Technical summary of the eReefs biogeochemical (BGC) marine water quality model for the 2023 reanalysis simulation:

gbr4_H3p5_BARRAr2_BRAN2020_G2G_B4p1_Cq4b_rean

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Summary:

This technical report is a summary of eReefs model reanalysis methods: gbr4_H3p5_BARRAr2_BRAN2020_G2G_B4p1_Cq4b_rean data assimilation assessment. The eReefs model configuration and results used in this paper are labelled gbr4: model grid with approximate 4 km grid resolution, H3p5_BARRAr2_BRAN2020_: hydrodynamic model version 3.5 with BARRA v2 and BRAN 2020 forcing, B4p1: biogeochemical model version 4.1, Cq4b SOURCE catchment model February 2022, rean: 2023 reanalysis.

Detailed description of earlier eReefs model and assessment are described in Skerratt et al. (2019) (B2p0) and Skerratt et al., 2019 (B3p0).

For more information on the eReefs simulations see biogeochemical -simulation naming protocol

The gbr4_H3p5_BARRAr2_BRAN2020_G2G_B4p1_Cq4b_rean simulation period is from 30th September 2020 to 1 Nov 2022.

Version Monday, 13 November 2023

Acknowledgements

eReefs simulations were developed as part of the eReefs project (http://ereefs.org.au/ereefs), a public-private collaboration between Australia's leading operational and scientific research agencies, government, and corporate Australia.

Particular thanks to our CSIRO eReefs colleagues: eReefs hydrodynamic modelling: Clothilde Langlais Data assimilation: Emlyn Jones. Roger Scott. Remote sensing: Thomas Schroeder and David Blondeau-Pattissier, Software engineer and architect: Farhan Rizwi and project overview and management: Mark Baird and Andy Steven.

We thank our many colleagues involved in developing the eReefs model; particularly Shawn Darr and Fred Bennet for the SOURCE catchment modelling nutrient and sediment loads and Cape York flow as part of the Queensland and Australian Government's Paddock to Reef (P2R) program that is funded by the Queensland Department of Natural Resources and the Queensland Department of Enviornoment and Science (DES). Thanks also to Bureau of Meteorology colleagues Urooj Khan and Richard Laugesen for the Grid to Grid (G2G) modelling used for river flows entering the eReefs marine model.

Thanks to our AIMS colleagues: Erick Lawry, Marc Hammerton and Daniel Moran.

Observational data to validate and compare the model simulation was from:

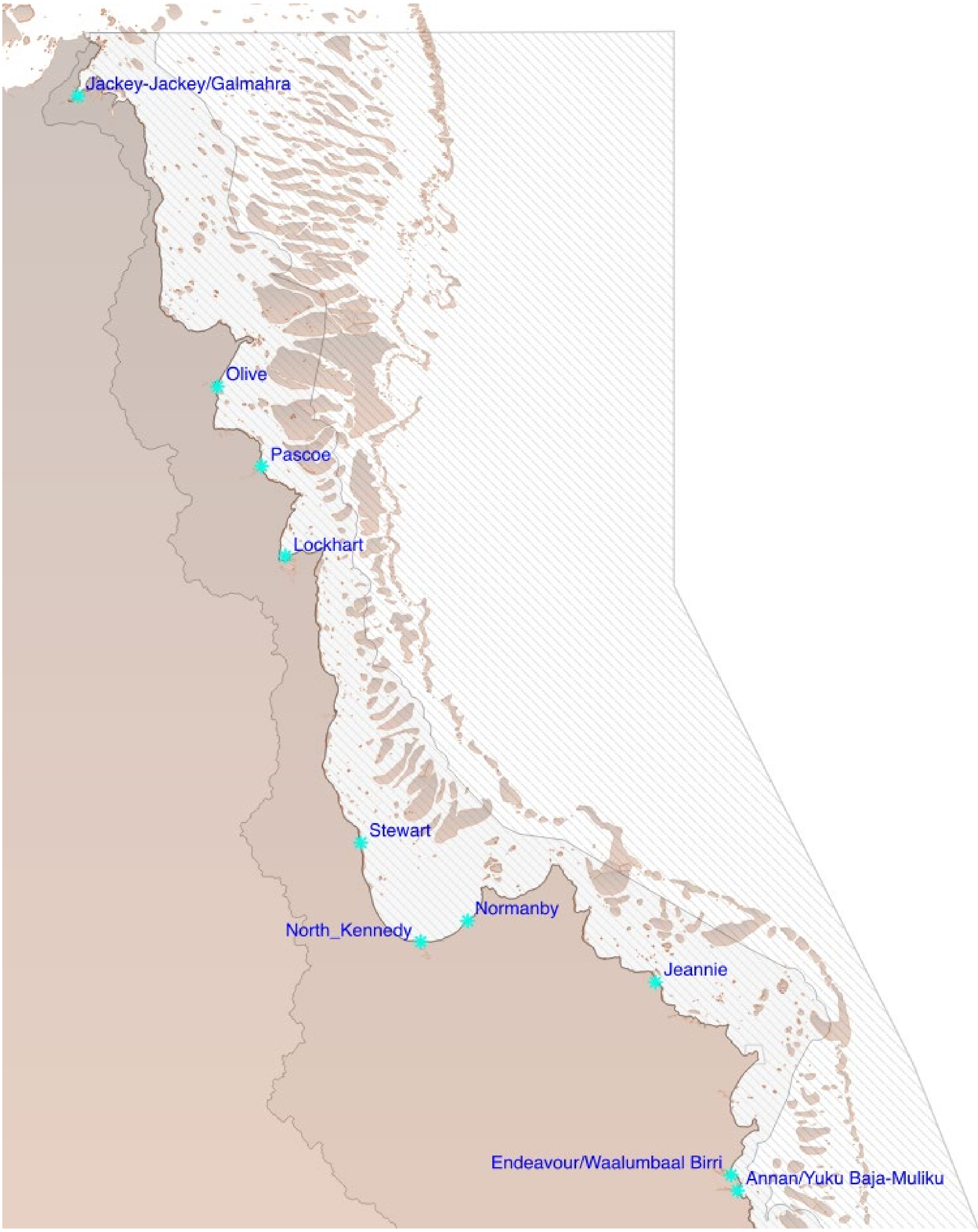
- Marine Monitoring Program (MMP) managed by the Great Barrier Reef Marine Park Authority (GBRMPA, Reef Authority), with funding from the Department of the Environment and Energy and co-funding from research partners and data were from supplied Marine Monitoring Program (MMP) moorings and water samples conducted by the Australian Institute of Marine Science (AIMS), James Cook University(JCU), University of Queensland (UQ), Reef Authority and community volunteers as
- Australia's Integrated Marine Observing System (IMOS) – IMOS is enabled by the National Collaborative Research Infrastructure Strategy (NCRIS)
- The Gidarjil Development Corporation water quality datasets.

