Supplement for:

CSIRO Environmental Modelling Suite (EMS): Scientific description of the optical and biogeochemical models (vB3p0).

Mark E. Baird[1], Karen A. Wild-Allen[1], John Parslow[1], Mathieu Mongin[1], Barbara Robson[2], Jennifer Skerratt[1], Farhan Rizwi[1], Monika Soja-Wozniak[1], Emlyn Jones[1], Mike Herzfeld[1], Nugzar Margvelashvili[1], John Andrewartha[1], Clothilde Langlais[1], Matthew P. Adams[3], Nagur Cherukuru[4], Malin Gustafsson[5], Scott Hadley[1], Peter J. Ralph[5], Uwe Rosebrock[1], Thomas Schroeder[1], Leonardo Laiolo[1], Daniel Harrison[6], and Andrew D. L. Steven[1]

[1]CSIRO, Oceans and Atmosphere, Hobart, Australia
[2]Australian Institute of Marine Science, Townsville, Australia
[3]School of Mathematical Sciences, Queensland University of Technology, Brisbane, Australia
[4]CSIRO, Land and Water, Canberra, Australia
[5]Plant Functional Biology and Climate Change Cluster, Faculty of Science, University of Technology Sydney, Sydney, Australia
[6]Southern Cross University, Coffs Harbour, Australia

Correspondence: Mark Baird (mark.baird@csiro.au)

1 Process list of B3p0

The processes described in this paper are for version B3p0, which is invoked with a configuration file listing the processes in each of the domains `water`, `sediment` and `epibenthic`:

```
water
{
tfactor
viscosity
moldiff
values_common
remineralization
microphytobenthos_spectral_grow_wc
phytoplankton_spectral_grow_wc(small)
phytoplankton_spectral_grow_wc(large)
trichodesmium_mortality_wc
trichodesmium_spectral_grow_wc
phytoplankton_spectral_mortality_wc(small)
phytoplankton_spectral_mortality_wc(large)
zooplankton_mortality_wc(small)
zooplankton_mortality_wc(large)
zooplankton_large_carnivore_spectral_grow_wc
zooplankton_small_spectral_grow_wc
nitrification_wc
p_adsorption_wc
carbon_chemistry_wc
gas_exchange_wc(carbon,oxygen)
light_spectral_wc(H,HPLC)
massbalance_wc
}
epibenthos
{
tfactor_epi()
values_common_epi()
macroalgae_spectral_grow_epi()
seagrass_spectral_grow_epi(Zostera)
seagrass_spectral_grow_epi(Halophila)
seagrass_spectral_grow_epi(Deep)
coral_spectral_grow_bleach_epi()
```

```
coral_spectral_carb_epi(H)
macroalgae_mortality_epi()
seagrass_spectral_mortality_proto_epi(Zostera)
seagrass_spectral_mortality_proto_epi(Halophila)
seagrass_spectral_mortality_proto_epi(Deep)
massbalance_epi()
light_spectral_uq_epi(H)
diffusion_epi()
}
sediment
{
tfactor
viscosity
moldiff
values_common
remineralization
light_spectral_sed(HPLC)
microphytobenthos_spectral_grow_sed
carbon_chemistry_wc()
microphytobenthos_spectral_mortality_sed
phytoplankton_spectral_mortality_sed(small)
phytoplankton_spectral_mortality_sed(large)
zooplankton_mortality_sed(small)
zooplankton_mortality_sed(large)
trichodesmium_mortality_sed
nitrification_denitrification_sed
p_adsorption_sed
massbalance_sed()
}
```

or alternatively with a call in the configuration file: `PROCESSFNAME B3p0`.

Other processes in the `process_library` can be validly called, but their scientific description is not given in this paper. The header in the source code for each process file gives detail about it use within the code, such as any arguments that it requires (for example `seagrass_spectral_grow_epi` requires the seagrass type as an argument).

2 Code architecture

This paper is a scientific description of the EMS ecological library (`/EMS/model/lib/ecology`). The ecological library consists primarily of a set of routines describing individual processes. The model chooses which processes it will include based on a configuration file (App. 1 provides the configuration file for B3p0). The model equations are primarily derivatives of the ecological state variables, and have been split in this paper into separate processes (such as a phytoplankton growth), thus aligning with the code (such as `phytoplankton_spectral_grow_wc.c`). This object-based approach allows individual processes to be included / excluded in a configuration file without re-writing the model code.

Within a process file, the routine containing the ecological derivatives is `<process_name>_calc`, and within that routine the ecological derivatives are stored within the array `y1`. Each element in the array `y1` stores the derivatives of a state variable. The index to the array for each state variable is determined within each process initialisation routine, `<process_name>_init`, and stored in the processes' workspace `ws`. In the case of nitrate, for example, the derivative held in `y1` will be the sum of the derivatives calculated in multiple processes (such as each autotrophic growth process, nitrification, denitrification, and each grazing and mortality process). The array of derivatives is then used by the model's adaptive integrator to update the model state, as held in the array `y`.

Some components of the ecological model are updated only once every time step without the derivatives being calculated. These include the optical and carbon chemistry model state variables. In these cases, the state variables, which are stored in the array `y`, are updated directly and this is done in either the routine `<process_name>_precalc` or `<process_name>_postcalc`.

