW,min._chlorophyll/C_ratio_bluegreens

cChDDiatMax: 0.012 # mgChl/mgDW, max._chlorophyll/C_ratio_diatoms

cChDDiatMin: 0.004 # mgChl/mgDW ,min._chlorophyll/C_ratio_diatoms

cChDGrenMax: 0.02 # mgChl/mgDW,max._chlorophyll/C_ratio_greens

cChDGrenMin: 0.01 # mgChl/mgDW, min._chlorophyll/C_ratio_greens

cCPerDW: 0.4 # gC/gDW, C content of organic

cExtSpBlue : 0.35 #0.35m2/gDW,specific_extinction_bluegreens

cExtSpDiat : 0.25 # 0.25m2/gDW,specific_extinction_diatoms

cExtSpGren : 0.25 # 0.25m2/gDW,specific_extinction_greens

cLOptRefBlue: 13.6 # W/m2, optimum PAR for blue-greens at 20 °C (Steele function)

cLOptRefDiat: 54.0 # W/m2, optimum PAR for diatoms at 20 °C (Steele function)

cMuMaxBlue: 0.6 # day-1,maximum_growth_rate_bluegreens'

cMuMaxDiat: 2.0 # day-1,maximum_growth_rate_diatoms

cMuMaxGren: 1.5 # day-1,maximum_growth_rate_greens

cNDBlueMax: 0.15 # mgN/mgDW, max. N/day ratio bluegreens

cNDBlueMin: 0.03 # mgN/mgDW, minimum N/day ratio bluegreens

```

cNDDiatMax: 0.05    # mgN/mgDW, max. N/day ratio diatoms
cNDDiatMin: 0.01    # mgN/mgDW, minimum N/day ratio diatoms
cNDGrenMax: 0.1     # mgN/mgDW, max. N/day ratio greens
cNDGrenMin: 0.02    # mgN/mgDW, minimum N/day ratio greens
cPDBlueMax: 0.025   # mgP/mgDW, max. P/day ratio blue-greens
cPDBlueMin: 0.0025  # mgP/mgDW, minimum P/day ratio bluegreens
cPDDiatMax: 0.005   # mgP/mgDW, max. P/day ratio diatoms
cPDDiatMin: 0.0005  # mgP/mgDW, minimum P/day ratio diatoms
cPDGrenMax: 0.015   # mgP/mgDW, max. P/day ratio greens
cPDGrenMin: 0.0015  # mgP/mgDW, minimum P/day ratio greens
cSiDDiat: 0.15      # mgSi/mgDW, Si/D ratio of diatoms
cSigTmBlue: 12.0    # °C, temperature constant bluegreens (sigma in Gaussian curve)
cSigTmDiat: 20.0    # °C, temperature constant diatoms (sigma in Gaussian curve)
cSigTmGren: 15.0    # °C, temperature constant greens (sigma in Gaussian curve)
cTmOptBlue: 25.0    # °C, optimum temperature bluegreens
cTmOptDiat: 18.0    # °C, optimum temperature diatoms
cTmOptGren: 25.0    # °C, optimum temperature of greens
cVNUpMaxBlue: 0.07  # mgN/mgDW/day, maximum N uptake capacity of bluegreens
cVNUpMaxDiat: 0.07  # mgN/mgDW/day, maximum N uptake capacity of diatoms
cVNUpMaxGren: 0.07  # mgN/mgDW/day, maximum N uptake capacity of greens
cVPUpMaxBlue: 0.04  # mgP/mgDW/day, maximum P uptake capacity of bluegreens
cVPUpMaxDiat: 0.01  # mgP/mgDW/day, maximum P uptake capacity of diatoms
cVPUpMaxGren: 0.01  # mgP/mgDW/day, maximum P uptake capacity of greens
fDissMortPhyt: 0.2   # [-], soluble_nutrient_fraction_of_died_
hLRefGren: 17.0     # W/m2, half-sat. PAR for greens at 20 °C (Lehmann function)
hO2BOD: 1.0         # mgO2/l, half-sat. oxygen conc. for BOD
hSiAssBlue: 0.0      # mgSi/l, half-sat. Si conc. for growth of bluegreens: 0
hSiAssDiat: 0.09    # mgSi/l, half-sat. Si for diatoms

```

```
hSiAssGren: 0.0    # mgSi/l, half-sat. Si conc. for growth of green algae: 0
kDRespBlue: 0.03   # day-1, maintenance respiration constant bluegreens (: 0.05 * MuMax)
kDRespDiat: 0.1    # day-1, maintenance respiration constant diatoms (: 0.05 * MuMax)
kDRespGren: 0.075  # day-1, maintenance respiration constant greens (: 0.05 * MuMax)
kMortBlueW: 0.01   # day-1, mortality constant of bluegreens in water
kMortDiatW: 0.01   # day-1, mortality constant of diatoms in water
kMortGrenW: 0.01   # day-1, mortality constant of diatoms in water
```