Contents

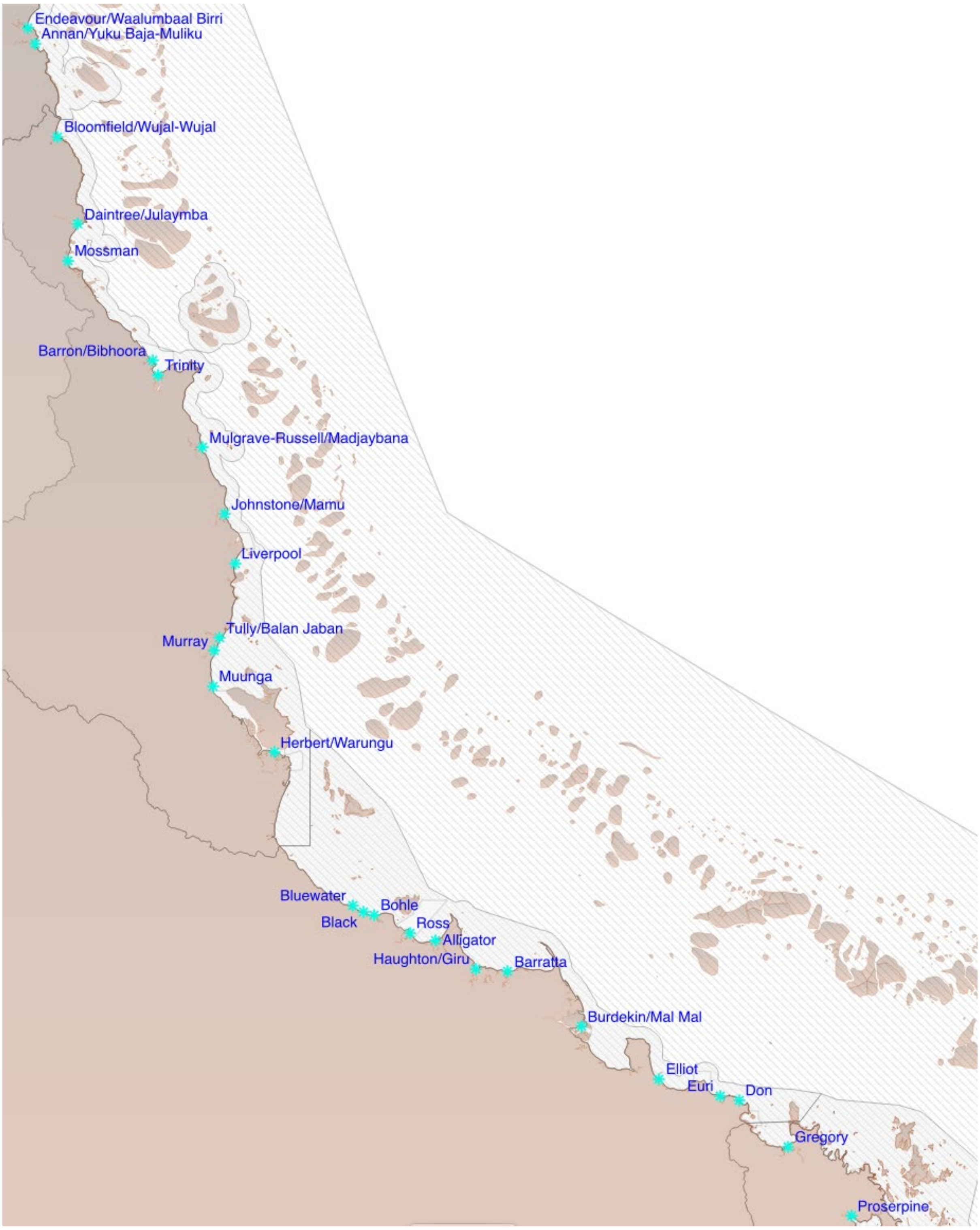
1. Abbreviations

AIMS	Australian Institute of Marine Science
AODN	Australian Ocean Data Network
Chl a	chlorophyll a
GBR	Great Barrier Reef
GBRMP	Great Barrier Reef Marine Park
GBRMPA	Great Barrier Reef Marine Park Authority
GBRWHA	Great Barrier Reef World Heritage Area
IMOS	Integrated Marine and Observing System
mae	mean absolute error
mape	mean absolute percentage error
MMP	Marine Monitoring Program
MODIS	Moderate Resolution Imaging Spectroradiometer
NRS	IMOS National reference stations within the model grid these are Yongala (GBRYON) and North Stradbroke Island (GBRNSI)
NSI	North Stradbroke Island
QA/QC	quality assurance/quality control
rms	root mean square
secchi	measurement of water transparency (depth in m)

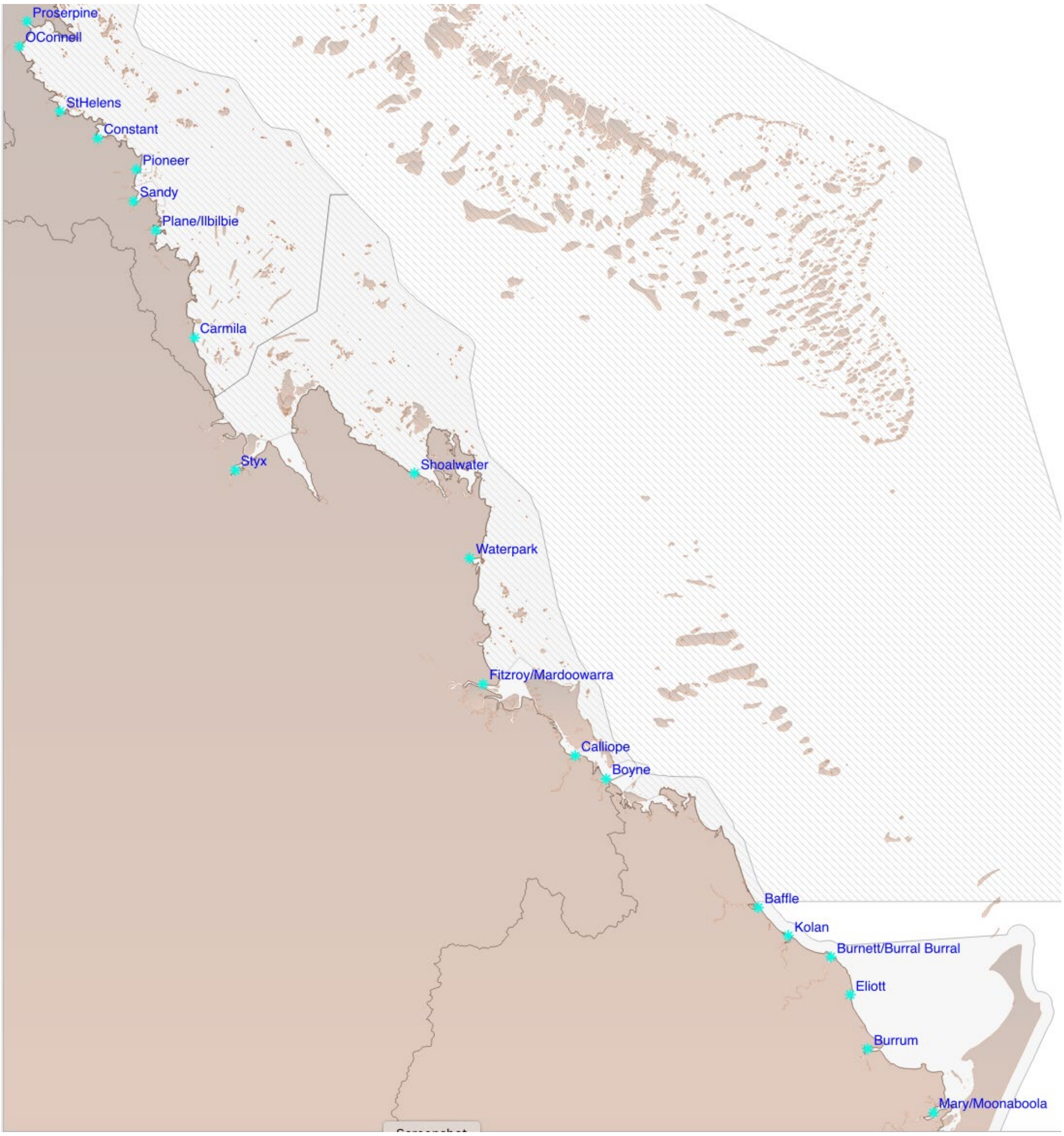
1. River and catchments in eReefs model (Fig 1 of 3)



