

Supplementary Information 1

Model configuration

Table SI1.1: Summary of the main characteristics of NB and SB model configuration.

Aspect	NEMO-BFM (NB)	ShyBFM (SB)
Physical model	NEMO v3.6 (Madec et al., 2024)	SHYFEM-MPI (Micaletto et al., 2022; Verri et al., 2023)
Grid type	Structured regular grid	Unstructured triangular finite-element (Arakawa-B-like)
Horizontal resolution	~2 km (uniform)	2 km offshore → 300 m at the coast
Domain	Whole Adriatic Sea; open boundary south of the Otranto Strait	Emilia-Romagna coastal subdomain (nested in NB)
Grid size	42214 active cells at the surface	15392 elements / 8142 nodes
Simulation period	1992-2020	2000–2009
Vertical coordinate	Free surface with 120 z-levels	Free surface with 43 z-levels
Vertical turbulence closure	TKE turbulence scheme	GOTM k-ε (Burchard et al., 1999)
Tracer advection scheme	MUSCL scheme for tracers; 2 nd centered scheme for momentum	First-order upwind
Time step and output frequency	120 s for baroclinic and 2 s for barotropic mode. Output freq. at 3 h for surface variables, daily for 3D variables.	200 s with hourly output freq.
BGC coupling	Offline, one-way (BFM driven by NEMO-TOP transport)	Online; ADR module; synchronous source splitting
BGC state variables	51 pelagic	51 pelagic
Functional groups	4 phytoplankton, 4 zooplankton, 1 bacteria, DOM/POM	4 phytoplankton, 4 zooplankton, 1 bacteria, DOM/POM
Benthic treatment	Benthic-return closure	Benthic-return closure
BGC parameters	Adriatic-wide tuning (Mentaschi et al., 2024)	ER-specific re-tuning (parameter tables below)
Atmospheric forcing	WRF 6 km at 6 h output freq. (Verri et al., 2024)	WRF 6 km at 6 h output frequency (Verri et al., 2024)
River runoff	WRF-Hydro 600 m at hourly output freq. (Verri et al., 2024)	WRF-Hydro 600 m at hourly output freq. (Verri et al., 2024)
River chemical inputs	Inorganic N/P/Si (Ludwig et al., 2009) + DIC + Total Alkalinity for Po River	Inorganic N/P/Si (Ludwig et al., 2009 + ARPAE) + DIC + TA for Po River
Initial & lateral conditions	Med-CORDEX RCM; BGC initial cond. from CMS reanalysis	From NB (nesting)

BFM parameter comparison

Table SI1.2: comparison of BFM namelists for NB and SB. Differences in the parameter values are highlighted.

Pelagic Bacteria Parameters – Pelagic Ecology

Functional groups: B1 (pelagic bacteria)

NAME	[UNIT]/KIND - DESCRIPTION	VALUE — NEMO-BFM (NB)	VALUE — ShyBFM (SB)
p_version	integer - Switch for bacteria parameterization	2	2
p_q10	[-] - Q10-value (temperature dependency)	2.95	2.95
p_chdo	[mmol/m3] - Half-saturation constant for O2 limitation	30.0	30.0
p_sd	[1/d] - Specific mortality rate	0.0	0.0
p_sd2	[1/d] - Density dependent specific mortality rate	0.0	0.0
p_suhR1	[1/d] - Specific potential uptake for nutrient-rich DOM	0.5	0.5
p_sulR1	[1/d] - Specific potential uptake for nutrient-poor DOM	0.0	0.0
p_suR2	[1/d] - Specific potential uptake for semi-labile DOC	0.25	0.25
p_suR3	[1/d] - Specific potential uptake for semi-refractory DOC	0.0	0.0
p_suR6	[1/d] - Specific potential uptake for POM	0.1	0.1
p_sum	[1/d] - Potential specific growth rate	8.38	8.38
p_pu_ra	[-] - Activity respiration fraction	0.6	0.7
p_pu_ra_o	[-] - Additional respiration fraction at low O2 conc	0.2	0.2
p_srs	[1/d] - Specific rest respiration	0.01	0.1
p_qncPBA	[mmolN/mgC] - Optimal N/C ratio	1.7e-2	1.85e-2
p_qpcPBA	[mmolP/mgC] - Optimal P/C ratio	1.9e-3	6.5e-4
p_qlnc	[mmolN/mgC] - Minimal N/C ratio	8.5e-3	8.5e-3
p_qlpc	[mmolP/mgC] - Minimal P/C ratio	9.5e-4	0.6e-3
p_qun	[mmolN/mgC/day] - Membrane affinity for N	0.05	0.05
p_qup	[mmolP/mgC/day] - Membrane affinity for P	0.005	0.005
p_chn	[mmolN/m3] - Half saturation ammonium conc. for uptake	0.05	0.05
p_chp	[mmolP/m3] - Half saturation phosphate conc. for uptake	1.00	1.00
p_ruen	[1/d] - Relaxation timescale for N uptake/remin.	1.0	1.0
p_ruep	[1/d] - Relaxation timescale for P uptake/remin.	1.0	1.0
p_rec	[1/d] - Relaxation timescale for semi-labile excretion	1.0	1.0
p_pu_ea_R3	[-] - Excretion of semi-refractory DOC	0.0	0.0

