Marine modelling methods

Reef Water Quality Report Card 2023–2025

Reef 2050 Water Quality Improvement Plan

Australian Government

Queensland Government

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The Marine Modelling Program directly supports the 2050 outcome of the Reef 2050 Water Quality Improvement Plan (Australia and Queensland governments), which states:

'Good water quality sustains the outstanding universal value of the Great Barrier Reef (GBR), builds resilience, improves ecosystem health and benefits communities.'

The Marine Modelling Program was established in 2016 to:

- assess trends in ecosystem health for the Great Barrier Reef in relation to water quality and its linkages to end-of-catchment loads by predicting, assessing and reporting trends in inshore water clarity (Secchi depth) and concentrations of chlorophyll-*a*
- predict physical and biogeochemical properties of Reef waters under a range of scenarios to assess the impact of management practices and contribute to the establishment or review of basin-level water quality targets
- support regional and whole-of-Great Barrier Reef water quality risk assessments by predicting the impact of rivers on the Great Barrier Reef waters under a range of conditions.

Given the scale of the Great Barrier Reef, it is impractical to measure and report water quality through the entire area and at a reasonable frequency using monitoring data alone. Satellite imaging is employed for extensive spatial coverage but can be less accurate in shallow areas and susceptible to seasonal influences such as cloud cover and smoke haze. Consequently, the eReefs marine modelling framework combines monitored data and satellite observations to extend water quality assessments across the entirety of the Great Barrier Reef. This eReefs marine model framework is used to derive the GBR marine water quality metric.

Marine models which integrate physical processes and ecosystem responses play an integral part in supporting resilience-based management and linking science and observations to policy and decision making.

In this context, the marine component of eReefs delivers and operates numerical models capable of simulating and predicting the physical hydrodynamic state, sediment transport, water quality and basal ecology of the Great Barrier Reef lagoon <https://research.csiro.au/ereefs/models/>. Together, these models provide the ability to simulate the transport and fate of waterborne material, from the ocean or land, and assess its impact on Reef water quality (Baird et al., 2021, Skerratt et al., 2019a).

In 2015–2016, eReefs models were used for the first time to report on chlorophyll-*a* (productivity linked to nutrient concentrations) and Secchi depth (proxy for water clarity and presence of fine sediments) across the entire Great Barrier Reef (Robillot et al., 2018). These measures underpinned a new water quality metric for the Reef water quality report cards. The metric considered all six regions in calculating the Reef-wide score and is based on open coastal waters. The approach to calculating Reef water quality indices and overall scores was independently peer-reviewed as part of NESP Project 3.2.5.

The metric is underpinned by the eReefs biogeochemical model and integrates multi spectral data from Sentinel 3a/b, and VIIRS for improved accuracy in what is commonly referred to as data assimilation (Baird et al., 2016, Jones et al., 2016). The eReefs marine model has also been used to determine various scenario catchment loads impacts on marine water quality in the GBR (Baird et al 2021) and 99 scientific publications (eReefs papers) have been published using the eReefs model water quality outputs since the establishment of the 2016 marine modelling program.

The eReefs model has been assessed extensively against *in situ* observations with detailed assessment findings available in the previous technical assessment of the eReefs biogeochemical simulation against observations (Maggiorano et al. 2026 in prep, Skerratt and Mongin 2023 and Skerratt et al. (2019) (B2p0) and Skerratt et al., 2019 (B3p0).)

This report describes the methods and changes to the eReefs model reanalysis simulation used to generate the marine water quality metric for the period 1 October 2022 to 30 September 2024 (water year 2022 and 2023 for the eReefs Marine Water Quality).

In this report we present the results of the Reanalysis of the 4 km resolution coupled hydrodynamic – biogeochemical model for the period 1 Oct 2022–30 Sep 2024 (designated gbr4_H4p0_ABARRAr2_OBRAN2023_FSOURCE_B4p2_Cq5b_Dhnd_2022_2024). A brief description of the modelling system is given, with an emphasis on changes since the previous report card simulations (Report Card 2021_2022 and Table 1).