3 State (prognostic) variables

The below tables list the ecologically-relevant physical variables (Table 1), 10 dissolved (Table 2), 20 microalgal (Table 3), 2 zooplankton (Table 4), 7 non-living inorganic particulate (Table 5), 7 non-living organic particulate (Table 6) and 7 epibenthic plant (Table 7) and 5 coral polyp (Table 8) and 4 reaction centre (Table 9) state variables. All state variables that exist in the water column layers have an equivalent in the sediment layers (and are specified by `<variable name>_sed`). The dissolved tracers are given as a concentration in the porewater, while the particulate tracers are given as a concentration per unit volume.

Name	Symbol	Units	Description
Temperature (temp)	T	$^{\circ}$C	Water temperature
Salinity (salt)	S	PSU	Water salinity
Sea level elevation (eta)	η	m	Sea level elevation relative to mean sea level
Porosity (porosity)	ϕ	-	Fraction of the volume made up of water
Bottom shear stress (ustrcw_skin)	τ	N m^{-2}	Shear stress due to currents and waves
Sand ripple height (PHYSRIPH)	-	m	Physical dimension used for estimating bottom roughness due to ripples according to **?**
Solar zenith (Zenith)	θ_{air}	radians	Solar zenith angle is the angle between the zenith and the centre of the Sun's disc, taking a value of zero with the sun directly above, and $\pi/2$ when at, or below, the horizon.

Table 1. Long name (and variable name) in model output files, symbol and units used in this document, and a description of ecologically-relevant physical state and diagnostic variables.

Name	Symbol	Units	Description
Total alkalinity (alk)	A_T	mol kg^{-1}	Concentration of ions that can be converted to uncharged species by a strong acid. The model assumes A_T =[HCO_3^-] + [CO_3^{2-}], often referred to as carbonate alkalinity. Alkalinity and DIC together quantify the equilibrium state of the seawater carbon chemistry.
Nitrate (NO3)	[NO_3^-]	mg N m^{-3}	Concentration of nitrate. In the absence of nitrite [NO_2^-] in the model, nitrate represents [NO_3^-] + [NO_2^-].
Ammonium (NH4)	[NH_4^-]	mg N m^{-3}	Concentration of dissolved ammonium.
Dissolved Inorganic Phosphorus (DIP)	P	mg P m^{-3}	Concentration of dissolved inorganic phosphorus, also referred to as orthophosphate or soluble reactive phosphorus, SRP, composed chiefly of HPO_4^{2-} ions, with a small percentage present as PO_4^{3-}.
Dissolved inorganic carbon (DIC)	DIC	mg C m^{-3}	Concentration of dissolved inorganic carbon, composed chiefly at seawater pH of HCO_3^-, with a small percentage present as CO_3^{2-}.
Dissolved oxygen (Oxygen)	[O_2]	mg O m^{-3}	Concentration of oxygen.
Chemical Oxygen Demand (COD)	COD	mg O m^{-3}	Concentration of products of anoxic respiration in oxygen units. This represents products such as hydrogen sulfide, H_2S, that are produced during anoxic respiration and which, upon reoxidation of the water, will consume oxygen.
Dissolved Organic Carbon (DOR_C)	O_C	mg C m^{-3}	The concentration of carbon in dissolved organic compounds.
Dissolved Organic Nitrogen (DOR_N)	O_N	mg N m^{-3}	The concentration of nitrogen in dissolved organic compounds.
Dissolved Organic Phosphorus (DOR_P)	O_P	mg P m^{-3}	The concentration of phosphorus in dissolved organic compounds.

Table 2. Long name (and variable name) in model output files, symbol and units used in this document, and a description of all dissolved state variables. When the concentration of an ion is given, the chemical formulae appears in [ ] brackets.

Name	Symbol & Units	Description
Phytoplankton N (*_N)	B [mg N m^{-3}]	Total structural biomass of nitrogen of the phytoplankton population. All microalgae have a C:N:P ratio of the structural material of 106:16:1. Thus the mass of phosphorus in the structural material of a population with a biomass B is given by: $\frac{1}{16}\frac{31}{14}B$ and the mass of carbon by: $\frac{106}{16}\frac{12}{14}$ B. The number of cells is given by B/m_N.
Phytoplankton N reserves (*_NR)	BR_N^* [mg N m^{-3}]	Total non-structural biomass of nitrogen of the phytoplankton population. Phytoplankton N reserves divided by Phytoplankton N is a number between 0 and 1 and represents the factor by which phytoplankton growth is inhibited due to the internal reserves of nitrogen.
Phytoplankton P reserves (*_PR)	$\frac{1}{16}\frac{31}{14}BR_P^*$ [mg P m^{-3}]	Total non-structural biomass of phosphorus of the phytoplankton population. Phytoplankton P reserves divided by (Phytoplankton N $\times\frac{1}{16}\frac{31}{14}$) is a number between 0 and 1 and represent the factor by which phytoplankton growth is inhibited due to the internal reserves of phosphorus.
Phytoplankton I reserves (*_I)	$\frac{1060}{16}\frac{1}{14}BR_I^*$ [mmol photon m^{-3}]	Total non-structural biomass of fixed carbon of the phytoplankton population, quantified in photons. Phytoplankton I reserves divided by (Phytoplankton N $\times\frac{1060}{16}\frac{1}{14}$) is a number between 0 and 1 and represent the factor by which phytoplankton growth is inhibited due to the internal reserves of energy (or fixed carbon).
Phytoplankton chlorophyll (*_Chl)	nc_iV [mg m^{-3}]	Concentration of the chlorophyll a pigment of the population. The four phytoplankton classes have two pigments, a chlorophyll a-based pigment and an accessory pigment. As the pigment concentration adjusts to optimise photosynthesis, including the presence of the accessory pigment, the intracellular content, c_iV, represents only the chlorophyll a-based pigment. As the model does not distinguish between mono-vinyl and di-vinyl forms of chlorophyll, this c_i represents either form, depending on the phytoplankton type.