Phytoplankton Parameters – Pelagic Ecology

Functional groups: P1 diatoms, P2 dinoflagellates, P3 picophytoplankton, P4 large phytoplankton

NAME	[UNIT]/KIND - DESCRIPTION	VALUE — NEMO-BFM (NB) P1 – P2 – P3 – P4	VALUE — ShyBFM (SB) P1 – P2 – P3 – P4
p_q10	[-] - Characteristic Q10 coefficient	2.0, 2.0, 2.0, 2.0	2.0, 2.0, 2.0, 2.0
p_temp	[-] - Cut-off threshold for temperature factor	0.0, 0.0, 0.75, 0.0	0.0, 0.0, 0.75, 0.0
p_sum	[1/d] - Maximal productivity at 10 °C	6.5, 3.5, 4.0, 2.0	7.5, 5.5, 4.0, 2.0
p_srs	[1/d] - Respiration rate at 10 °C	0.1, 0.05, 0.1, 0.1	0.1, 0.05, 0.1, 0.1
p_sdmo	[1/d] - Max. specific nutrient-stress lysis rate	0.0, 0.0, 0.0, 0.0	0.0, 0.0, 0.0, 0.0
p_thdo	[-] - Half saturation constant for nutrient stress lysis	0.0, 0.0, 0.0, 0.0	0.0, 0.0, 0.0, 0.0
p_seo	[1/d] - Extra lysis rate	0.0, 0.0, 0.0, 0.0	0.0, 0.0, 0.0, 0.0
p_sheo	[mgC/m3] - Half saturation constant for extra lysis	0.0, 0.0, 0.0, 100.0	0.0, 0.0, 0.0, 100.0
p_pu_ea	[-] - Excreted fraction of primary production	0.05, 0.1, 0.1, 0.15	0.05, 0.1, 0.1, 0.15
p_pu_ra	[-] - Activity respiration fraction	0.1, 0.1, 0.2, 0.1	0.1, 0.1, 0.2, 0.1
p_switchDOC	[1-3] - Switch for type of DOC excretion	2, 2, 2, 2	2, 2, 2, 2
p_netgrowth	[T/F] - Nutrient-limited growth switch	.T., .T., .T., .T.	.T., .T., .T., .T.
p_limnut	[1-3] - Switch for N-P co-limitation	1, 1, 1, 1	1, 1, 1, 1
p_qun	[m3/mgC/d] - Membrane affinity for N	0.025, 0.025, 0.25, 0.025	0.035, 0.035, 0.35, 0.035
p_IN4	[mmolN/m3] - NH4 uptake preference over NO3	1.0, 0.5, 0.1, 1.0	1.0, 0.5, 0.1, 1.0
p_qnlc	[mmolN/mgC] - Minimum quotum N:C	4.19e-3, 4.19e-3, 4.19e-3, 4.19e-3	3.5e-3, 3.5e-3, 3.5e-3, 3.5e-3
p_qncPPY	[mmolN/mgC] - Reference quotum N:C	1.26e-2, 1.26e-2, 1.26e-2, 1.26e-2	1.26e-2, 1.26e-2, 1.26e-2, 1.26e-2
p_xqn	[-] - Multiplication factor for luxury storage	2.0, 2.0, 2.0, 2.0	2.0, 2.0, 2.0, 2.0
p_qup	[m3/mgC/d] - Membrane affinity for P	7.5e-3, 2.5e-3, 2.5e-3, 2.5e-3	8.5e-3, 3.5e-3, 3.5e-3, 3.5e-3
p_qplc	[mmolP/mgC] - Minimum quotum P:C	1.8e-4, 4.29e-4, 4.29e-4, 4.29e-4	1.8e-4, 4.29e-4, 4.29e-4, 4.29e-4
p_qpcPPY	[mmolP/mgC] - Reference quotum P:C	7.86e-4, 7.86e-4, 7.86e-4, 7.86e-4	7.86e-4, 7.86e-4, 7.86e-4, 7.86e-4
p_xqp	[-] - Multiplication factor for luxury storage	2.0, 2.0, 2.0, 2.0	2.0, 2.0, 2.0, 2.0
p_switchSi	[1-2] - Switch for Si limitation	2, 0, 0, 0	2, 0, 0, 0
p_chPs	[mmolSi/m3] - Half saturation conc. for Si	0.3, 0.0, 0.0, 0.0	0.3, 0.0, 0.0, 0.0
p_qus	[m3/mgC/d] - Membrane affinity for Si	2.5e-3, 0.0, 0.0, 0.0	3.5e-3, 0.0, 0.0, 0.0
p_qslc	[mmolSi/mgC] - Minimum quotum Si:C	7.0e-3, 0.0, 0.0, 0.0	4.3e-3, 0.0, 0.0, 0.0
p_qscPPY	[mmolSi/mgC] - Reference quotum Si:C	0.01, 0.0, 0.0, 0.0	0.01, 0.0, 0.0, 0.0