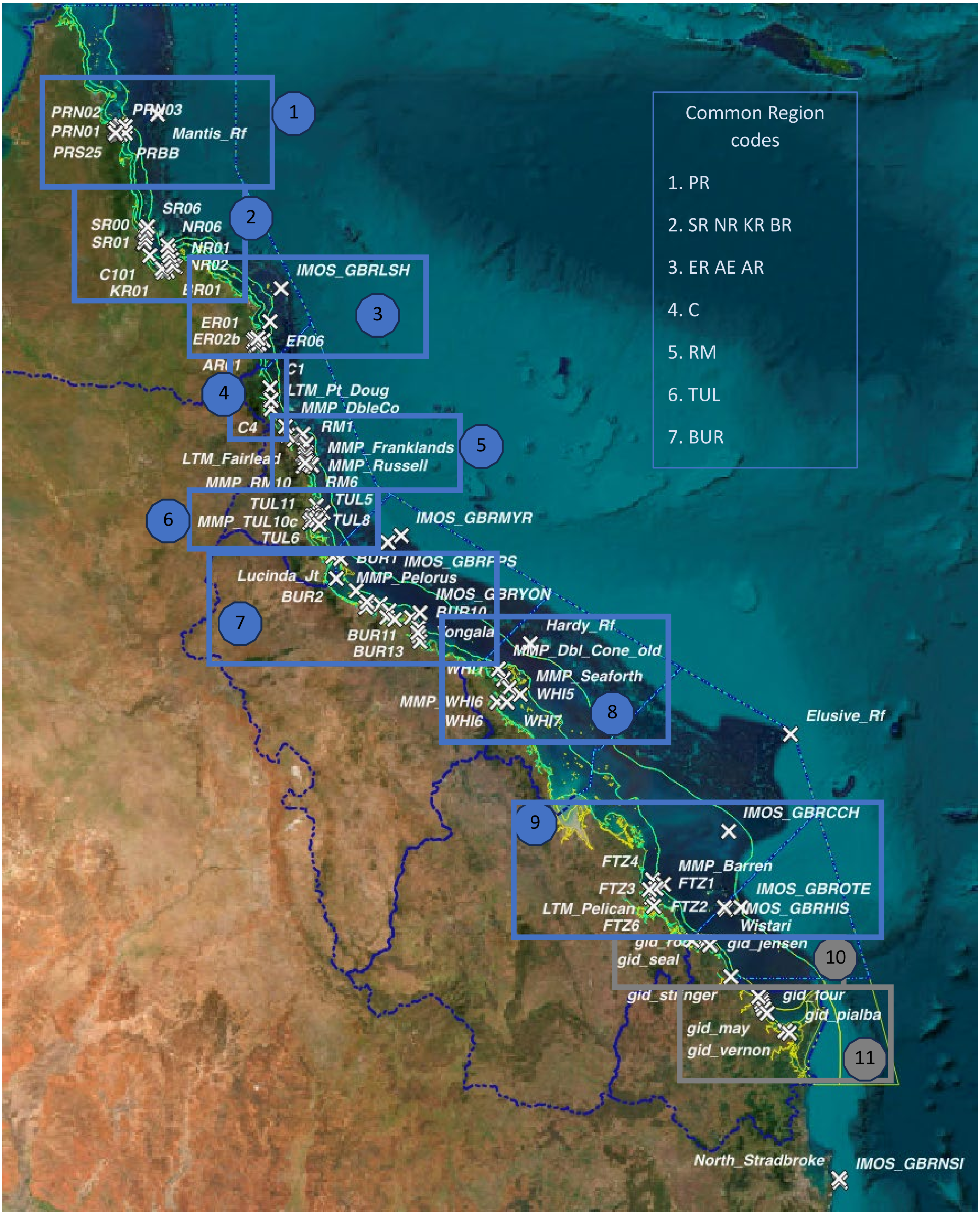
River and catchments in eReefs model (Fig 2 of 3)



River and catchments in eReefs model (Fig 3 of 3)



2. AIMS Marine Monitoring Program, Gidarjyl development cooportiaon and IMOS sites used in eReef model: Overview below with insets on following pages

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PRN02
PRS05
PRN01
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SR06
NR06
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SR00
C101
NR01
KR01
BR01
IMOS_GBRLSH
ER06
ER02b
ER03
ER01
AE04
AR01
AR02b
LTM_Cape_Trib
LTM_Snapper
C5
C4
C11
RM2
LTM_Yorkeys
MMP_Franklands
RM10
RM11
MMP_Russell
TUL1
TUL2
TUL11
TUL3
IMOS_GBRMYR
TUL9
Lucinda_Jt
BUR1
IMOS_GBRPPS
MMP_Pandora
MMP_Pelorus
BUR2
BUR6
BUR3
IMOS_GBRYON
BUR5
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BUR10
BUR13
BUR12
Hardy_Rf
BUR15
WHI1
MMP_Pine
MMP_Dbl_Cone_old
MMP_Seaforth
WHI6
MMP_WHI6
MMP_WHI7
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LTM_Barren
MMP_Pelican
MMP_Humpy
LTM_Pelican
FTZ2
IMOS_GBROTE
IMOS_GBRHIS
MMP_FTZ6
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gid_seal
gid_rod
gid_stringer
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gid_barolin
gid_burkitt
gid_four
gid_pialba
gid_vernon