Table 3. Long name (and variable name) in model output files, symbol and units used in this document, and description of all microalgae state variables in the model. The model contains four categories of phytoplankton (category shown as * in left column, and given in brackets in following list): small (PhyS), $r < 2$ μm phytoplankton; large (PhyL): $r > 2\,\mu$m phytoplankton; *Trichodesmium* (Tricho): nitrogen fixing phytoplankton; and benthic microalgae (MPB): fast-sinking diatoms that are suspended primarily in the top layer of sediment porewaters. The elemental ratio of phytoplankton including both structural material and reserves is given by: C:N:P = $106(1+R_C^*):16(1+R_N^*):(1+R_P^*)$. In the model description (this document) we have more correctly described fixed carbon as carbon reserves, while in the model outputs they are represented quantified as energy reserves. The relationship is 1 mg C of carbon reserves is equal to $(1060/106)/12.01$ mmol photons of energy reserves.

Name	Symbol	Units	Description
Zooplankton N (ZooS_N, ZooL_N)	Z	[mg N m^{-3}]	Total biomass of nitrogen in animals. With only small and large zooplankton categories resolved, small zooplankton represents the biomass of unicellular fast growing animals (protozoans) and large zooplankton represents the biomass of all other animals (metazoans). All zooplankton have a C:N:P ratio of 106:16:1. Thus the mass of phosphorus of a population with a biomass Z is given by: $\frac{1}{16}\frac{31}{14}Z$ and the mass of carbon by: $\frac{106}{16}\frac{12}{14}$ Z.

Table 4. Long name (and variable name) in model output files, symbol, unit used in this document, and description of zooplankton state variables in the model.

Name	Symbol	Units	Description
Fine Sediment (FineSed)	$FineSed$	[kg m^{-3}]	Identical to Mud-mineral, except that it is initialised to zero in the model domain, and enters only from the catchments.
Dust (Dust)	$Dust$	[kg m^{-3}]	Very small sized, re-suspending particles with a sinking velocity of 1 m d^{-1} and mass-specific optical properties based on observations in Gladstone Harbour.
Mud-mineral (Mud-mineral)	$Mud_{\mathrm{non-CaCO_3}}$	[kg m^{-3}]	Small sized, re-suspending particles with a sinking velocity of 17 m d^{-1}, and mass-specific optical properties based on observations in Gladstone Harbour.
Mud-carbonate (Mud-carbonate)	$Mud_{\mathrm{CaCO_3}}$	[kg m^{-3}]	Small sized, re-suspending particles with a sinking velocity of 17 m d^{-1}, and mass-specific optical properties based on observations of suspended carbonates at Lucinda Jetty.
Sand-mineral (Sand-mineral)	$Sand_{\mathrm{non-CaCO_3}}$	[kg m^{-3}]	Medium sized, re-suspending particles with a sinking velocity of 173 m d^{-1} and mass-specific optical properties based on observations in Gladstone Harbour.
Sand-carbonate (Sand-carbonate)	$Sand_{\mathrm{CaCO_3}}$	[kg m^{-3}]	Medium sized, re-suspending particles with a sinking velocity of 173 m d^{-1} and mass-specific optical properties based on observations of suspended carbonates at Lucinda Jetty.
Gravel-mineral (Gravel-mineral)	$Gravel_{\mathrm{non-CaCO_3}}$	[kg m^{-3}]	Large, non-resuspending particles.
Gravel-carbonate (Gravel-carbonate)	$Gravel_{\mathrm{CaCO_3}}$	[kg m^{-3}]	Large, non-resuspending particles.

Table 5. Long name (and variable name) in model output files, symbol, unit used in this document, and description of all inorganic particulate state variables in the model.