NAME	[UNIT]/KIND - DESCRIPTION	VALUE — NEMO-BFM (NB) P1 – P2 – P3 – P4	VALUE — ShyBFM (SB) P1 – P2 – P3 – P4
p_esNI	[-] - Nutrient stress threshold for sinking	0.7, 0.75, 0.75, 0.75	0.7, 0.75, 0.75, 0.75
p_res	[m/d] - Maximum sinking velocity	5.0, 0.0, 0.0, 2.5	5.0, 0.0, 0.0, 2.5
p_caco3r	[-] - Reference PIC:POC ratio	0.0, 0.3, 0.0, 0.0	0.0, 0.3, 0.0, 0.0
p_switchChl	[1-4] - Switch for Chl-a synthesis	2, 2, 2, 2	2, 2, 2, 2
p_sdchl	[1/d] - Specific turnover rate for Chl-a	0.2, 0.2, 0.2, 0.2	0.2, 0.2, 0.2, 0.2
p_alpha_chl	[-] - Initial slope of P-E curve	1.38e-5, 0.46e-5, 1.52e-5, 0.68e-5	1.38e-5, 0.46e-5, 1.52e-5, 0.68e-5
p_qlcPPY	[mgChla/mgC] - Reference quatum Chla:C	0.03, 0.02, 0.02, 0.02	0.04, 0.03, 0.02, 0.02
p_epsChla	[m2/mgChla] - Chla-specific extinction coefficient	0.02, 0.045, 0.045, 0.045	0.02, 0.03, 0.03, 0.03
p_tochl_relt	[1/d] - Relaxation rate towards max Chla:C	0.0, 0.0, 0.0, 0.0	0.25, 0.25, 0.25, 0.25
p_EpEk_or	[-] - Optimal value of E_PAR/E_K	0.0, 0.0, 0.0, 0.0	0.0, 0.0, 0.0, 0.0
p_iswLtyp	[0-6] - Shape of productivity function	5, 5, 5, 5	5, 5, 5, 5
p_addepth	[m] - Adaptation depth	50.0, 50.0, 50.0, 50.0	50.0, 50.0, 50.0, 50.0
p_chELiPPY	[W/m2] - Maximum Iopt	100.0, 100.0, 100.0, 100.0	100.0, 100.0, 100.0, 100.0
p_clELiPPY	[W/m2] - Minimum Iopt	8.0, 10.0, 6.0, 12.0	8.0, 10.0, 6.0, 12.0
p_ruELiPPY	[1/d] - Maximum daily shift in Iopt	0.2, 0.25, 0.3, 0.15	0.2, 0.25, 0.3, 0.15
p_rPIIm	[m/d] - Background sinking rate	0.0, 0.0, 0.0, 0.0	0.0, 0.0, 0.0, 0.0

Mesozooplankton Parameters – Pelagic Ecology

Functional groups: Z3, Z4 (mesozooplankton)