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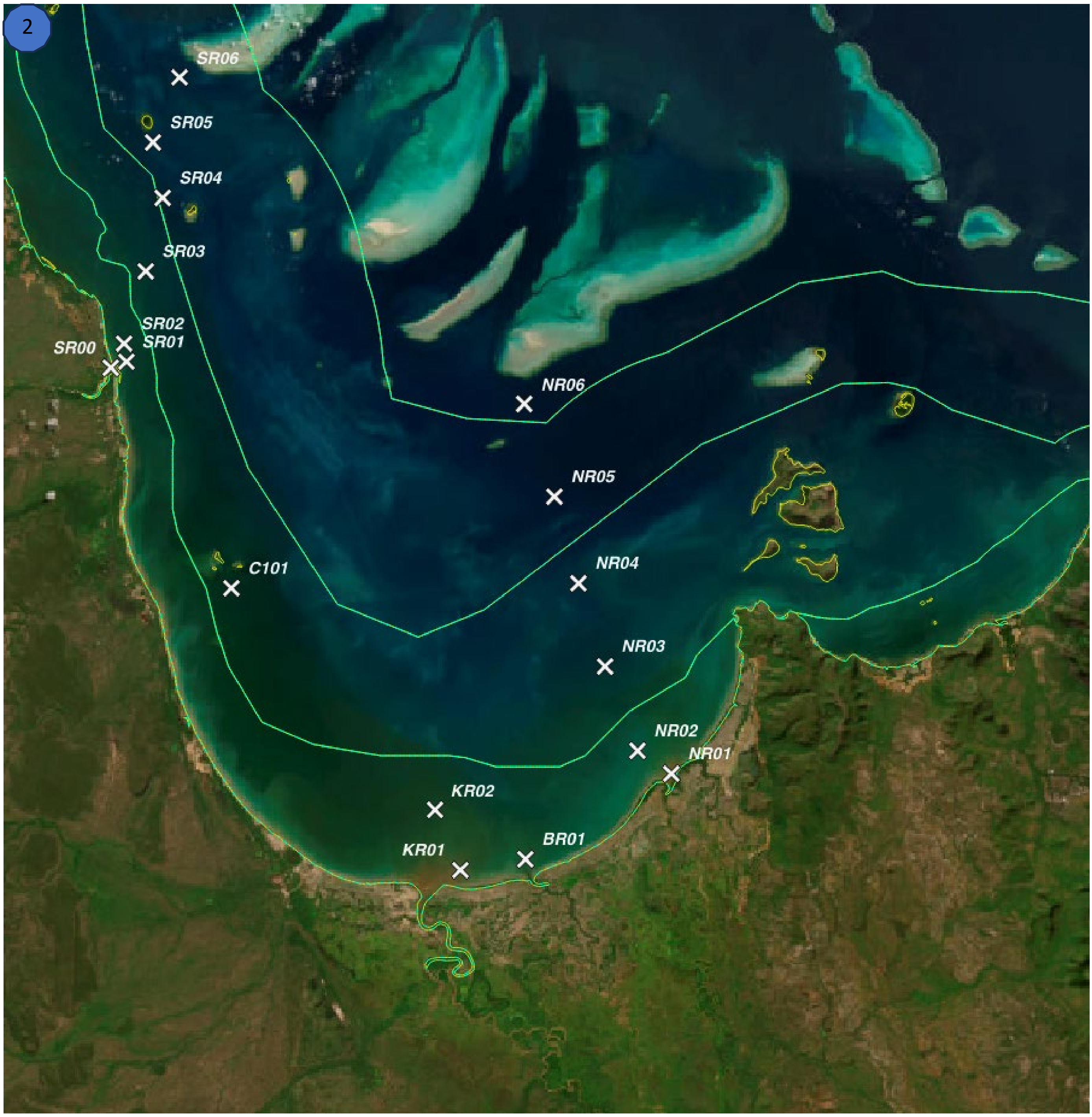
PRS02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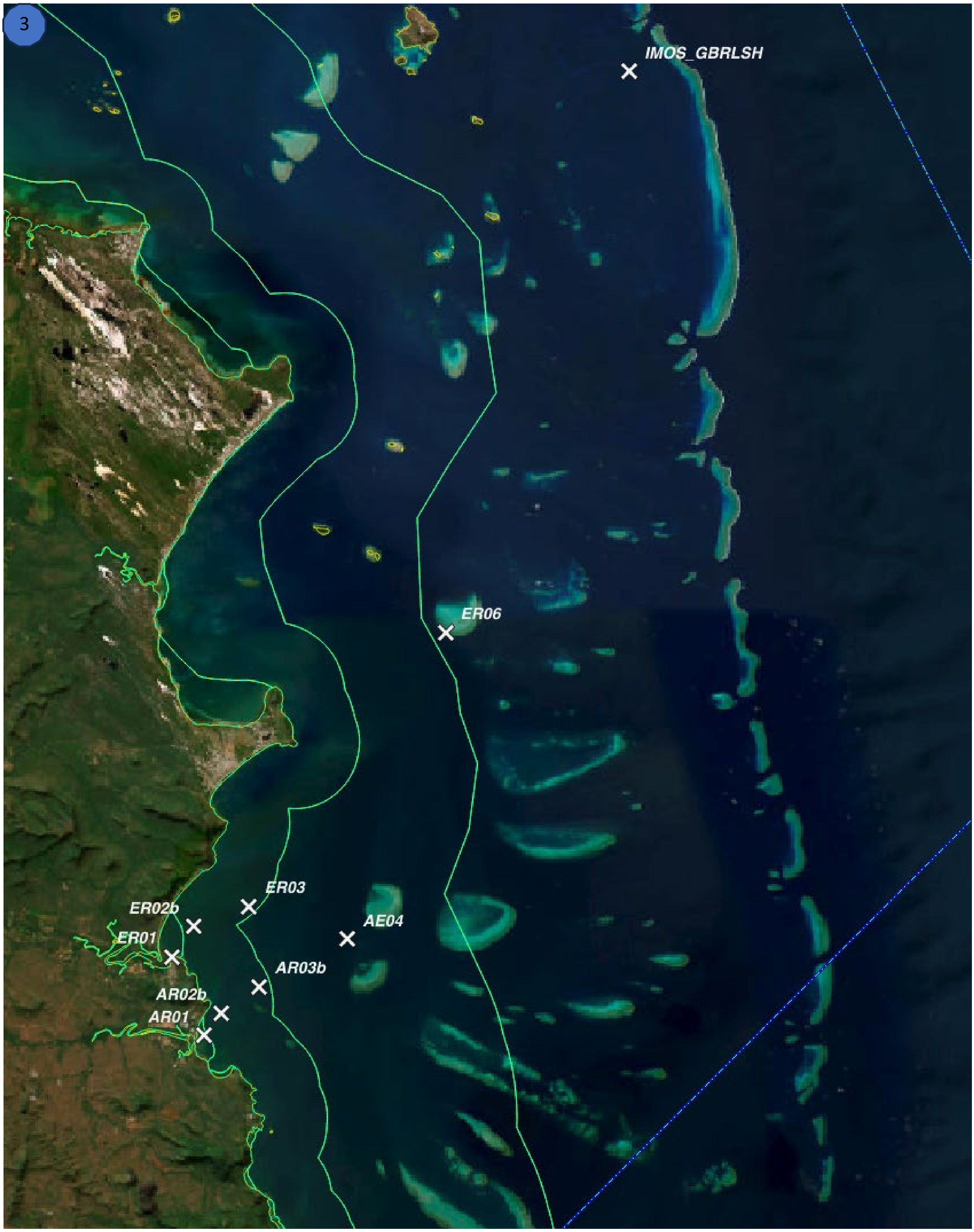
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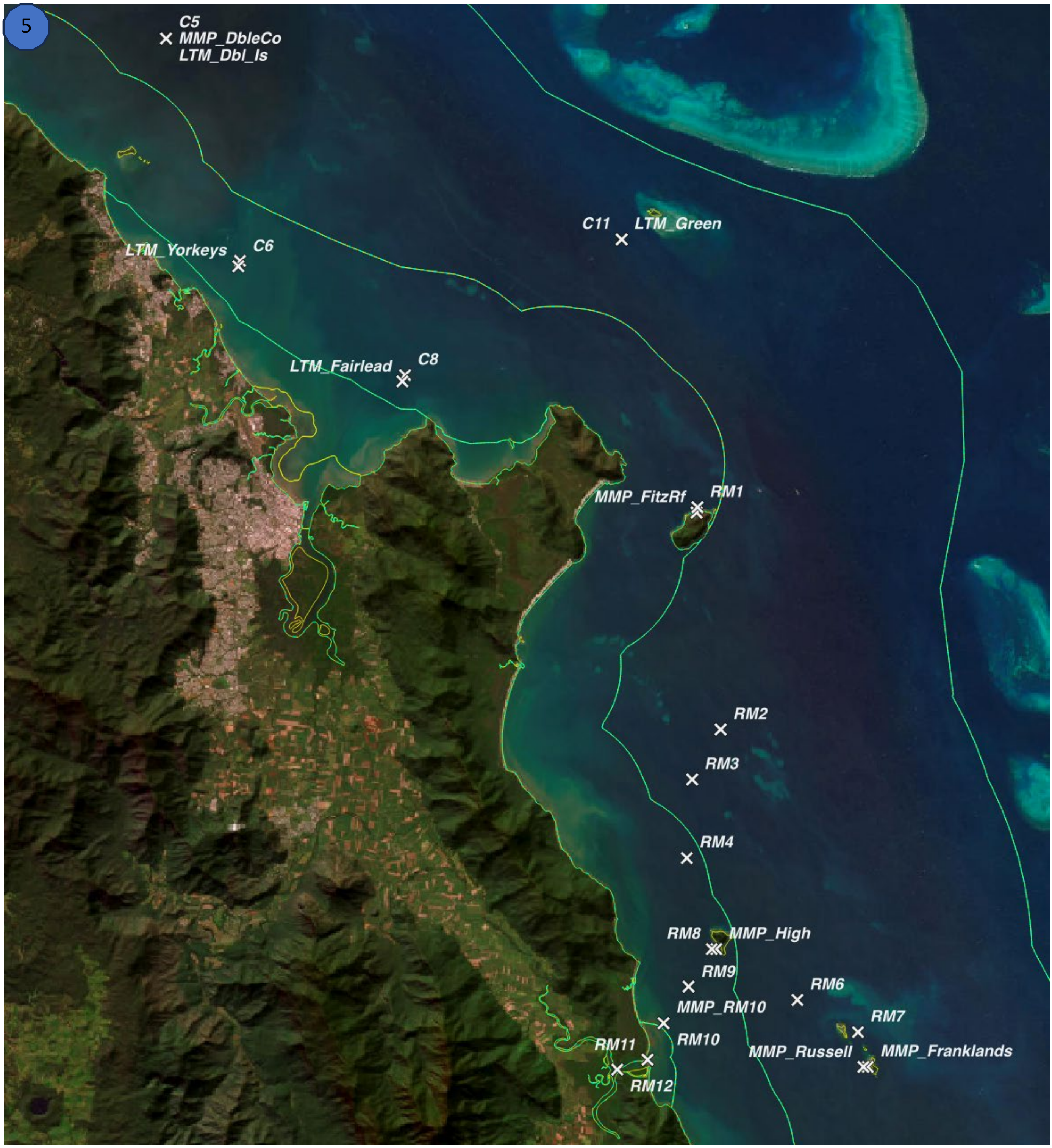
LTM_Snapper
MMP_Snapper
C4
LTM_Pt_Doug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C6
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RM1
RM2
RM3
RM4
RM8
MMP_High
RM9
RM6
MMP_RM10
RM7
RM10
RM11
MMP_Russell
MMP_Franklands
RM12