sinking

```
cVSetDiat: -0.5   # m/day, sedimentation velocity diatoms
cVSetGren: -0.2   # m/day, sedimentation velocity of greens
cVSetBlue: -0.06  # m/day, sedimentation velocity bluegreens
```

coupling:

```
SiO2_pool_water: abiotic_water/sSiO2W
sPO4_pool_water: abiotic_water/sPO4W
sNH4_pool_water: abiotic_water/sNH4W
sNO3_pool_water: abiotic_water/sNO3W
oxygen_pool_water: abiotic_water/sO2W
detritus_DW_pool_water: abiotic_water/sDDetW
detritus_N_pool_water: abiotic_water/sNDetW
detritus_P_pool_water: abiotic_water/sPDetW
detritus_Si_pool_water: abiotic_water/sSiDetW
surface_vegetation_coverage: macrophytes/afCovSurfVeg
```

S3.4 FABM-PCLake_phytoplankton_sediment

model: pclake_phytoplankton_sediment

long_name: phytoplankton_in_sediment

initialization:

```
sDDiatS: 0.001  # diatoms_DW_on_lake_sediment
```

```
sPDIatS: 0.00001 # diatoms_P_on_lake_sediment  
sNDiatS: 0.0001 # diatoms_N_on_lake_sediment  
sDGrenS: 0.001 # green_algae_DW_on_lake_sediment  
sPGrenS: 0.00001 # green_algae_P_on_lake_sediment  
sNGrenS: 0.0001 # green_algae_N_on_lake_sediment  
sDBlueS: 0.001 # bluegreens_DW_on_lake_sediment  
sPBlueS: 0.00001 # bluegreens_P_on_lake_sediment  
sNBlueS: 0.0001 # bluegreens_N_on_lake_sediment
```

parameters:

```
cNDBlueMax: 0.15 # mgN/mgDW, max. N/day ratio bluegreens  
cNDBlueMin: 0.03 # mgN/mgDW, minimum N/day ratio bluegreens  
cNDDiatMax: 0.05 # mgN/mgDW, max. N/day ratio diatoms  
cNDDiatMin: 0.01 # mgN/mgDW, minimum N/day ratio diatoms  
cNDGrenMax: 0.1 # mgN/mgDW, max. N/day ratio greens  
cNDGrenMin: 0.02 # mgN/mgDW, minimum N/day ratio greens  
cPDBlueMax: 0.025 # mgP/mgDW, max. P/day ratio bluegreens  
cPDBlueMin: 0.0025 # mgP/mgDW, minimum P/day ratio bluegreens  
cPDDiatMax: 0.005 # mgP/mgDW, max. P/day ratio diatoms  
cPDDiatMin: 0.0005 # mgP/mgDW, minimum P/day ratio diatoms  
cPDGrenMax: 0.015 # mgP/mgDW, max. P/day ratio greens  
cPDGrenMin: 0.0015 # mgP/mgDW, minimum P/day ratio greens  
cSiDDiat: 0.15 # mgSi/mgDW, Si/D ratio of diatoms  
cSigTmBlue: 12.0 # °C, temperature constant bluegreens (sigma in Gaussian curve)  
cSigTmDiat: 20.0 # °C, temperature constant diatoms (sigma in Gaussian curve)  
cSigTmGren: 15.0 # °C, temperature constant greens (sigma in Gaussian curve)  
cTmOptBlue: 25.0 # °C, optimum temperature bluegreens  
cTmOptDiat: 18.0 # °C, optimum temperature diatoms  
cTmOptGren: 25.0 # °C, optimum temperature of greens
```

```
fDissMortPhyt: 0.2 # -, soluble nutrient fraction of dead algae  
kDRespBlue: 0.03 # day-1, maintenance respiration constant gluegreens (: 0.05 * MuMax)  
kDRespDiat: 0.10 # day-1, maintenance respiration constant diatoms (: 0.05 * MuMax)  
kDRespGren: 0.075 # day-1, maintenance respiration constant greens (: 0.05 * MuMax)  
kMortBlueS: 0.2 # day-1, mortality constant bluegreens  
kMortDiatS: 0.05 # day-1, mortality constant of sed. diatoms  
kMortGrenS: 0.05 # day-1, mortality constant greens
```

coupling:

```
sPO4_pool_sediment: abiotic_sediment/sPO4S  
sNH4_pool_sediment: abiotic_sediment/sNH4S  
sNO3_pool_sediment: abiotic_sediment/sNO3S  
detritus_DW_pool_sediment: abiotic_sediment/sDDetS  
detritus_N_pool_sediment: abiotic_sediment/sNDetS  
detritus_P_pool_sediment: abiotic_sediment/sPDetS  
detritus_Si_pool_sediment: abiotic_sediment/sSiDetS  
SiO2_pool_water: abiotic_water/sSiO2W
```