Name	Symbol	Units	Description
Particulate Inorganic Phosphorus (PIP)	PIP	[mg P m^{-3}]	Phosphorus ions that are absorbed onto particles. It is considered a particulate with the same properties as Mud.
Immobilised Particulate Inorganic Phosphorus (PIPI)	$PIPI$	[mg P m^{-3}]	Phosphorus that is permanently removed from the system through burial of PIP.
Labile Detritus Nitrogen Plank (DetPL_N)	D_{Red}	[mg N m^{-3}]	Concentration of N in labile (quickly broken down) organic matter with a C:N:P ratio of 106:16:1 derived from living microalgae, zooplankton, coral host tissue and zooxanthellae with the same C:N:P ratio. Thus the mass of phosphorus in D_{Red} is given by: $\frac{1}{16}\frac{31}{14}D_{Red}$ and the mass of carbon by: $\frac{106}{16}\frac{12}{14}D_{Red}$.
Labile Detritus Nitrogen Benthic (DetBL_N)	D_{Atk}	[mg N m^{-3}]	Concentration of N in labile (quickly broken down) organic matter with a C:N:P ratio of 550:30:1 derived from living seagrass and macroalgae with the same C:N:P ratio. Thus the mass of phosphorus in D_{Atk} is given by: $\frac{1}{30}\frac{31}{14}D_{Atk}$ and the mass of carbon by: $\frac{550}{30}\frac{12}{14}D_{Atk}$.
Refractory Detritus Carbon (DetR_C)	D_C	[mg C m^{-3}]	Concentration of carbon as particulate refractory (slowly breaking down) material. It is sourced only from the breakdown of labile detritus, and from rivers.
Refractory Detritus Nitrogen (DetR_N)	D_N	[mg N m^{-3}]	Concentration of nitrogen as particulate refractory (slowly breaking down) material. It is sourced only from the breakdown of labile detritus, and from rivers.
Refractory Detritus Phosphorus (DetR_P)	D_P	[mg P m^{-3}]	Concentration of phosphorus as particulate refractory (slowly breaking down) material. It is sourced only from the breakdown of labile detritus, and from rivers.

Table 6. Long name (and variable name) in model output files, symbol, unit used in this document, and description of all particulate detrital state variables in the model.

Name	Symbol	Description
Macroalgae (MA)	MA [g N m^{-2}]	Concentration of nitrogen biomass per m^2 of macrolagae. Macroalgae (or seaweed) grows above all other benthic plants (corals, seagrasses, benthic microalgae). It is parameterised as a non-calcifying leafy algae, with a C:N:P ratio of 550:30:1, and a formulation for calculating the percentage of the bottom covered as $1 - \exp(-\Omega_{MA}\ MA)$. In the model, in the absence of both calcifying macroalgae (particularly *Halimeda*) and unicellular epiphytes, macroalgae represents the biomass of all seaweeds and epiphytes.
Seagrass (SG)	SG [g N m^{-2}]	Concentration of nitrogen biomass per m^2 of a seagrass form parameterised to be similar to *Zostera*. This form captures light after it has passed through macroalgae and before it passes through *Halophila*. This form is better adapted to high light, low nutrient conditions than *Halophila* as a result of a deeper root structure and being able to shade it. See macroalgae for elemental ratio and bottom cover.
Halophila (SGH)	SGH [g N m^{-2}]	Concentration of nitrogen biomass per m^2 of a seagrass form parameterised to be similar to *Halophila ovalis*. This form captures light after it has passed through the *Zostera* seagrass form. The *Halophila ovalis* form is batter adapted to low light conditions than *Zostera*, having a faster growth rate and lower minimum light requirement. See macroalgae for elemental ratio and bottom cover.
Deep seagrass (SGD)	SGD [g N m^{-2}]	Concentration of nitrogen biomass per m^2 of a seagrass form parameterised to be similar to *Halophila deciphens*. This form captures light after it has passed through the *Zostera* and *Halophila ovalis* seagrass form.
*root N	$*ROOT\_N$ [g N m^{-2}]	Concentration of nitrogen biomass per m^2 in the roots of seagrass type * (SG, SGH or SGD). While this biomass in reality exists in multiple depths in the sediments, and in the model accesses multiple layers for nutrient uptake, it is quantified in the epibenthic compartment.

Table 7. Long name (and variable name) in model output files, units, symbol used in this document, and description of macroalgae and seagrass state variables in the model. The order in the above table corresponds to their vertical position, and therefore the order in which they access light. Benthic microalage, being suspended in porewaters, is consider as a particulate in Table 5.

Name	Symbol	Description
Coral host N (CH_N)	CH [g N m^{-2}]	Concentration of nitrogen biomass per m^2 of coral host tissue in the entire grid cell. Unlike other epibenthic variables, corals area is assumed to exist in communities that are potentially smaller than the grid size. The fraction of the grid cell covered by corals is given by A_{CH}. Thus the biomass in the occupied region is given by CH/A_{CH}. The percent coverage of the coral of the bottom for the whole cell is given by $A_{CH}\,(1-\exp(-\Omega_{CH}\ CH/A_{CH}))$. With only one type of coral resolved, CH represents the biomass of all symbiotic corals. Since the model contains no other benthic filter-feeders, CH best represent the sum of the biomass of all symbiotic filter-feeding organisms such as corals, sponges, clams etc. C:N:P is 106:16:1.
Coral symbiont N (CS_N)	CS [mg N m^{-2}]	Concentration of nitrogen biomass per m^2 of coral symbiont cells, or zooxanthellae. To determine the density of cells, use $n = CS/m_N$. The percentage of the bottom covered is given by $\frac{\pi}{2\sqrt{3}} n\pi r_{zoo}^2$ where πr^2 is the projected area of the cell, n is the number of cells, and $\pi/(2\sqrt{3}) \sim 0.9069$ accounts for the maximum packaging of spheres. C:N:P is 106:16:1.
Coral symbiont chl (CS_Chl)	nc_iV [mg chl m^{-2}]	Concentration of chlorophyll biomass per m^2 of coral symbiont cells.
Coral symbiont diadinoxanthin (CS_Xp)	nx_pV [mg pig m^{-2}]	Concentration of the photosynthetic xanthophyll cycle pigment per m^2 of coral symbiont cells.
Coral symbiont diatoxanthin (CS_Xh)	nx_hV [mg pig m^{-2}]	Concentration of heat dissipating xanthophyll cycle pigment biomass per m^2 of coral symbiont cells.