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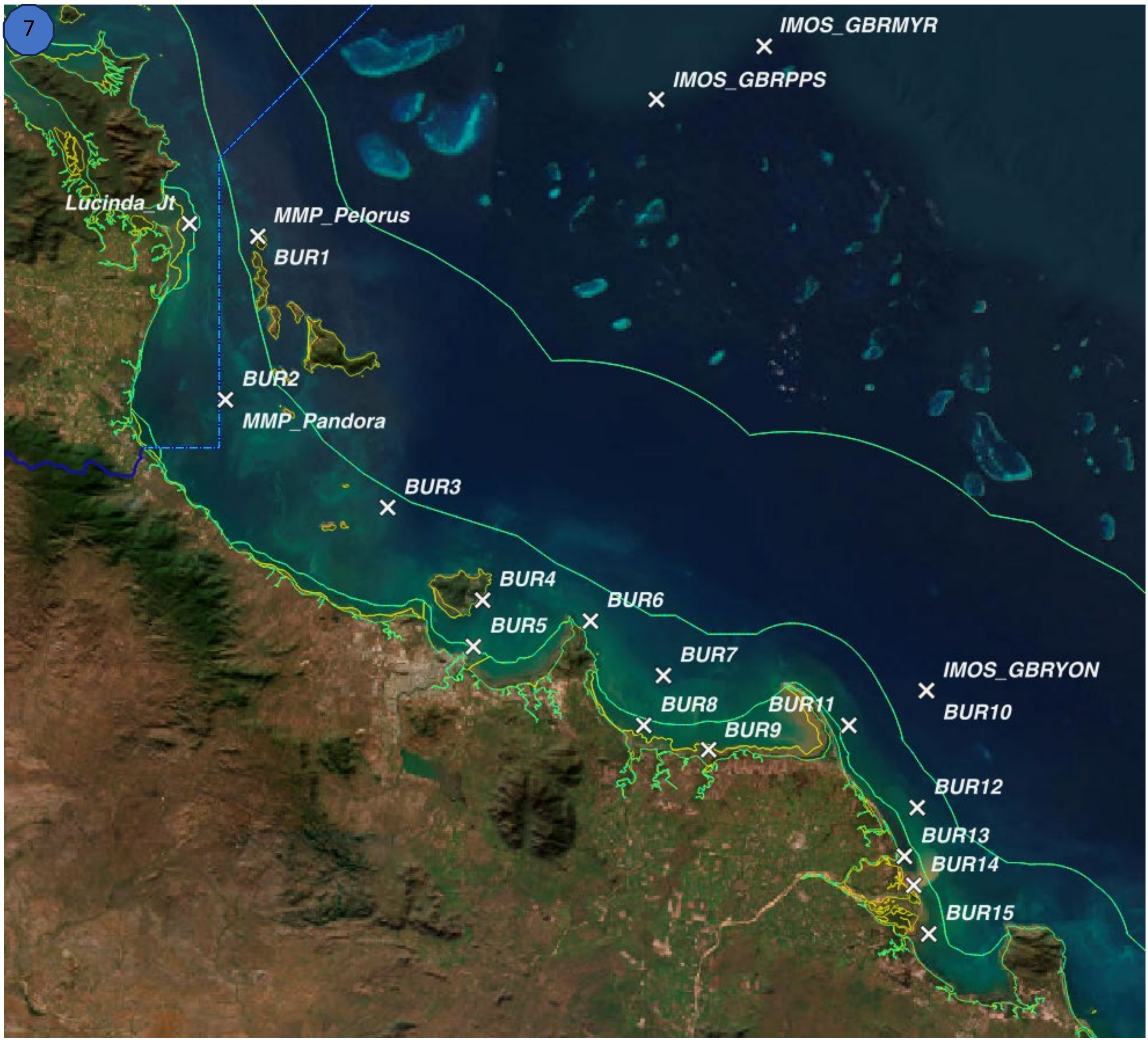
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BUR15