S3.5 FABM-PCLake_macrophytes

model: pclake_macrophytes

long_name: macrophytes

initialization:

```
sDVeg: 1.0 # vegetation_DW_in_lake_water  
sNVeg: 0.02 # vegetation_N_in_lake_water  
sPVeg: 0.002 # vegetation_P_in_lake_water
```

parameters:

```
bPorS: 0.847947 # porosity [m3 water m-3 sediment]  
cAffNUptVeg: 0.2 # l/mgDW/day,initial_N_uptake_affinity_vegetation  
cAffPUptVeg: 0.2 # l/mgDW/day,initial_P_uptake_affinity_vegetation
```

```

cCovSpVeg: 0.5      # %_cover/gDW/m2      specific_cover
cCPerDW: 0.4        # gC/gDW, C content of organic matte
cDayWinVeg: 259.0   # day, end of growing season: 16 Sep
cDCarrVeg: 400.0    # gDW/m2, max. vegetation standing crop
cDepthS: 0.1        # sediment depth [m]
cDLayerVeg: 0.0     # gD/m2, biomass of a single layer floating leaves
cDVegIn: 1.0         # gD/m2, external vegetation density
cExtSpVeg : 0.01    # 0.01 m2/gDW,specific_extinction
cLengAllo: 15.0     # day, duration of allocation and reallocation phase
cLengMort: 15.0     # day, length of shoot mortality period
cMuMaxVeg: 0.2      # g/g shoot/day, maximum growth rate of vegetation at 20°C
cNDVeg0: 0.02        # gN/gD, initial N fraction in vegetation
cNDVegMax: 0.035    # mgN/mgD, maximum N/day ratio vegetation
cNDVegMin: 0.01      # mgN/mgD, minimum N/day ratio vegetation
cPDVeg0: 0.002       # gP/gD, initial P fraction in vegetation
cPDVegMax: 0.0035    # mgP/mgD, maximum P/day ratio vegetation
cPDVegMin: 0.0008    # mgP/mg, minimum P/day ratio vegetation
cQ10ProdVeg: 1.2     # temperature quotient of production
cQ10RespVeg: 2.0     # temperature quotient of respiration
cTmInitVeg: 9.0      # oC, temperature for initial growth
cVNUpMaxVeg: 0.1     # mgN/mgDW/day, maximum_N_uptake_capacity_of_vegetation
cVPUpMaxVeg: 0.01    # mgP/mgDW/day ,maximum_P_uptake_capacity_of_vegetation
fDepth1Veg: 0.5

#max._upper_depth_of_submerged_veget._layer,_as_fraction_of_water_depth
fDepth2Veg: 1.0      #
max._lower_depth_of_submerged_veget._layer,_as_fraction_of_water_depth
fDetWMortVeg: 0.1    # fraction_of_shoot_mortality_becoming_water_detritus
fDissMortVeg: 0.25   # fraction_dissolved_nutrients_from_died_plants

```

```

fEmergVeg: 0.0      # g floating / g shoot, emergent fraction of shoot
fFloatVeg: 0.0      # g floating / g shoot, floating fraction of shoot
fRootVegSum: 0.1    # g root / g veg, root fraction outside growing season
fRootVegWin: 0.6    # g root / g veg, root fraction outside growing season
fSedUptVegCoef: 2.66 # sigm._regr._coeff._for_sediment_fraction_of_nutrient_uptake
fSedUptVegExp : -0.83 #
exponent_in_sigm._regr._for_sediment_fraction_of_nutrient_uptake
fSedUptVegMax: 0.998 # maximum_sediment_fraction_of_nutrient_uptake
fWinVeg: 0.3        # fraction surviving in winter
hLRefVeg: 17.0     # W/m2 PAR, half-sat. light at 20°C
hO2BOD: 1.0        # mgO2/l, half-sat. oxygen conc. for BOD
kDRespVeg: 0.02    # day-1, dark respiration rate of vegetation
kMigrVeg: 0.001    # day-1, vegetation migration rate
kMortVegSum: 0.005  # day-1, vegetation mortality rate in Spring and Summer
UseEmpUpt: 0        # 0=do_not_use_this_empirical_relation

```

coupling:

```

ammonium_pool_water: abiotic_water/sNH4W
nitrate_pool_water: abiotic_water/sNO3W
phosphate_pool_water: abiotic_water/sPO4W
ammonium_pool_sediment: abiotic_sediment/sNH4S
nitrate_pool_sediment: abiotic_sediment/sNO3S
phosphate_pool_sediment: abiotic_sediment/sPO4S
oxygen_pool_water: abiotic_water/sO2W
detritus_DW_pool_water: abiotic_water/sDDetW
detritus_N_pool_water: abiotic_water/sPDetW
detritus_P_pool_water: abiotic_water/sNDetW
detritus_DW_pool_sediment: abiotic_sediment/sDDetS
detritus_N_pool_sediment: abiotic_sediment/sNDetS