Table 8. Long name (and variable name) in model output files, units, symbol used in this document, and description of coral state variables in the model.

Name	Symbol	Description
Symbiont oxidised RC (CS_Qox)	Q_{ox} [mg N m^{-2}]	Concentration of symbiont reaction centres in an oxidised state per m^2, residing in the symbiont, of in the entire grid cell.
Symbiont reduced RC (CS_Qred)	Q_{red} [mg N m^{-2}]	Concentration of symbiont reaction centres in a reduced state per m^2, residing in the symbiont, of in the entire grid cell.
Symbiont inhibited RC (CS_Qin)	Q_{in} [mg N m^{-2}]	Concentration of symbiont reaction centres in an inhibited state per m^2, residing in the symbiont, of in the entire grid cell.
Symbiont reactive oxygen (CS_RO)	$[ROS]$ [mg N m^{-2}]	Concentration of reactive oxygen per m^2, residing in the symbiont, of in the entire grid cell.

Table 9. Long name (and variable name) in model output files, units, symbol used in this document, and description of coral reaction state variables in the model.

4 Parameter values used in eReefs biogeochemical model (B3p0).

The below five tables of parameters are specified for each run, and can be automatically generated by the EMS software after a simulation from the parameter file. At model initialisation the model produces a file `ecology_setup.txt` that contains a list of all the parameter values used, both those specified in the parameter file, and those using model defaults.

Description	Name in code	Symbol	Value	Units
Reference temperature	Tref	T_{ref}	2.000000e+01	Deg C
Temperature coefficient for rate parameters	Q10	$Q10$	2.000000e+00	none
Nominal rate of TKE dissipation in water column	TKEeps	ϵ	1.000000e-06	m^2 s^{-3}
Atmospheric CO2	xco2_in_air	$p\mathrm{CO}_2$	3.964800e+02	ppmv
Concentration of dissolved N2	N2	$[\mathrm{N}_2]_{gas}$	2.000000e+03	mg N m^{-3}
DOC-specific absorption of CDOM 443 nm	acdom443star	$k_{CDOM,443}$	1.300000e-04	m^2 mg C^{-1}

Table 10. Environmental parameters in eReefs biogeochemical model (B3p0).

Description	Name in code	Symbol	Value	Units
Chl-specific scattering coef. for microalgae	bphy	b_{phy}	2.000000e-01	m^{-1}(mg Chla $m^{-3})^{-1}$
Nominal N:Chl a ratio in phytoplankton by weight	NtoCHL	$R_{N:Chl}$	7.000000e+00	g N(g Chla$)^{-1}$
Maximum growth rate of PL at Tref	PLumax	μ_{PL}^{max}	1.400000e+00	d^{-1}
Radius of the large phytoplankton cells	PLrad	r_{PL}	4.000000e-06	m
Natural (linear) mortality rate, large phytoplankton	PhyL_mL	$m_{L,PL}$	1.000000e-01	d^{-1}
Natural (linear) mortality rate in sed., large phyto.	PhyL_mL_sed	$m_{L,PL,sed}$	1.000000e+01	d^{-1}
Maximum growth rate of PS at Tref	PSumax	μ_{PL}^{max}	1.600000e+00	d^{-1}
Radius of the small phytoplankton cells	PSrad	r_{PS}	1.000000e-06	m
Natural (linear) mortality rate, small phyto.	PhyS_mL	$m_{L,PS}$	1.000000e-01	d^{-1}
Natural (linear) mortality rate in sed., small phyto.	PhyS_mL_sed	$m_{L,PS,sed}$	1.000000e+00	d^{-1}
Maximum growth rate of MB at Tref	MBumax	μ_{MPB}^{max}	8.390000e-01	d^{-1}
Radius of the MPB cells	MBrad	r_{MPB}	1.000000e-05	m
Natural (quadratic) mortality rate, MPB (in sed)	MPB_mQ	$m_{Q,MPB}$	1.000000e-04	d^{-1}(mg N $m^{-3})^{-1}$
Ratio of xanthophyll to chl a of PS	PSxan2chl	$\Theta_{xan2chl,PS}$	5.100000e-01	mg mg $^{-1}$
Ratio of xanthophyll to chl a of PL	PLxan2chl	$\Theta_{xan2chl,PL}$	8.100000e-01	mg mg $^{-1}$
Ratio of xanthophyll to chl a of MPB	MBxan2chl	$\Theta_{xan2chl,MPB}$	8.100000e-01	mg mg $^{-1}$
Maximum growth rate of Trichodesmium at Tref	Tricho_umax	μ_{MPB}^{max}	2.000000e-01	d^{-1}
Radius of Trichodesmium colonies	Tricho_rad	r_{MPB}	5.000000e-06	m
Sherwood number for the Tricho dimensionless	Tricho_Sh	Sh_{Tricho}	1.000000e+00	none
Linear mortality for Tricho in sediment	Tricho_mL	$m_{L,Tricho}$	1.000000e-01	d^{-1}
Quadratic mortality for Tricho due to phages in wc	Tricho_mQ	$m_{Q,Tricho}$	1.000000e-01	d^{-1}(mg N $m^{-3})^{-1}$
Critical Tricho above which quadratic mortality applies	Tricho_crit		2.000000e-04	mg N m^{-3}
Minimum density of Trichodesmium	p_min	$\rho_{min,Tricho}$	9.000000e+02	kg m^{-3}
Maximum density of Trichodesmium	p_max	$\rho_{max,Tricho}$	1.050000e+03	kg m^{-3}
DIN conc below which Tricho N fixes	DINcrit	DIN_{crit}	1.000000e+01	mg N m^{-3}
Ratio of xanthophyll to chl a of Trichodesmium	Trichoxan2chl	$\Theta_{xan2chl,Tricho}$	5.000000e-01	mg mg $^{-1}$
Minimum carbon to chlorophyll a ratio	C2Chlmin	θ_{min}	2.000000e+01	wt/wt