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Hardy_Rf
MMP_Dbl_Cone_old
WHI1
LTM_Daydream
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MMP_Seaforth
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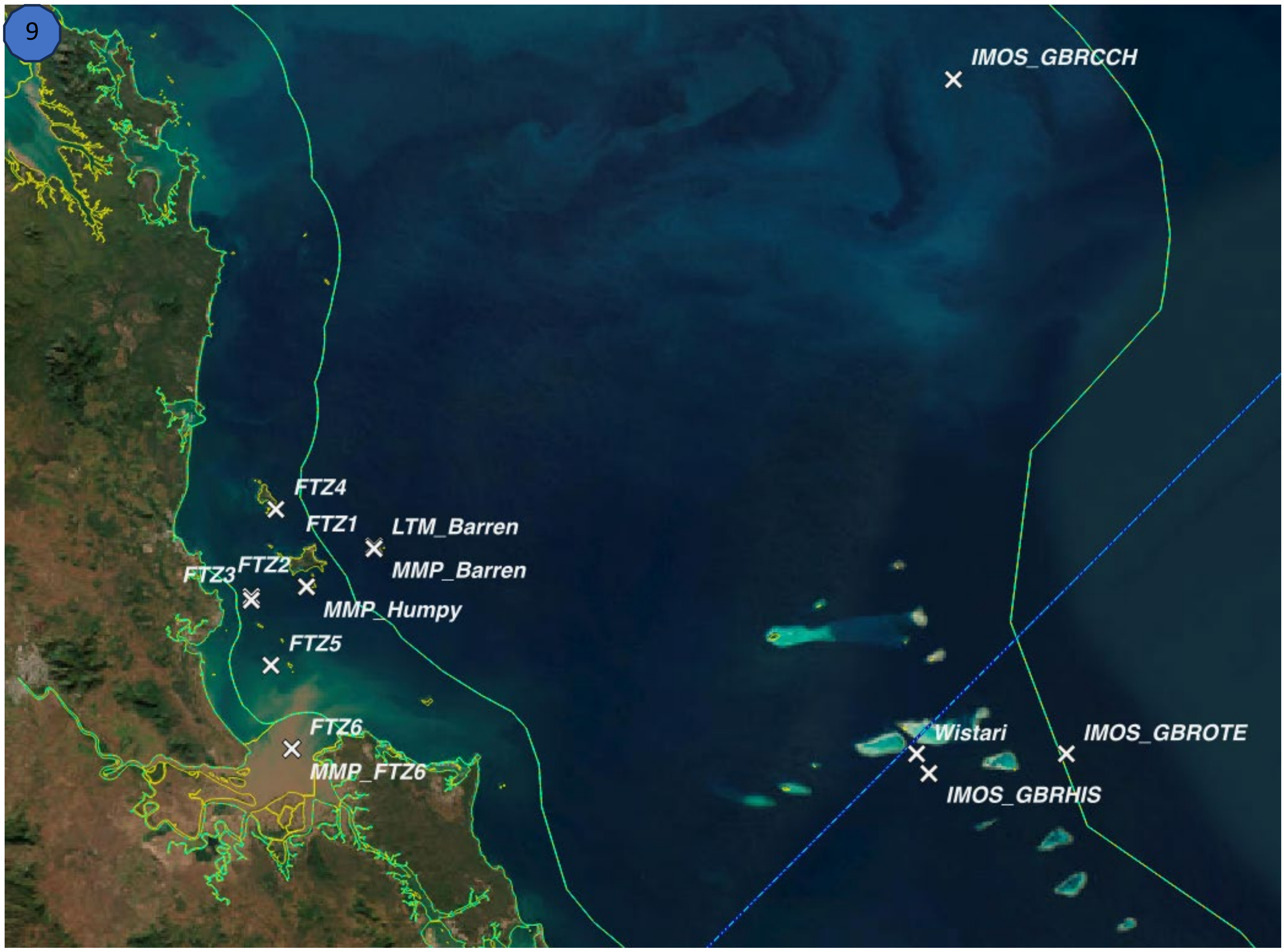
MMP_WHI7
WHI7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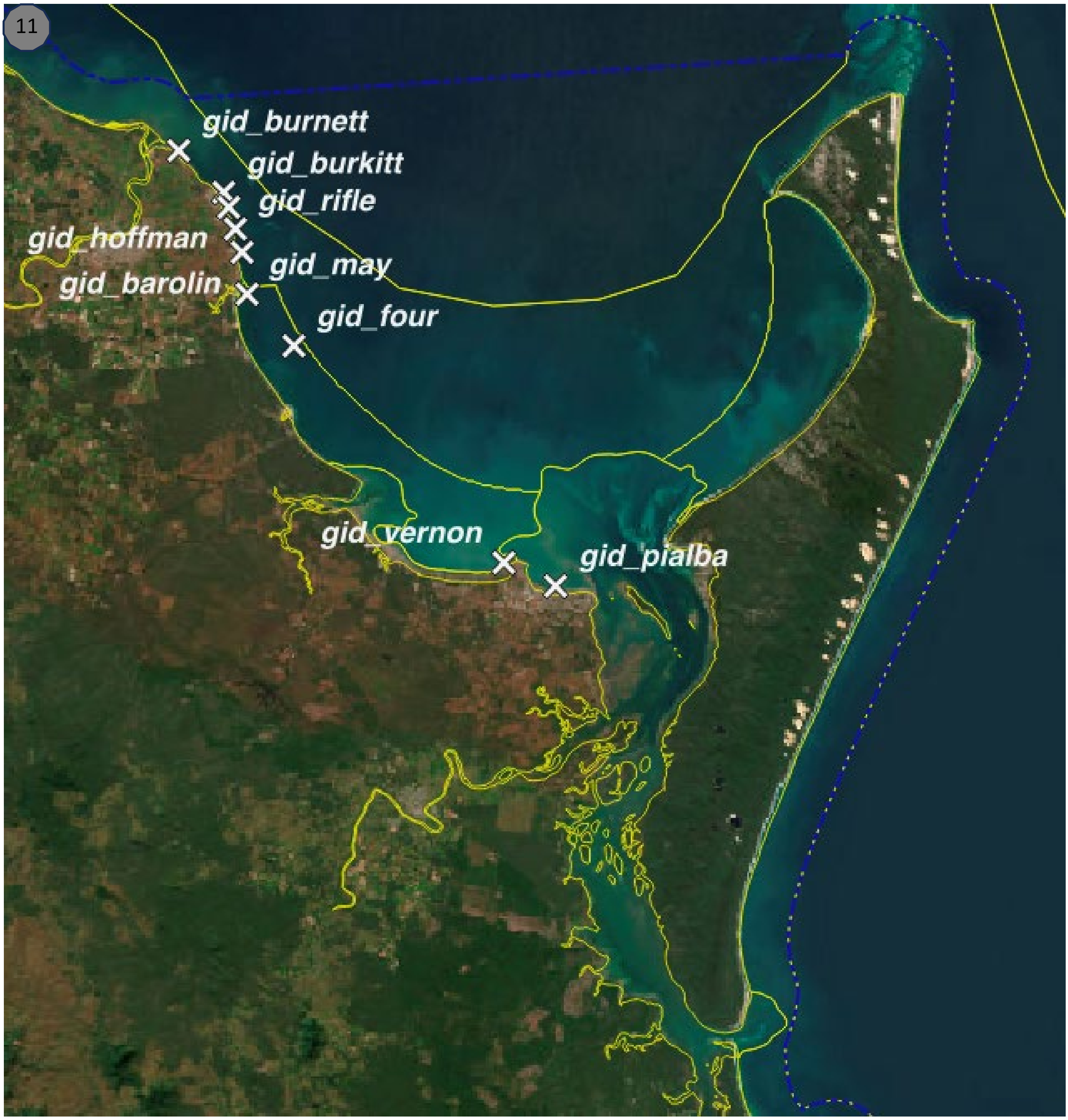
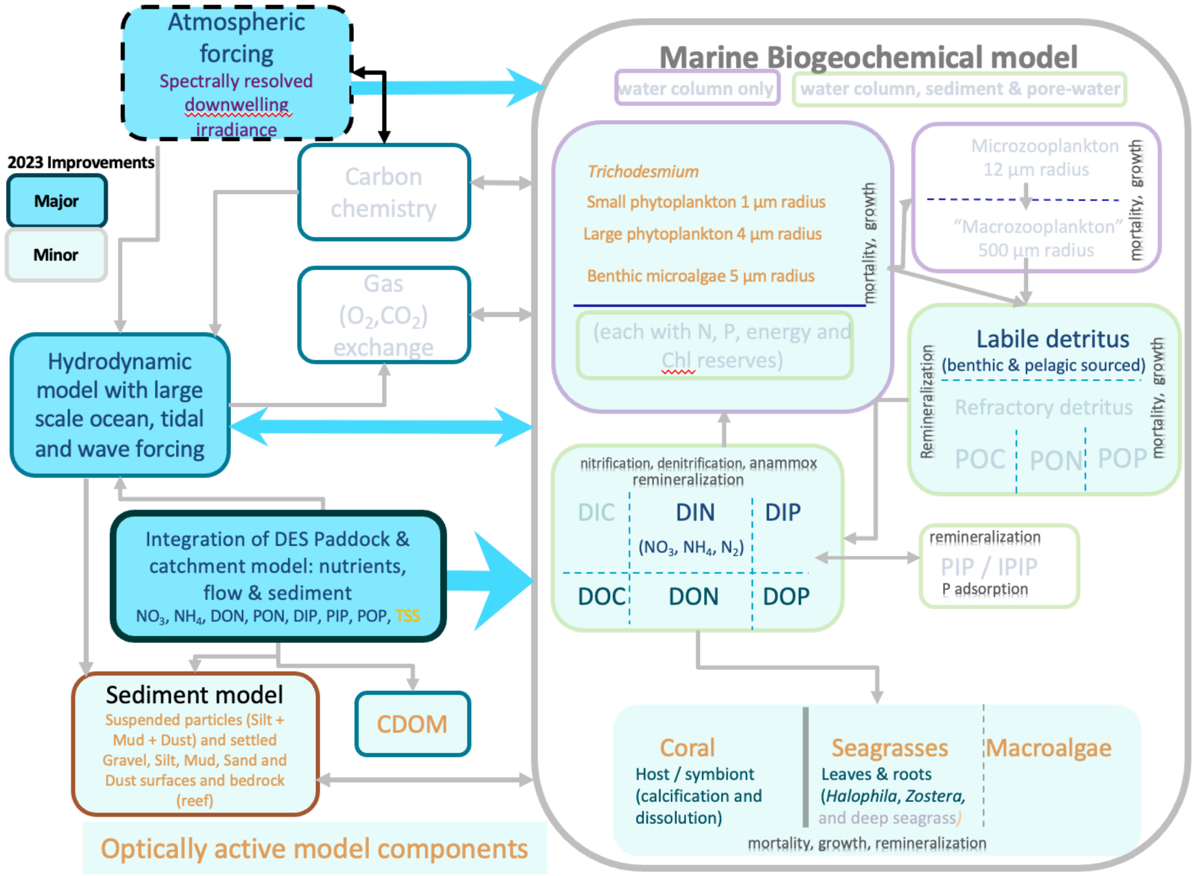


Figure 2 Map of observational sites in this report

3. eReefs model: Biogeochemical Model schematic

The eReefs marine biogeochemical model conceptual framework with major improvements for this report card shaded in dark blue with dark blue arrows showing major process improvements and minor improvements shaded in light blue. Orange variables are optically active (i.e., either scatter or absorb light) this allows the model to make use of and incorporate remote sensing data



4. Model skill metrics description

To evaluate model skill, we consider; bias, the root mean square (RMS) error and the mean absolute error (MAE).

Model bias assesses whether the simulated variables are under- or over-predicting observed values. The RMS error is a measure of the absolute magnitude of the "error"/square deviation averaged over the time-series. An RMS or MAE of 0 indicates a perfect fit.