```

detritus_P_pool_sediment: abiotic_sediment/sPDetS

oxic_layer_value: abiotic_sediment/afOxySed

S3.6 FABM-PCLake_zooplankton

model: zooplankton

long_name: zooplankton

initialization:

sDZoo: 0.05 #zooplankton DW in water (g m-3)

sPZoo: 0.0005 #zooplankton P in water (g m-3)

sNZoo: 0.0035 # zooplankton N in water (g m-3)

parameters:

cSigTmZoo: 13.0 # temperature constant zooplankton(sigma in Gaussian curve) ($\diamond C$), default = 13.0

cTmOptZoo: 25.0 # optimum temp. zooplankton ($\diamond C$), default = 25.0

cDCarrZoo: 25.0 # carrying capacity of zooplankton (gm-3), default = 25.0

kMortZoo: 0.04 # mortality_constant_herb.zooplankton (d-1), default = 0.04

kDRespZoo: 0.15 # maintenance respiration constant herb.zooplankton (d-1), default= 0.15

cPrefDiat: 0.75 # selection factor for Diatoms ([]), default = 0.75

cPrefGren: 0.75 # selection factor for Greens ([]), default = 0.75

cPrefBlue: 0.125 # selection factor for Bluegreens Cal. ([]), default = 0.125

cPrefDet: 0.25 # selection factor for detritus ([]), default = 0.25

hFilt: 1.0 # half-sat. food conc. for filtering (gDW m-3), default = 1.0

fDAssZoo: 0.35 # DW-assimilation efficiency of herb. zooplankton ([]), default = 0.35

cFiltMax: 4.5 # maximum filtering rate (ltr/mgDW/d), default = 4.5

cPDZooRef: 0.01 # reference P/C-ratio herb. zooplankton (mgP/mgDW), default = 0.01

cNDZooRef: 0.07 # reference N/C-ratio herb. zooplankton (mgN/mgDW), default = 0.07

```

fDissEgesZoo: 0.25 # soluble_nutrient_fraction_of_by_herb.zoopl._egested_foodcVSetDiat
([-]), default = 0.25

fDissMortZoo: 0.1 # soluble_nutrient_fraction_of_died_zooplanktoncVSetGren ([-]), default
= 0.1

cSiDDiat: 0.15 # Si/DW_ratio_of_daitomscVSetBlue (mgSi/mgDW), default = 0.15

cNDDiatMin: 0.01 # minimum N/day ratio Diatoms (mgN/mgDW), default = 0.01

cPDDiatMin: 0.0005 # minimum P/day ratio Diatoms (mgP/mgDW), default = 0.0005

cNDGrenMin: 0.02 # minimum N/day ratio greens (mgN/mgDW), default = 0.02

cPDGrenMin: 0.0015 # minimum P/day ratio greens (mgP/mgDW), default = 0.0015

cNDBlueMin: 0.03 # minimum N/day ratio Bluegreens (mgN/mgDW), default = 0.03

cPDBlueMin: 0.0025 # minimum P/day ratio Bluegreens (mgP/mgDW), default = 0.0025

cNDBlueMax: 0.15 # max. N/day ratio Bluegreens (mgN/mgDW), default = 0.15

cNDDiatMax: 0.05 # max. N/day ratio Diatoms (mgN/mgDW), default = 0.05

cNDGrenMax: 0.1 # max. N/day goratio greens (mgN/mgDW), default = 0.1

cPDBlueMax: 0.025 # max. P/day ratio blue-greens (mgP/mgDW), default = 0.025

cPDDiatMax: 0.005 # max. P/day ratio Diatoms (mgP/mgDW), default = 0.005

cPDGrenMax: 0.015 # max. P/day ratio greens (mgP/mgDW), default = 0.01

```

coupling:

diatom_as_food_DW: phytoplankton_water/sDDiatW	# diatom_as_food_DW (g m-3)
green_as_food_DW: phytoplankton_water/sDGrenW	# green_as_food_DW (g m-3)
blue_as_food_DW: phytoplankton_water/sDBlueW	# blue_as_food_DW (g m-3)
diatom_as_food_N: phytoplankton_water/sNDiatW	# diatom_as_food_N (g m-3)
green_as_food_N: phytoplankton_water/sNGrenW	# green_as_food_N (g m-3)
blue_as_food_N: phytoplankton_water/sNBlueW	# blue_as_food_N (g m-3)
diatom_as_food_P: phytoplankton_water/sPDiatiW	# diatom_as_food_P (g m-3)
green_as_food_P: phytoplankton_water/sPGrenW	# green_as_food_P (g m-3)
blue_as_food_P: phytoplankton_water/sPBlueW	# blue_as_food_P (g m-3)
detritus_DW_pool_water: abiotic_water/sDDetW	# detritus_DW_pool_water (g m-3)

```

detritus_N_pool_water: abiotic_water/sNDetW           # detritus_N_pool_water (g m-3)
detritus_P_pool_water: abiotic_water/sPDetW          # detritus_P_pool_water (g m-3)
detritus_Si_pool_water: abiotic_water/sSiDetW         # detritus_Si_pool_water (g m-3)
NH4_pool_water: abiotic_water/sNH4W                  # NH4_pool_water (g m-3)
NO3_pool_water: abiotic_water/sNO3W                  # NO3_pool_water (g m-3)
PO4_pool_water: abiotic_water/sPO4W                  # PO4_pool_water (g m-3)