Table 1 Report Card and water years for the eReefs Marine Water Quality reporting.

	Years documented	Year report published
Report Card 2016	1 Oct 2015–30 Sep 2016	2017
Report Card 2017 and 2018 (2 years)	1 Oct 2016–30 Sep 2018	2019
Report Card 2019	1 Oct 2018–30 Sep 2019	2020
Report Card 2020	1 Oct 2019–30 Sep 2020	2022
Report Card 2021 and 2022 (2 years)	1 Oct 2020–30 Sep 2022	2024
Report Card 2023–2025 (3 years and 2 years: 2023 and 2024 for the eReefs Marine Water Quality reporting)	1 Oct 2022–30 Sep 2025 (2023–2024 Marine Water Quality reporting)	2026

eReefs coupled hydrodynamic biogeochemical model

Water quality on the GBR is driven by meteorological factors such as winds, waves, and solar radiation, as well as large-scale ocean currents and nutrient and sediment loads from the catchments. In order to accurately model water quality, a comprehensive approach is therefore needed. This involves using a coupled catchment-hydrodynamic-biogeochemical model that is driven by global atmospheric and ocean models. The eReefs Project, developed collaboratively by CSIRO, Queensland Department of the Environment, Tourism, Science and Innovation, Australian Institute of Marine Science, and Bureau of Meteorology, provides such a model (**Error! Reference source not found.**). This integrated system allows for a more holistic understanding of water quality dynamics.

The eReefs coupled hydrodynamic, sediment and biogeochemical modelling system involves the application of a range of physical, chemical and biological process descriptions to quantify the rate of change of physical and biological variables.

The process descriptions are generally based either on a fundamental understanding of processes or on actual measurements when a specific process was able to be isolated and studied. The model also requires external inputs, such as observed river flows and pollutant loads (Figure 1 and 2).