NAME	[UNIT]/KIND - DESCRIPTION	VALUE — NEMO-BFM (NB)	VALUE — ShyBFM (SB)
p_q10	[-] - Q10 value for physiological rates	2.0, 2.0	2.0, 2.0
p_srs	[1/d] - Respiration rate at 10 °C	0.01, 0.02	0.03, 0.05
p_sum	[1/d] - Maximal productivity at 10 °C	2.0, 2.0	2.0, 2.0
p_vum	[m3/mgC/d] - Specific search volume	0.008, 0.02	0.008, 0.02
p_puI	[-] - Assimilation efficiency	0.6, 0.6	0.6, 0.6
p_peI	[-] - Fraction of faeces production	0.3, 0.35	0.3, 0.35
p_sdo	[m3/mgC/d] - Density-dependent mortality	0.01, 0.01	0.01, 0.01
p_sd	[1/d] - Background natural mortality	0.02, 0.02	0.02, 0.02
p_sds	[-] - Exponent of density-dependent mortality	2.0, 2.0	2.0, 2.0
p_pecaco3	[-] - Portion of egested calcified shells	0.75, 0.75	0.75, 0.75

NAME	[UNIT]/KIND - DESCRIPTION	VALUE — NEMO-BFM (NB)	VALUE — ShyBFM (SB)
p_qpcMEZ	[mmolP/mgC] - Maximum quotient P:C	1.67e-3, 1.67e-3	1.67e-3, 1.67e-3
p_qncMEZ	[mmolN/mgC] - Maximum quotient N:C	0.015, 0.015	0.015, 0.015
p_clO2o	[mmolO2/m3] - Half-saturation O2 conc.	30.0, 30.0	30.0, 30.0
p_paPPY	[-] - Availability of Phytoplankton groups (P1, P2, P3, P4)	Z3: 0.0, 0.0, 0.0, 1.0 Z4: 1.0, 0.75, 0.0, 1.0	Z3: 0.0, 0.0, 0.0, 1.0 Z4: 1.0, 0.75, 0.0, 1.0
p_paMIZ	[-] - Availability of MicroZooplankton groups (Z5, Z6)	Z3: 0.0, 0.0 Z4: 1.0, 0.0	Z3: 0.0, 0.0 Z4: 1.0, 0.0
p_paMEZ	[-] - Availability of MesoZooplankton groups (Z3, Z4)	Z3: 1.0, 1.0 Z4: 0.0, 1.0	Z3: 1.0, 1.0 Z4: 0.0, 1.0

Microzooplankton Parameters – Pelagic Ecology

Functional groups: Z5 microzooplankton, Z6 heterotrophic nanoflagellates

NAME	[UNIT]/KIND - DESCRIPTION	VALUE — NEMO-BFM (NB)	VALUE — ShyBFM (SB)
p_q10	[-] - Q10 value for physiological rates	2.0, 2.0	2.0, 2.0
p_srs	[1/d] - Respiration rate at 10 °C	0.02, 0.02	0.05, 0.05
p_sum	[1/d] - Potential growth rate	2.0, 5.0	2.0, 5.0
p_sdo	[1/d] - Mortality rate due to O2 limitation	0.05, 0.05	0.05, 0.05
p_sd	[1/d] - Temperature independent mortality rate	0.0, 0.0	0.0, 0.0
p_pu	[-] - Assimilation efficiency	0.5, 0.3	0.5, 0.3
p_pu_ea	[-] - Fraction of activity excretion	0.5, 0.5	0.5, 0.5
p_chro	[mmolO2/m3] - Half-saturation O2 conc.	8, 8	8, 8
p_chuc	[mgC/m3] - Half-saturation Food conc. for Type II	30.0, 100.0	30.0, 100.0
p_minfood	[mgC/m3] - Food preference factor	50.0, 50.0	50.0, 50.0
p_pecaco3	[-] - Portion of egested calcified shells	0.5, 0.5	0.5, 0.5
p_qpcMIZ	[mmolP/mgC] - Maximum quotient P:C	1.85e-3, 1.85e-3	1.85e-3, 1.85e-3
p_qncMIZ	[mmolN/mgC] - Maximum quotient N:C	1.67e-2, 1.67e-2	1.67e-2, 1.67e-2
p_paPBA	[-] - Availability of Pelagic Bacteria	Z5: 0.1; Z6: 1.0	Z5: 0.1; Z6: 1.0
p_paPPY	[-] - Availability of Phytoplankton groups (P1, P2, P3, P4)	Z5: 0.7, 1.0, 0.1, 0.1 Z6: 0.0, 0.2, 1.0, 0.0	Z5: 0.7, 1.0, 0.1, 0.1 Z6: 0.0, 0.2, 1.0, 0.0
p_paMIZ	[-] - Availability of MicroZooplankton groups (Z5, Z6)	Z5: 1.0, 1.0 Z6: 0.0, 0.2	Z5: 1.0, 1.0 Z6: 0.0, 0.2