```

S3.7 FABM-PCLake_fish

model: fish

long_name: fish

initialization:

```

sDFiJv: 0.25      # juvenile fish DW in water (g m-3)
sPFIJv: 0.0055   # juvenile fish P in water (g m-3)
sNFiJv: 0.025    # juvenile fish N in water (g m-3)
sDFiAd: 1.0       # adult fish DW in water (g m-3)
sPFIAd: 0.022    # adult fish P in water (g m-3)
sNFIAd: 0.1       # adult fish N in water (g m-3)
sDPisc: 0.005    # piscivorous fish DW in water (g m-3)

```

parameters:

```

kMigrFish: 0.001 # fish migration rate (d-1), default = 0.001
cDFiJvIn: 0.005  # external fish density (gDW m-2), default = 0.005
cDFiAdIn: 0.005  # external fish density (gDW m-2), default = 0.005
cDPiscln: 0.001  # external Pi_sc. density (gDW m-2), default = 0.001
kMigrPisc: 0.001 # Pi_sc. migration rate (d-1), default = 0.001
fDBone: 0.35     # fraction of fish C fixed in bones and scales ([]), default = 0.35
fPBone: 0.5       # fraction of fish P fixed in bones and scales ([]), default = 0.5
cDCarrFish: 15.0  # carrying capacity of fish (gDW m-2), default = 15.0
fDissEgesFish: 0.25 # soluble nutrient fraction of by fish egested food ([]), default = 0.25

```

fDissMortFish: 0.1 # soluble nutrient fraction of died fish(excl. bones and scales ([-]),
 default = 0.1

cTmOptFish: 25.0 # optimum temp. of fish ($\text{ }^\circ\text{C}$), default = 25.0

cSigTmFish: 10.0 # temperature constant of fish(sigma in Gaussian curve) ($\text{ }^\circ\text{C}$), default
 = 10.0

cDayReprFish: 120.0 # reproduction date of fish ([-]), default = 120.0

fReprFish: 0.02 # yearly reproduction fraction of adult fish, daily rate ([-]), default =
 0.02

fAgeFish: 0.5 # yearly ageing fraction of young fish,.daily rate ([-]), default = 0.5

kDAssFiJv: 0.12 # maximum assimilation rate of young fish (d-1), default = 0.12

hDZooFiJv: 1.25 # half-saturating zooplankton biomass for young fish predation (g m-2),
 default = 1.25

fDAssFiJv: 0.4 # C assimilation efficiency of young fish ([-]), default = 0.4

kDRespFiJv: 0.01 # maintenance respiration constant of young fish (d-1), default = 0.01

kMortFiJv: 0.00137 # specific mortality of young fish (d-1), default = 0.00137

kDRespFiAd: 0.004 # maintenance respiration constant of adult fish (d-1), default = 0.004

kMortFiAd: 0.00027 # specific mortality of adult fish (d-1), default = 0.00027

cDCarrPiscMax: 1.2 # maximum carrying capacity of P_i_{sc} (gDW m-2), default = 1.2

cDCarrPiscMin: 0.1 # minimum carrying capacity of P_i_{sc} (gDW m-2), default = 0.1

cDCarrPiscBare: 0.1 # carrying capacity of P_i_{sc} for lake without marsh zone (gDW m-2),
 default = 0.1

cDPhraMinPisc: 50.0 # min. reed biomass for P_i_{sc} (gDW m-2), default = 50.0

cCovVegMin: 40.0 # min. subm.veg. coverage for P_i_{sc} (%), default = 40.0

cRelPhraPisc: 0.075 # rel. P_i_{sc} density per reed if subm.veg. absent (gDW m-2), default
 = 0.075

cRelVegPisc: 0.03 # extra rel. P_i_{sc} density perreed if aCovVeg > cCovVegMin (gDW
 m-2), default = 0.03

```

kDAssPisc: 0.025      # maximum assimilation rate (d-1), default = 0.025
hDVegPisc: 5.0        # half-sat. vegetation biomass for Pi_sc growth (g m-2), default = 5.0
hDFishPisc: 1.0        # half-saturating DFish for Pi_sc predation (g m-2), default = 1.0
fDAssPisc: 0.4        # C ass. efficiency of Pi_sc ([-]), default = 0.4
fDissEgesPisc: 0.25    # soluble P fraction of by fish egested food ([-]), default = 0.25
kDRespPisc: 0.005     # maint. respiration constant of Pi_sc (d-1), default = 0.005
kMortPisc: 0.00027    # specific mortality of Pi_sc (d-1), default = 0.00027
fDissMortPisc: 0.1     # soluble nutrient fraction of died Pi_sc(excl. bones and scales ([-]),
default = 0.1
cTmOptPisc: 25.0      # optimum temp. of Pi_sc (°C), default = 25.0
cSigTmPisc: 10.0       # temperature constant of Pi_sc(sigma in Gaussian curve) (°C),
default = 10.0
cPDFishRef: 0.022     # reference P/C ratio of Fish (mgP/mgDW), default = 0.022
cNDFishRef: 0.1        # reference N/C ratio of Fish (mgN/mgDW), default = 0.1
cPDPisc: 0.022        # reference P/C ratio of Pi_sc (mgP/mgDW), default = 0.022
cNDPisc: 0.1           # reference N/C ratio of Pi_sc (mgN/mgDW), default = 0.1
# Fish manipulation switches