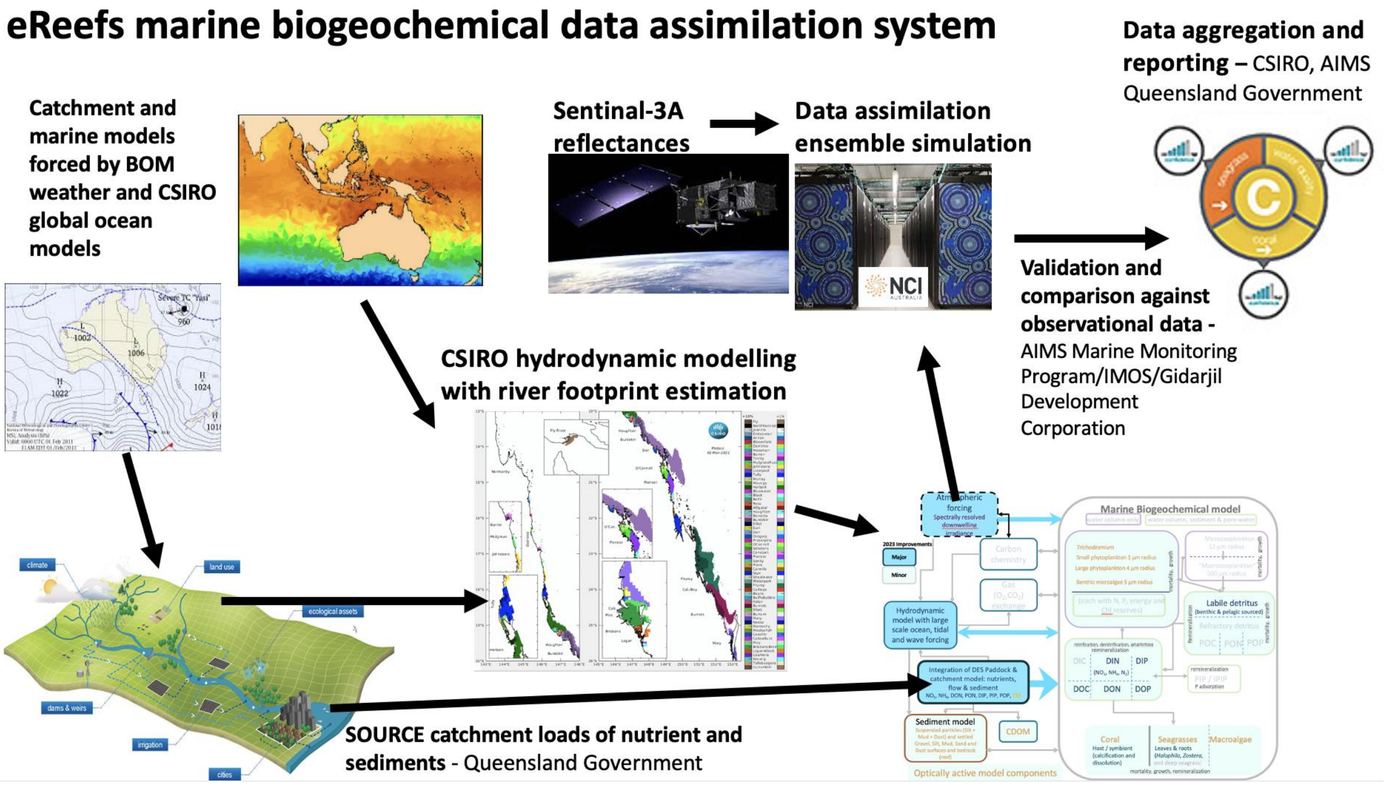


Figure 1 Schematic of the eReefs marine modelling system illustrating the modelling and observational products that are assembled to generate the data assimilating ensemble simulations that are implemented on the National Computing Infrastructure and aggregated to form the Report Card scores. Enlargement of BGC model in figure 2 dark blue with dark blue arrows showing major process improvements and minor improvements shaded in light blue.

The four main components of the marine model described in more detail later in the report are:

- the hydrodynamic 3D model based on Herzfeld, 2006 and 2015 which now incorporates improved oceanic and atmospheric forcing and increased river boundaries (Langlais, 2023)
- the sediment transport model, which is a multilayer sediment bed to the hydrodynamic model grid and simulates sinking, deposition and resuspension of multiple size classes of suspended sediment (Margvelashvili, 2009, Margvelashvili et al., 2016)
- the biogeochemical model, which simulates optical, nutrient, plankton, benthic organisms (seagrass, macroalgae and coral), detritus, chemical and sediment dynamics across the GBR region. (Baird et al., 2020) Figure 2)
- the data assimilating biogeochemical model which incorporates remote sensing observations into the marine biogeochemical model to produce the BGC reanalysis (described below).