Light / PAR Parameters - Pelagic Environment

NAME	[UNIT]/KIND - DESCRIPTION	VALUE — NEMO-BFM (NB)	VALUE — ShyBFM (SB)
LightPeriodFlag	[1-2] - Light averaging-period flag	1	1
LightLocationFlag	[1-3] - Light location-in-layer flag	2	2
ChlAttenFlag	[0-1] - Chlorophyll attenuation flag	1	1
p_PAR	[-] - Fraction of photosynthetically available radiation (PAR)	0.40	0.45
p_eps0	[1/m] - Background (water) extinction coefficient	0.0435	0.0435
p_epsIR	[-] - Infrared extinction coefficient	2.857	2.857
p_epsESS	[m2/g] - Extinction by inorganic suspended matter	0.04d-3	0.04d-3
p_epsR6	[m2/mgC] - Extinction by particulate detritus (POM)	0.1d-3	0.1d-3

Pelagic Chemistry Parameters - Pelagic Environment

NAME	[UNIT]/KIND - DESCRIPTION	VALUE — NEMO-BFM (NB)	VALUE — ShyBFM (SB)
p_q10N4N3	[-] - Q10 for nitrification	2.367	2.367
p_sN4N3	[1/d] - Specific nitrification rate	0.01	0.01
p_clO2o	[mmolO2/m3] - Half-saturation O2 (nitrification/reoxidation)	10.0	10.0
p_rOS	[1/d] - Reoxidation rate of reduction equivalents	0.05	0.05
p_sN3O4n	[1/d] - Denitrification rate	0.35	0.35
p_clN6r	[mmolHS/m3] - Half-saturation for denitrification	1.0	1.0
p_rPAo	[-] - Reoxidation ratio (O2 : reduction equivalents)	1.0	1.0
p_sR6N5	[1/d] - Specific dissolution rate of biogenic silica	0.1	0.1
p_aeR6N5	[kJ/mol] - Arrhenius activation energy for Si dissolution	60.0	60.0

Pelagic Global – sinking Parameters - Pelagic Environment

NAME	[UNIT]/KIND - DESCRIPTION	VALUE — NEMO-BFM (NB)	VALUE — ShyBFM (SB)
p_rR6m	[m/d] - POM (R6) sinking velocity	5.0	5.0
KSINK_rPPY	[m] - Depth threshold for phytoplankton sinking	150.0	150.0
p_rR3m	[m/d] - Semi-refractory DOC (R3) sinking velocity	0.0	0.0
p_rO5m	[m/d] - Calcite (O5) sinking velocity	0.0	0.0

Settling / Burial Parameters - Benthic Environment

NAME	[UNIT]/KIND - DESCRIPTION	VALUE — NEMO-BFM (NB)	VALUE — ShyBFM (SB)
p_burvel_R6	[m/d] - Burial velocity of POM (R6)	1.5	1.5
p_burvel_O5	[m/d] - Burial velocity of calcite (O5)	30.0	30.0
p_burvel_R2	[m/d] - Burial velocity of semi-labile DOC (R2)	0.0	0.0
p_burvel_PI	[m/d] - Burial velocity of phytoplankton/PIC	0.0	0.0
R6DeepBurial	[T/F] - Deep-burial switch	.FALSE.	.FALSE.
p_burvel_R3	[m/d] - Burial velocity of semi-refractory DOC (R3)	0.0	0.0

Benthic Return Parameters - Benthic Environment

NAME	[UNIT]/KIND - DESCRIPTION	VALUE — NEMO-BFM (NB)	VALUE — ShyBFM (SB)
p_rmnQ1c	[1/d] - Remineralization rate, labile benthic org. C	0.1	0.1
p_rmnQ1n	[1/d] - Remineralization rate, labile benthic org. N	0.1	0.1
p_rmnQ1p	[1/d] - Remineralization rate, labile benthic org. P	0.1	0.1
p_rmnQ6c	[1/d] - Remineralization rate, refractory benthic org. C	0.05	0.05
p_rmnQ6n	[1/d] - Remineralization rate, refractory benthic org. N	0.05	0.05
p_rmnQ6p	[1/d] - Remineralization rate, refractory benthic org. P	0.05	0.05
p_rmnQ6s	[1/d] - Remineralization rate, refractory benthic org. Si	0.05	0.05
p_pQIN3	[-] - Fraction of benthic N returned as nitrate	0.1	0.1