```

Manipulate_FiAd : .false. # Turned on/off external fish manipulation rate, + values,remove
the fish;- values, add fish

Manipulate_FiJv : .false. # Turned on/off external fish manipulation rate, + values,remove
the fish;- values, add fish

Manipulate_Pisc : .false. # Turned on/off external fish manipulation rate, + values,remove
the fish;- values, add fish

coupling:

detritus_DW_pool_water: abiotic_water/sDDetW	# detritus_DW_pool_water (g m-3)
detritus_N_pool_water: abiotic_water/sNDetW	# detritus_N_pool_water (g m-3)
detritus_P_pool_water: abiotic_water/sPDetW	# detritus_P_pool_water (g m-3)

```

NH4_pool_water: abiotic_water/sNH4W           # NH4_pool_water (g m-3)
PO4_pool_water: abiotic_water/sPO4W           # PO4_pool_water (g m-3)
env_correction_adfish: zoobenthos /tDEnvFiAd   # env_correction_adfish ([])
submerged_vegetation: macrophytes/aDSubVeg     # submerged_vegetation (g m-2)
food_limit_function_adfish: zoobenthos/aDSatFiAd # food_limit_function_adfish ([])

```

Zooplankton_D_Food: zooplankton/sDZoo

Zooplankton_N_Food: zooplankton/sNZoo

Zooplankton_P_Food: zooplankton/sPZoo

S3.8 FABM-PCLake_zoobenthos

model: pclake_zoobenthos

long_name: zoobenthos

initialization:

sDBent: 1.0 # zoobenthos_DW_in_lake_sediment

sPBent: 0.01 # zoobenthos_P_in_lake_sediment

sNBent: 0.07 # zoobenthos_N_in_lake_sediment

parameters:

cDBentIn: 0.01 # gDW/m²,external_zoobenthos_density

cDCarrBent: 10.0 # gDW/m²,carrying_capacity_of_zoobenthos

cDCarrFish: 15 # gDW/m²,carrying_capacity_of_fish(: _100_gFW/m²,Grimm_1983)

cNDBentRef: 0.07 # mgN/mgDW, reference_N/C_ratio_of_zoobenthos

cNDFishRef: 0.1 # mgN/mgDW,reference_N/C_ratio_of_Fish

cPDBentRef: 0.01 # mgP/mgDW,reference_P/C_ratio_of_zoobenthos

cPDFishRef: 0.022 # mgP/mgDW,reference_P/C_ratio_of_Fish

cRelVegFish: 0.009 # - ,decrease_of_fish_feeding_per_%_vegetation_cover(max._0.01)

cSiDDiat: 0.15 # mgSi/mgDW, Si/DW_ratio_of_daitoms

cSigTmBent: 16.0 #

°C,temperature_constant_of_zoobenthos(sigma_in_Gaussian_curve)

cSigTmFish: 10 # °C,temperature_constant_of_fish(sigma_in_Gaussian_curve)

```

cTmOptBent: 25.0      #  °C, optimum_temp._of_zoobenthos
cTmOptFish: 25       #  °C , optimum_temp._of_fish
fDAssBent: 0.3        #  -,C_ass._efficiency_of_zoobenthos
fDAssFiAd: 0.4        #  -,C_assimilation_efficiency_of_adult_fish
fDissEgesBent: 0.25   #  -,soluble_nutrient_fraction_of_by_zoobenthos_egested_food
fDissEgesFish: 0.25   #  -,soluble_nutrient_fraction_of_by_fish_egested_food
fDissMortBent: 0.1    #  -,soluble_P_fraction_of_died_zoobenthos_P
hDBentFiAd: 2.5      #  g/m2,half-
saturating_zoobenthos_biomass_for_adult_fish_predation
hDFoodBent: 200.0     #  g/m2,half-saturating_food_for_zoobenthos
kDAssBent: 0.1        #  day-1, maximum_assimilation_rate
kDAssFiAd: 0.06       #  day-1 ,maximum_assimilation_rate_of_adult_fish
kDRspBent: 0.005      #  day-1,maint._respiration_constant_of_zoobenthos
kDRspFiAd: 0.004      #  day-1 ,maintenance_respiration_constant_of_adult_fish
kMigrBent: 0.001      #  day-1,zoobenthos_migration_rate
kMortBent: 0.005      #  day-1 ,mortality_constant_of_zoobenthos
kMortFiAd: 0.00027    #  day-1,specific_mortality_of_adult_fish(: _0.1_y-1)
cNDBlueMax: 0.15      # mgN/mgDW, max. N/day ratio bluegreens
cNDBlueMin: 0.03      # mgN/mgDW, minimum N/day ratio bluegreens
cNDdiatMax: 0.05      # mgN/mgDW, max. N/day ratio diatoms
cNDdiatMin: 0.01      # mgN/mgDW, minimum N/day ratio diatoms
cNDGrenMax: 0.1        # mgN/mgDW, max. N/day ratio greens
cNDGrenMin: 0.02      # mgN/mgDW, minimum N/day ratio greens
cPDBlueMax: 0.025     # mgP/mgDW, max. P/day ratio bluegreens
cPDBlueMin: 0.0025    # mgP/mgDW, minimum P/day ratio bluegreens
cPDDiatMax: 0.05      # mgP/mgDW, max. P/day ratio diatoms
cPDDiatMin: 0.005     # mgP/mgDW, minimum P/day ratio diatoms
cPDGrenMax: 0.015     # mgP/mgDW, max. P/day ratio greens