Table 11. Phytoplankton parameters in eReefs biogeochemical model (B3p0).

Description	Name in code	Symbol	Value	Units
Maximum growth rate of ZS at Tref	ZSumax	μ^{ZS}_{max}	4.000000e+00	d^{-1}
Radius of the small zooplankton cells	ZSrad	r_{ZS}	5.000000e-06	m
Swimming velocity for small zooplankton	ZSswim	U_{ZS}	2.000000e-04	$m\ s^{-1}$
Grazing technique of small zooplankton	ZSmeth		rect	none
Maximum growth rate of ZL at Tref	ZLumax	μ^{ZL}_{max}	1.330000e+00	d^{-1}
Radius of the large zooplankton cells	ZLrad	r_{ZL}	3.200000e-04	m
Swimming velocity for large zooplankton	ZLswim	U_{ZL}	3.000000e-03	$m\ s^{-1}$
Grazing technique of large zooplankton	ZLmeth		rect	none
Growth efficiency, large zooplankton	ZL_E	E_{ZL}	4.260000e-01	none
Growth efficiency, small zooplankton	ZS_E	E_{ZS}	4.620000e-01	none
Natural (quadratic) mortality rate, large zooplankton	ZL_mQ	$m_{Q,ZL}$	1.200000e-02	$d^{-1}(mg\ N\ m^{-3})^{-1}$
Natural (quadratic) mortality rate, small zooplankton	ZS_mQ	$m_{Q,ZS}$	2.000000e-02	$d^{-1}(mg\ N\ m^{-3})^{-1}$
Fraction of growth inefficiency lost to detritus, large zoo.	ZL_FDG	γ_{ZL}	5.000000e-01	none
Fraction of mortality lost to detritus, large zoo.	ZL_FDM	N/A	1.000000e+00	none
Fraction of growth inefficiency lost to detritus, small zoo.	ZS_FDG	γ_{ZS}	5.000000e-01	none
Fraction of mortality lost to detritus, small zooplankton	ZS_FDM	N/A	1.000000e+00	none

Table 12. Zooplankton parameters in eReefs biogeochemical model (B3p0).

Description	Name in code	Symbol	Value	Units
Fraction of labile detritus converted to refractory detritus	F_LD_RD	ζ_{Red}	1.900000e-01	none
Fraction of labile detritus converted to DOM	F_LD_DOM	ϑ_{Red}	1.000000e-01	none
fraction of refractory detritus that breaks down to DOM	F_RD_DOM	ϑ_{Ref}	5.000000e-02	none
Breakdown rate of labile detritus at 106:16:1	r_DetPL	r_{Red}	4.000000e-02	d^{-1}
Breakdown rate of labile detritus at 550:30:1	r_DetBL	r_{Atk}	1.000000e-03	d^{-1}
Breakdown rate of refractory detritus	r_RD	r_R	1.000000e-03	d^{-1}
Breakdown rate of dissolved organic matter	r_DOM	r_O	1.000000e-04	d^{-1}
Respiration as a fraction of umax	Plank_resp	ϕ	2.500000e-02	none
Oxygen half-saturation for aerobic respiration	KO_aer	K_{OA}	2.560000e+02	mg O m^{-3}
Maximum nitrification rate in water column	r_nit_wc	$\tau_{nit,wc}$	1.000000e-01	d^{-1}
Maximum nitrification rate in water sediment	r_nit_sed	$\tau_{nit,sed}$	2.000000e+01	d^{-1}
Oxygen half-saturation for nitrification	KO_nit	$K_{\mathrm{O}_2,nit}$	5.000000e+02	mg O m^{-3}
Rate at which P reaches adsorbed/desorbed equilibrium	Pads_r	τ_{Pabs}	4.000000e-02	d^{-1}
Freundlich Isothermic Const P adsorption to TSS in wc	Pads_Kwc	$k_{Pads,wc}$	3.000000e+01	mg P kg TSS^{-1}
Freundlich Isothermic Const P adsorption to TSS in sed	Pads_Ksed	$k_{Pads,sed}$	7.400000e+01	mg P kg TSS^{-1}
Oxygen half-saturation for P adsorption	Pads_KO	$K_{\mathrm{O}_2,abs}$	2.000000e+03	mg O m^{-3}
Exponent for Freundlich Isotherm	Pads_exp	N/A	1.000000e+00	none
Maximum denitrification rate	r_den	τ_{denit}	8.000000e-01	d^{-1}
Oxygen half-saturation constant for denitrification	KO_den	$K_{\mathrm{O}_2,denit}$	1.000000e+04	mg O m^{-3}
Rate of conversion of PIP to immobilised PIP	r_immob_PIP	τ_{Pimm}	1.200000e-03	d^{-1}