5. Parameter tables for gbr4_H2p0_B3p0_Cb

The following 4 pages give the parameters used in the model

Parameter description	Symbol	Units	Value	Reference
Phytoplankton				
Chl-specific scattering coefficient. for microalgae	bphy	m^{-1} (mg Chl a $m^{-3})^{-1}$	0.2	Typical microalgae value, Kirk (1994)
Natural (linear) mortality rate, large phytoplankton	PhyL_mL	d^{-1}	0.1	Not attributed
Natural (linear) mortality rate in sediment, large phytoplankton	PhyL_mL_sed	d^{-1}	10	Not attributed
Natural (linear) mortality rate, small phytoplankton	PhyS_mL	d^{-1}	0.1	Not attributed
Natural (linear) mortality rate in sediment, small phytoplankton	PhyS_mL_sed	d^{-1}	1	Not attributed
Respiration as a fraction of umax	Plank_resp	none	0.025	Not attributed
Radius of the large phytoplankton cells	PLrad	m	0.000004	Not attributed
Maximum growth rate of PL at Tref	PLumax	d^{-1}	1.4	CSIRO Parameter Library
Ratio of xanthophyll to chl a of PL	PLxan2chl	mg mg^{-1}	0.81	CSIRO Parameter Library
Radius of the small phytoplankton cells	PSrad	m	0.000001	Not attributed
Maximum growth rate of PS at Tref	PSumax	d^{-1}	1.6	CSIRO Parameter Library
Ratio of xanthophyll to chl a of PS	PSxan2chl	mg mg^{-1}	0.51	CSIRO Parameter Library
Trichodesmium				
DIN conc below which *Trichodesmium* N fixes	DINcrit	mg N m^{-3}	10	Lower end of Robson et al., (2013) 4-20 mg N m^{-3}
Maximum density of *Trichodesmium*	p_max	kg m^{-3}	1050	Not attributed
Minimum density of *Trichodesmium*	p_min	kg m^{-3}	900	Not attributed
Radius of *Trichodesmium* colonies	Tricho_colrad	m	0.000005	Not attributed
Critical *Trichodesmium* above which quadratic mortality applies	Tricho_crit	mg N m^{-3}	0.0002	Not used in code
Linear mortality for *Trichodesmium* in sediment	Tricho_mL	d^{-1}	0.1	Not attributed
Quadratic mortality for *Trichodesmium* due to phages in water column	Tricho_mQ	d^{-1} (mg N $m^{-3})^{-1}$	0.1	At steady-state, indep. of temp, Tricho_N ~ Tricho_umax / Tricho_mQ = 0.27 / 0.405 = 0.7 mg N m^{-3} ~ 0.1 mg Chl m^{-3}
Trichodesmium grazing preference	Tricho_pref	none	0	Not attributed
Radius of *Trichodesmium* colonies	Tricho_rad	m	0.000005	Not attributed
Sherwood number for the *Trichodesmium* dimensionless	Tricho_Sh	none	1	Not attributed
Maximum growth rate of *Trichodesmium* at Tref	Tricho_umax	d^{-1}	0.2	Robson et al., 2013 + Parameter library
Ratio of xanthophyll to chl a of *Trichodesmium*	Trichoxan2chl	mg mg^{-1}	0.5	Subramaniam et al. 1999. LO 44:618-627
Microphytobenthos				
Respiration as a fraction of umax	Benth_resp	none	0.025	Not attributed
Radius of the MPB cells	MBrad	m	0.00001	Not attributed
Maximum growth rate of MB at Tref	MBumax	d^{-1}	0.839	CSIRO Parameter Library
Ratio of xanthophyll to chl a of MPB	MBxan2chl	mg mg^{-1}	0.81	Not attributed
Natural (quadratic) mortality rate, microphytobenthos, applied in sediment	MPB_mQ	d^{-1} (mg N $m^{-3})^{-1}$	0.0001	SS argument

Parameter description	Symbol	Units	Value	Reference
Zooplankton				
Growth efficiency, large zooplankton	ZL_E	none	0.426	CSIRO Parameter Library, [0.341 (0.017900) Baird and Suthers, 2007 from Hansen et al (1997) LO 42: 687-704]
Fraction of growth inefficiency lost to detritus, large zooplankton	ZL_FDG	none	0.5	Not attributed
Fraction of mortality lost to detritus, large zooplankton	ZL_FDM	none	1	Not attributed
Natural (quadratic) mortality rate, large zooplankton	ZL_mQ	d^{-1} (mg N $m^{-3})^{-1}$	0.012	Not attributed
Diel vertical migration rate of ZL	ZLdvmrate	m d^{-1}	0	Not attributed
Grazing technique of large zooplankton	ZLmeth	none	rect	Not attributed
Light at which the	ZLpar	mol photons m^{-2} s^{-1}	1.00E-12	Not attributed
Radius of the large zooplankton cells	ZLrad	m	0.00032	Not attributed
Swimming velocity for large zooplankton	ZLswim	m s^{-1}	0.003	Not attributed
Maximum growth rate of ZL at Tref	ZLumax	d^{-1}	1.33	Not attributed
Growth efficiency, small zooplankton	ZS_E	none	0.462	CSIRO Parameter Library [0.3080000 (0.026600) Baird and Suthers, 2007 from Hansen et al (1997) LO 42: 687-704]
Fraction of growth inefficiency lost to detritus, small zooplankton	ZS_FDG	none	0.5	Not attributed
Fraction of mortality lost to detritus, small zooplankton	ZS_FDM	none	1	Not attributed
Natural (quadratic) mortality rate, small zooplankton	ZS_mQ	d^{-1} (mg N $m^{-3})^{-1}$	0.02	Not attributed
Grazing technique of small zooplankton	ZSmeth	none	rect	Not attributed
Radius of the small zooplankton cells	ZSrad	m	0.000005	Not attributed
Swimming velocity for small zooplankton	ZSswim	m s^{-1}	0.0002	Not attributed
Maximum growth rate of ZS at Tref	ZSumax	d^{-1}	4	Not attributed
Coral				
Quadratic mortality rate of coral polyp	CHmort	(g N $m^{-3})^{-1}$ d^{-1}	0.01	Not attributed
Nitrogen-specific area of coral polyp density	CHpolypden	m2 g N^{-1}	2	Not attributed
Fraction of Host death translocated.	CHremin	-	0.5	Not attributed
Max. growth rate of Coral at Tref	CHumax	d^{-1}	0.05	Not attributed
Linear mortality rate of Zooxanthellae	CSmort	d^{-1}	0.04	Not attributed
Radius of the Zooxanthellae	CSrad	m	0.000005	Not attributed
Fraction of Zooxanthellae growth to Host.	CStoCHfrac	-	0.9	Gustafsson et al. (2013) Ecol. Mod. 250: 183-194
Max. growth rate of Zooxanthellae at Tref	CSumax	d^{-1}	0.4	Not attributed
Maximum daytime net coral calcification	k_day_coral	mmol C m^{-2} s^{-1}	0.0132	Anthony et al. (2013), Biogeosciences 10:4897-4909, Fig 5A: 50, 50, 35 55 mmol m^{-2} h^{-1} for Acropora aspera n=4
Grid scale to reef scale ratio	CHarea	m m^{-1}	0.1	Not attributed
Maximum night time net coral calcification	k_night_coral	mmol C m^{-2} s^{-1}	0.0069	Anthony et al. (2013), Biogeosciences 10:4897-4909, Fig 5A: 20, 30, 20, 30 mmol m^{-2} h^{-1} for Acropora aspera n=4
Rate coefficient for plankton uptake by corals	Splank	m d^{-1}	3	Ribes (2003), PARAMETER library analysis;Ribes and Atkinson (2007) Coral Reefs 26: 413-421