```

cPDGrenMin: 0.0015 # mgP/mgDW, minimum P/day ratio greens

coupling:

diatom_as_food_DW: phytoplankton_sediment/sDDiatS

green_as_food_DW: phytoplankton_sediment/sDGrenS

blue_as_food_DW: phytoplankton_sediment/sDBlueS

diatom_as_food_N: phytoplankton_sediment/sNDiatS

green_as_food_N: phytoplankton_sediment/sNGrenS

blue_as_food_N: phytoplankton_sediment/sNBlueS

diatom_as_food_P: phytoplankton_sediment/sPDiats

green_as_food_P: phytoplankton_sediment/sPGrenS

blue_as_food_P: phytoplankton_sediment/sPBlueS

detritus_DW_pool_sediment: abiotic_sediment/sDDets

detritus_P_pool_sediment: abiotic_sediment/sPDetS

detritus_N_pool_sediment: abiotic_sediment/sNDetS

detritus_Si_pool_sediment: abiotic_sediment/sSiDetS

NH4_pool_sediment: abiotic_sediment/sNH4S

NO3_pool_sediment: abiotic_sediment/sNO3S

PO4_pool_sediment: abiotic_sediment/sPO4S

adult_fish_biomass:fish/sDFiAd

adult_fish_nitrogen: fish/sNFiAd

adult_fish_phosphorus: fish/sPFiAd

NH4_pool_water: abiotic_water/sNH4W

PO4_pool_water: abiotic_water/sPO4W

DDet_pool_water: abiotic_water/sDDetW

NDet_pool_water: abiotic_water/sNDetW

PDet_pool_water: abiotic_water/sPDetW

vegetation_coverage: macrophytes/aCovVeg

young_fish_biomass: fish/sDFiJv

S3.9FABM-PCLake_auxiliary

model: pclake_auxiliary

long_name: extra_processes

parameters:

cDepthS: 0.1 # sediment depth [m]
cThetaSet: 1.01 # $1/e^0$ C, temp. parameter of sedimentation
kVegResus: 0.01 # m²/gDW, rel. resuspension reduction per g vegetation
kTurbFish: 1.0 # g/g fish/day, relative resuspension by adult fish browsing
cSuspRef: 0.5 # reference suspended matter function [-]
cSuspMin: 6.1 # minimum value of logistic function
cSuspMax: 25.2 # maximum value of logistic function
cSuspSlope: 2.1 # slope of logistic function
hDepthSusp: 2.0 # half-sat. value of depth in logistic function
cFetchRef: 1000.0 # reference fetch [m]
cFetch: 1000.0 # fetch [m], the length of the lake in the prevailing wind direction
fLutum: 0.1 # lutum content of inorg. matter
fLutumRef: 0.2 # reference lutum fraction
bPorS: 0.847947 # porosity [m³ water m⁻³ sediment]
kResusPhytMax: 0.25 # day⁻¹, max. phytopl. resuspension
cResusPhytExp: -0.379 # (gDW/m²/day)⁻¹, exp. par. for phytopl. resuspension
cVSetIM: 1.0 # m/day, max. sedimentation velocity of inert org. matter
cVSetDet: 0.25 # m/day, max. sedimentation velocity of detritus
cVSetDiat: 0.5 # m/day, sedimentation velocity diatoms
cVSetGren: 0.2 # m/day, sedimentation velocity of greens
cVSetBlue: 0.06 # m/day, sedimentation velocity blue-greens
cRhoIM: 2500000.0 # g/m³ solid, density of sediment IM