Table 13. Detritus parameters in eReefs biogeochemical model (B3p0).

Description	Name in code	Symbol	Value	Units
Sediment-water diffusion coefficient	EpiDiffCoeff	D	3.000000e-07	m^2 s^{-1}
Thickness of diffusive layer	EpiDiffDz	h	6.500000e-03	m
Maximum growth rate of MA at Tref	MAumax	μ_{MA}^{max}	1.000000e+00	d^{-1}
Natural (linear) mortality rate, macroalgae	MA_mL	ζ_{MA}	1.000000e-02	d^{-1}
Nitrogen-specific leaf area of macroalgae	MAleafden	Ω_{MA}	1.000000e+00	m^2 g N^{-1}
Respiration as a fraction of umax	Benth_resp	ϕ	2.500000e-02	none
net dissolution rate of sediment without coral	dissCaCO3_sed	d_{sand}	1.000000e-03	mmol C m^{-2} s^{-1}
Grid scale to reef scale ratio	CHarea	A_{CH}	1.000000e-01	m^2 m^{-2}
Nitrogen-specific host area of coral polyp	CHpolypden	Ω_{CH}	2.000000e+00	m^2 g N^{-1}
Max. growth rate of Coral at Tref	CHumax	μ_{CH}^{max}	5.000000e-02	d^{-1}
Max. growth rate of zooxanthellae at Tref	CSumax	μ_{CS}^{max}	4.000000e-01	d^{-1}
Radius of the zooxanthellae	CSrad	r_{CS}	5.000000e-06	m
Quadratic mortality rate of coral polyp	CHmort	ζ_{CH}	1.000000e-02	(g N $m^{-2})^{-1}$ d^{-1}
Linear mortality rate of zooxanthellae	CSmort	ζ_{CS}	4.000000e-02	d^{-1}
Fraction of coral host death translocated.	CHremin	f_{remin}	5.000000e-01	-
Rate coefficent for particle uptake by corals	Splank	S_{part}	3.000000e+00	m d^{-1}
Maximum daytime coral calcification	k_day_coral	k_{day}	1.320000e-02	mmol C m^{-2} s^{-1}
Maximum nightime coral calcification	k_night_coral	k_{night}	6.900000e-03	mmol C m^{-2} s^{-1}
Carbonate sediment dissolution rate on shelf	dissCaCO3_shelf	d_{shelf}	1.000000e-04	mmol C m^{-2} s^{-1}
Age tracer growth rate per day	ageing_decay	n/a	1.000000e+00	d d^{-1}
Age tracer decay rate per day outside source	anti_ageing_decay	Φ	1.000000e-01	d^{-1}
Bleaching ROS threshold	ROSthreshold	ϕ_{ROS}	5.000000e-04	mg O $cell^{-1}$
Xanthophyll switching rate coefficient	Xanth_tau	τ_{xan}	8.333333e-04	s^{-1}
Ratio of RCII to Chlorophyll a	chla2rcii	A_{RCII}	2.238413e-06	mol RCII g Chl^{-1}
Stoichiometric ratio of RCII units to photons	photon2rcii	m_{RCII}	1.000000e-07	mol RCII mol $photon^{-1}$
Maximium zooxanthellae expulsion rate	ROSmaxrate	γ	1.000000e+00	d^{-1}
Scaling of DetP to DOP, relative to N	r_RD_NtoP	r_{RD_NtoP}	2.000000e+00	-
Scaling of DOM to DIP, relative to N	r_DOM_NtoP	r_{DOM_NtoP}	1.500000e+00	-
Radius of Trichodesmium colonies	Tricho_colrad	$r_{Trichocolony}$	5.000000e-06	m

Table 14. Benthic parameters in eReefs biogeochemical model (B3p0), excluding seagrass