Parameter description	Symbol	Units	Value	Reference
Seagrass				
Half-saturation of SG N uptake in SED	SG_KN	mg N m^{-3}	420	Lee and Dunton (1999) 1204-1215. Table 3 Zostera
Half-saturation of SG P uptake in SED	SG_KP	mg P m^{-3}	96	Gras et al. (2003) Aquatic Botany 76:299-315. Thalassia testudinum.
Natural (linear) mortality rate, seagrass	SG_mL	d^{-1}	0.03	Fourquean et al.(2003) Chem. Ecol. 19: 373-390.Thalassia leaves with one component decay
Critical shear stress for SG loss	SG_tau_critical	N m^{$^{-2}$}	1	NESP project
Time-scale for critical shear stress for SG loss	SG_tau_efold	s	43200	NESP project
Half-saturation of SGD N uptake in SED	SGD_KN	mg N m^{-3}	420	Not attributed
Half-saturation of SGD P uptake in SED	SGD_KP	mg P m^{-3}	96	Not attributed
Natural (linear) mortality rate, aboveground SGD	SGD_mL	d^{-1}	0.06	NESP project
Critical shear stress for SGD loss	SGD_tau_critical	N m^{-2}	1	NESP project
Time-scale for critical shear stress for SGD loss	SGD_tau_efold	s	43200	NESP project
Fraction (target) of SGD biomass below-ground	SGDfrac	-	0.25	Duarte (1999) Aquatic Biol. 65: 159-174, Halophila ovalis.
Nitrogen-specific leaf area of SGD	SGDleafden	m^2 g N^{-1}	1.9	Halophila ovalis: leaf dimensions from Vermaat et al. (1995)
Compensation irradiance for Halophila	SGDmlr	mol m^{-2}	1.5	NESP project
Sine of nadir Deep Segrass canopy bending angle	SGDorient	-	1	No source
Natural (linear) mortality rate, belowground SGD	SGDROOT_mL	d^{-1}	0.004	NESP project
Maximum depth for Halophila roots	SGDrootdepth	m	-0.05	NESP project
Halophila seed biomass as fraction of 63 % cover	SGDseedfrac	-	0.01	Not attributed
Time scale for seagrass translocation	SGDtransrate	d^{-1}	0.0333	Loosely based on Zostera marine Kaldy et al., 2013 MEPS 487:27-39
Maximum growth rate of SGD at Tref	SGDumax	d^{-1}	0.4	x2 nighttime, x2 for roots.
Fraction (target) of SG biomass below-ground	SGfrac	-	0.75	Babcock (2015) Zostera capricornii
Half-saturation of SGH N uptake in SED	SGH_KN	mg N m^{-3}	420	Not attributed
Half-saturation of SGH P uptake in SED	SGH_KP	mg P m^{-3}	96	Not attributed
Natural (linear) mortality rate, seagrassH	SGH_mL	d^{-1}	0.06	Fourquean et al.(2003) Chem. Ecol. 19: 373-390.Thalassia leaves with one component decay
Critical shear stress for SGH loss	SGH_tau_critical	N m^{-2}	1	NESP project
Time-scale for critical shear stress for SGH loss	SGH_tau_efold	s	43200	NESP project
Fraction (target) of SGH biomass below-ground	SGHfrac	-	0.5	Babcock 2015, Halophila ovalis
Nitrogen-specific area of seagrass leaf	SGHleafden	m2 g N^{-1}	1.9	Halophila ovalis: leaf dimensions from Vermaat et al. (1995)
Compensation irradiance for SG	SGHmlr	mol m^{-2}	2	Not attributed
Sine of nadir Halophila canopy bending angle	SGHorient	-	1	No source
Natural (linear) mortality rate, seagrassH	SGHROOT_mL	d^{-1}	0.004	Fourquean et al. (2003) Chem. Ecol. 19: 373-390. Thalassia roots with one component decay
Maximum depth for Halophila roots	SGHrootdepth	m	-0.08	Roberts (1993) Aust. J. Mar. Fresh. Res. 44:85-100.
Halophila seed biomass as fraction of 63 % cover	SGHseedfrac	-	0.01	Not attributed
Time scale for seagrass translocation	SGHtransrate	d^{-1}	0.0333	Loosely based on Zostera marine Kaldy et al., 2013 MEPS 487:27-39
Maximum growth rate of SGH at Tref	SGHumax	d^{-1}	0.4	x2 night-time, x2 for roots.
Nitrogen-specific area of seagrass leaf	SGleafden	m2 g N^{-1}	1.5	Zostera capricornia: leaf dimensions Kemp et al (1987) Mar Ecol. Prog. Ser. 41:79-86.
Compensation irradiance for SG SGorient	SGmlr	mol m^{-2}	4.5	Not attributed
	SGorient		0.5	Not attributed
Natural (linear) mortality rate, seagrass	SGROOT_mL	d^{-1}	0.004	Fourquean et al. (2003) Chem. Ecol. 19: 373-390. Thalassia roots with one component decay
Maximum depth for Zostera roots	SGrootdepth	m	-0.15	Roberts (1993) Aust. J. Mar. Fresh. Res. 44:85-100.
Seagrass seed biomass as fraction of 63 % cover	SGseedfrac	-	0.01	No source
Time scale for seagrass translocation	SGtransrate	d^{-1}	0.0333	Loosely based on Zostera marine Kaldy et al., 2013 MEPS 487:27-39
Maximum growth rate of SG at Tref	SGumax	d^{-1}	0.4	x2 nighttime, x2 for roots.

Parameter description	Symbol	Units	Value	Reference
Macroalgae				
Natural (linear) mortality rate, macroalgae	MA_mL	d^{-1}	0.01	Not attributed
Nitrogen-specific area of macroalgae leaf	MAleafden	m^2 g N^{-1}	1	Not attributed
Maximum growth rate of MA at Tref	MAumax	d^{-1}	1	Not attributed

Parameter description	Symbol	Units	Value	Reference
Reference temperature	Tref	Deg C	20	CSIRO Parameter Library
Temperature coefficient for rate parameters	Q10	none	2	CSIRO Parameter Library
Nominal rate of TKE dissipation in water column	TKEeps	m_2 s_{-3}	0.000001	Not attributed
Atmospheric CO2	xco2_in_air_dum	ppmv	396.48	Mean 2013 at Mauna Loa: htttrp://co2now.org/current-co2/co2-now/
Wavelengths of light	Light_lambda	nm	Various*	Approx. 20 nm resolution with 10 nm about 440 nm. PAR (400-700) is integral of bands 2-22 (290 310 330 350 370 390 410 430 440 450 470 490 510 530 550 570 590 610 630 650 670 690 710 800)*
Nominal N:Chl a ratio in phytoplankton by weight	NtoCHL	g N (g Chl a)$^{-1}$	7	Represents a C:Chl ratio of 39.25, Baird et al. (2013) Limnol. Oceanogr. 58: 1215-1226.
Concentration of dissolved N2	N2	mg N m^{-3}	2000	Robson et al. (2013)
Fraction of labile detritus converted to refractory detritus	F_LD_RD	none	0.19	Not attributed
Fraction of labile detritus converted to dissolved organic matter	F_LD_DOM	none	0.1	Not attributed
fraction of refractory detritus that breaks down to DOM	F_RD_DOM	none	0.05	Not attributed
Breakdown rate of labile detritus at 106:16:1	r_DetPL	d_{-1}	0.04	Not attributed
Breakdown rate of labile detritus at 550:30:1	r_DetBL	d_{-1}	0.001	Not attributed
Breakdown rate of refractory detritus	r_RD	d_{-1}	0.001	Not attributed
Breakdown rate of dissolved organic matter	r_DOM	d_{-1}	0.0001	Achieves approx. SS of global ocean at 20 C.
Oxygen half-saturation for aerobic respiration	KO_aer	mg O m^{-3}	256	Not attributed
Maximal nitrification rate in water column	r_nit_wc	d_{-1}	0.1	Not attributed
Maximal nitrification rate in water sediment	r_nit_sed	d_{-1}	20	Not attributed
Oxygen half-saturation for nitrification	KO_nit	mg O m^{-3}	500	Not attributed
Rate at which P reaches adsorbed/desorbed equilibrium	Pads_r	d_{-1}	0.04	Not attributed
Freundlich Isothermic Const P adsorption to TSS in water column	Pads_Kwc	mg P kg TSS^{-1}	30	Not attributed
Freundlich Isothermic Const P adsorption to TSS in sediment	Pads_Ksed	mg P kg TSS^{-1}	74	Not attributed
Oxygen half-saturation for P adsorption	Pads_KO	mg O m^{-3}	2000	Not attributed
Exponent for Freundlich Isotherm	Pads_exp	none	1	Not attributed
Maximum denitrification rate	r_den	d_{-1}	0.8	Not attributed
Oxygen half-inhibition of denitrification rate	KO_den	mg O m^{-3}	10000	Not attributed
Rate of conversion of PIP to immobilised PIP	r_immob_PIP	d_{-1}	0.0012	Not attributed
Sediment-water diffusion coefficient	EpiDiffCoeff	m_2 s_{-1}	3.00E-07	Not attributed
Thickness of diffusive layer	EpiDiffDz	m	0.0065	Not attributed
age tracer growth rate per day	ageing_decay	d_{-1}	1	Not attributed
age tracer decay rate per day outside source	anti_ageing_decay	d_{-1}	0.1	Not attributed
net dissolution rate of sediment without coral	dissCaCO3_sed	mmol C m^{-2} s^{-1}	0.001	Anthony et al. (2013), Biogeosciences 10:4897-4909, Fig 5E: -1 2 3 6 mmol m^{-2} h^{-1}
DOC-specific absorption of CDOM at 443 nm	acdom443star	m^{2} mg C^{-1}	0.00013	Not attributed
Minimum carbon to chlorophyll ratio	C2Chlmin	wt/wt	20	Not attributed
swr scaling factor	SWRscale	none	1	Not attributed
Bleaching ROS threshold	ROSthreshold	-	5.00E-04	Not attributed
increased breakdown fraction DetrP to DOP	r_RD_NtoP	-	2	Not attributed
increased breakdown fraction DOMP to DIP	r_DOM_NtoP	-	1.5	Not attributed

6. Simulated chl a assessments against observations