cRhoOM: 1400000.0 # g/m3, density of sediment detritus
 fDOrgSoil: 0.1 # fraction soil organic matter
 cPO4Ground: 0.1 # mgP/l, PO4 cone in groundwater
 cNH4Ground: 1.0 # mgN/l, NH4 cone in groundwater
 cNO3Ground: 0.1 # mgN/l, NO3 cone in groundwater
 cTmOptFish: 25 # °C,optimum_temp._of_fish
 cSigTmFish: 10 # °C,temperature_constant_of_fish(sigma_in_Gaussian_curve)
 cLoadPO4: 0.005 # gP/m2/day, constant, different from cLoadIM
 cLoadNO3: 0.05 # gN/m2/day, constant
 uQIn: 20.0 # mm/day, net water load rate, constant
 cDErosTot: 0.1 # g/m2/day,Erosion_input_(tentative)
 fSedErosIM: 0.95 # instantly_sedimentating_fraction_of_IM
 cNDBlueMax: 0.15 # mgN/mgDW, max. N/day ratio bluegreens
 cNDBlueMin: 0.03 # mgN/mgDW, minimum N/day ratio bluegreens
 cNDDiatMax: 0.05 # mgN/mgDW, max. N/day ratio diatoms
 cNDDiatMin: 0.01 # mgN/mgDW, minimum N/day ratio diatoms
 cNDGrenMax: 0.1 # mgN/mgDW, max. N/day ratio greens
 cNDGrenMin: 0.02 # mgN/mgDW, minimum N/day ratio greens
 cPDBlueMax: 0.025 # mgP/mgDW, max. P/day ratio bluegreens
 cPDBlueMin: 0.0025 # mgP/mgDW, minimum P/day ratio bluegreens
 cPDDiatMax: 0.005 # mgP/mgDW, max. P/day ratio diatoms
 cPDDiatMin: 0.0005 # mgP/mgDW, minimum P/day ratio diatoms
 cPDGrenMax: 0.015 # mgP/mgDW, max. P/day ratio greens
 cPDGrenMin: 0.0015 # mgP/mgDW, minimum P/day ratio greens

coupling:

Ammonia_pool_in_water: abiotic_water/sNH4W

Nitrate_pool_in_water: abiotic_water/sNO3W

Phosphate_pool_in_water: abiotic_water/sPO4W

Adsorbed_phosphorus_in_water: abiotic_water/sPAIMW
Oxygen_pool_in_water: abiotic_water/sO2W
Inorg_pool_in_water: abiotic_water/sDIMW
Detritus_DW_in_water: abiotic_water/sDDetW
Detritus_N_in_water: abiotic_water/sNDetW
Detritus_P_in_water: abiotic_water/sPDetW
Detritus_Si_in_water: abiotic_water/sSiDetW
Diatom_DW_in_water: phytoplankton_water/sDDiatW
Green_DW_in_water: phytoplankton_water/sDGrenW
Blue_DW_in_water: phytoplankton_water/sDBlueW
Diatom_N_in_water: phytoplankton_water/sNDiatW
Green_N_in_water: phytoplankton_water/sNGrenW
Blue_N_in_water: phytoplankton_water/sNBlueW
Diatom_P_in_water: phytoplankton_water/sPDIatW
Green_P_in_water: phytoplankton_water/sPGrenW
Blue_P_in_water: phytoplankton_water/sPBlueW
Ammonia_pool_in_sediment: abiotic_sediment/sNH4S
Nitrate_pool_in_sediment: abiotic_sediment/sNO3S
Phosphate_pool_in_sediment: abiotic_sediment/sPO4S
Adsorbed_phosphorus_in_sediment: abiotic_sediment/sPAIMS
Inorg_pool_in_sediment: abiotic_sediment/sDIMS
Detritus_DW_in_sediment: abiotic_sediment/sDDetS
Detritus_N_in_sediment: abiotic_sediment/sNDetS
Detritus_P_in_sediment: abiotic_sediment/sPDetS
Detritus_Si_in_sediment: abiotic_sediment/sSiDetS
Diatom_DW_in_sediment: phytoplankton_sediment/sDDiatS
Green_DW_in_sediment: phytoplankton_sediment/sDGrenS
Blue_DW_in_sediment: phytoplankton_sediment/sDBlueS

Diatom_N_in_sediment: phytoplankton_sediment/sNDiatS
Green_N_in_sediment: phytoplankton_sediment/sNGrenS
Blue_N_in_sediment: phytoplankton_sediment/sNBlueS
Diatom_P_in_sediment: phytoplankton_sediment/sPDiats
Green_P_in_sediment: phytoplankton_sediment/sPGrenS
Blue_P_in_sediment: phytoplankton_sediment/sPBlueS
vegetation_DW: macrophytes/sDVeg
adult_fish_DW: fish/sDFiAd
Detritus_abiotic_update: abiotic_sediment/tDAbioDetS
Detritus_from_algae: phytoplankton_sediment/tDPrimDetS
Detritus_from_vegetation: macrophytes/tDBedDetS
Detritus_from_zoobenthos: zoobenthos/tDWebDetS
Humus_DW_in_sediment: abiotic_sediment/sDHumS
Humus_N_in_sediment: abiotic_sediment/sNHumS
Humus_P_in_sediment: abiotic_sediment/sPHumS
Humus_abiotic_update: abiotic_sediment/tDAbioHumS
Zooplankton_DW: zooplankton/sDZoo
Zooplankton_P: zooplankton/sPZoo
Zooplankton_N: zooplankton/sNZoo
SiO2_pool_water: abiotic_water/sSiO2W

S4. References

Janse, J. H. 2005. Model studies on the eutrophication of shallow lakes and ditches. Jan H. Janse, Ph.D. Thesis, Wageningen University, ISBN 90-8504-214-3, 378p.