Description	Name in code	Symbol	Value	Units
Maximum growth rate of SG at Tref	SGumax	μ_{SG}^{max}	4.000000e-01	d^{-1}
Half-saturation of SG N uptake in SED	SG_KN	$K_{SG,N}$	4.200000e+02	$mg\ N\ m^{-3}$
Half-saturation of SG P uptake in SED	SG_KP	$K_{SG,P}$	9.600000e+01	$mg\ P\ m^{-3}$
Natural (linear) mortality rate aboveground seagrass	SG_mL	ζ_{SG_A}	3.000000e-02	d^{-1}
Natural (linear) mortality rate belowground seagrass	SGROOT_mL	ζ_{SG_B}	4.000000e-03	d^{-1}
Fraction (target) of SG biomass below-ground	SGfrac	$f_{below,SG}$	7.500000e-01	-
Time scale for seagrass translocation	SGtransrate	$\tau_{tran,SG}$	3.330000e-02	d^{-1}
Nitrogen-specific leaf area of seagrass	SGleafden	Ω_{SG}	1.500000e+00	$m^2\ g\ N^{-1}$
Seagrass seed biomass as fraction of 63 % cover	SGseedfrac	$f_{seed,SG}$	1.000000e-02	-
Sine of nadir Zostera canopy bending angle	SGorient	$\sin\beta_{blade,SG}$	5.000000e-01	-
Compensation irradiance for Zostera	SGmlr	$E_{comp,SG}$	4.500000e+00	$mol\ m^{-2}$
Maximum depth for Zostera roots	SGrootdepth	$z_{root,SG}$	-1.500000e-01	m
Critical shear stress for SG loss	SG_tau_critical	$\tau_{SG,shear}$	1.000000e+00	$N\ m^{-2}$
Time-scale for critical shear stress for SG loss	SG_tau_time	$\tau_{SG,time}$	4.320000e+04	s
Maximum growth rate of SGH at Tref	SGHumax	μ_{SGH}^{max}	4.000000e-01	d^{-1}
Half-saturation of SGH N uptake in SED	SGH_KN	$K_{SGH,N}$	4.200000e+02	$mg\ N\ m^{-3}$
Half-saturation of SGH P uptake in SED	SGH_KP	$K_{SGH,P}$	9.600000e+01	$mg\ P\ m^{-3}$
Nitrogen-specific leaf area of SGH	SGHleafden	Ω_{SGH}	1.900000e+00	$m^2\ g\ N^{-1}$
Natural (linear) mortality rate, aboveground SGH	SGH_mL	ζ_{SGH_A}	6.000000e-02	d^{-1}
Natural (linear) mortality rate, belowground SGH	SGHROOT_mL	ζ_{SGH_B}	4.000000e-03	d^{-1}
Fraction (target) of SGH biomass below-ground	SGHfrac	$f_{below,SGH}$	5.000000e-01	-
Time scale for Halophila translocation	SGHtransrate	$\tau_{tran,SGH}$	3.330000e-02	d^{-1}
Halophila seed biomass as fraction of 63 % cover	SGHseedfrac	$f_{seed,SGH}$	1.000000e-02	-
Sine of nadir Halophila canopy bending angle	SGHorient	$\sin\beta_{blade,SGH}$	1.000000e+00	-
Compensation irradiance for Halophila	SGHmlr	$E_{comp,SGH}$	2.000000e+00	$mol\ m^{-2}$
Maximum depth for Halophila roots	SGHrootdepth	$z_{root,SGH}$	-8.000000e-02	m
Critical shear stress for SGH loss	SGH_tau_critical	$\tau_{SGH,shear}$	1.000000e+00	$N\ m^{-2}$
Time-scale for critical shear stress for SGH loss	SGH_tau_time	$\tau_{SGH,time}$	4.320000e+04	s

Table 15. Seagrass parameters in eReefs biogeochemical model (B3p0).

Description	Name in code	Symbol	Value	Units
Maximum growth rate of SGD at Tref	SGDumax	μ_{SGD}^{max}	4.000000e-01	d^{-1}
Half-saturation of SGD N uptake in SED	SGD_KN	$K_{SGD,N}$	4.200000e+02	mg N m^{-3}
Half-saturation of SGD P uptake in SED	SGD_KP	$K_{SGD,P}$	9.600000e+01	mg P m^{-3}
Nitrogen-specific leaf area of SGD	SGDleafden	Ω_{SGD}	1.900000e+00	m^2 g N^{-1}
Natural (linear) mortality rate, aboveground SGD	SGD_mL	ζ_{SGD_A}	6.000000e-02	d^{-1}
Natural (linear) mortality rate, belowground SGD	SGDROOT_mL	ζ_{SGD_B}	4.000000e-03	d^{-1}
Fraction (target) of SGD biomass below-ground	SGDfrac	$f_{below,SGD}$	2.500000e-01	-
Time scale for deep SG translocation	SGDtransrate	$\tau_{tran,SGD}$	3.330000e-02	d^{-1}
Deep SG seed biomass as fraction of 63 % cover	SGDseedfrac	$f_{seed,SGD}$	1.000000e-02	-
Sine of nadir deep SG canopy bending angle	SGDorient	$\sin\beta_{blade,SGD}$	1.000000e+00	-
Compensation irradiance for deep SG	SGDmlr	$E_{comp,SGD}$	1.500000e+00	mol m^{-2}
Maximum depth for deep SG roots	SGDrootdepth	$z_{root,SGD}$	-5.000000e-02	m
Critical shear stress for deep SG loss	SGD_tau_critical	$\tau_{SGD,shear}$	1.000000e+00	N m^{-2}
Time-scale for shear stress for deep SG loss	SGD_tau_time	$\tau_{SGD,time}$	4.320000e+04	s

Table 16. Deep seagrass parameters in eReefs biogeochemical model (B3p0).