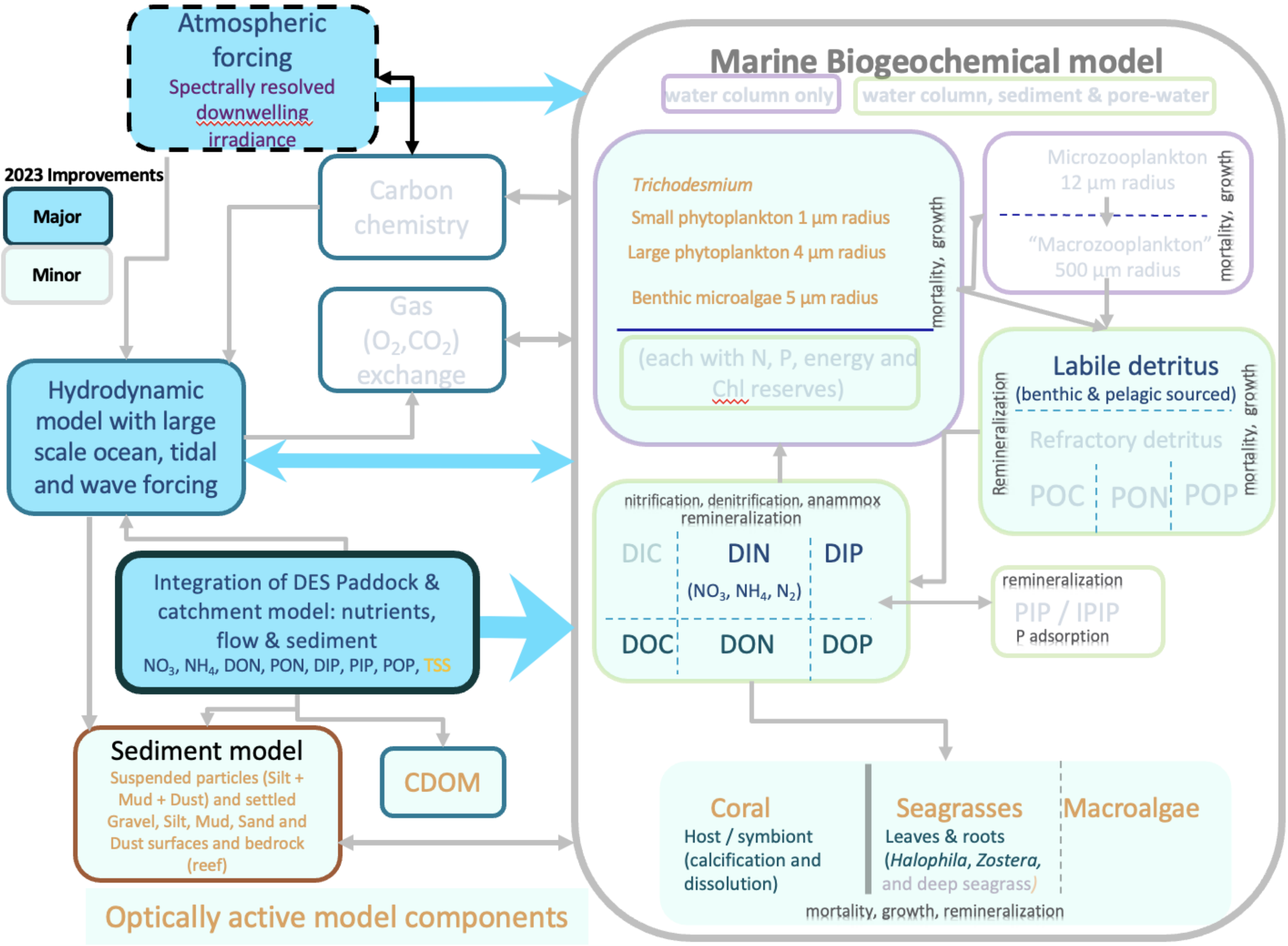


Figure 2. The eReefs marine biogeochemical model conceptual framework with major improvements for this report card shaded in dark blue with dark blue arrows showing major process improvements and minor improvements shaded in light blue. Orange variables are optically active (i.e., either scatter or absorb light) this allows the model to make use of and incorporate remote sensing data.

Briefly, the biogeochemical model considers four groups of microalgae (small and large phytoplankton, *Trichodesmium* and microphytobenthos), two zooplankton groups, four macrophytes (seagrass types corresponding to *Zostera sp.*, two *Halophila sp.* types, and macroalgae) and coral communities. The differences in coral life histories are not covered in the eReefs model (or many reef scale models) despite phototropic octocorals being highly sensitive to chlorophyll-*a*, light limitation and suspended particles. This simplification is due to practical modelling constraints rather than ecological insignificance, as incorporating multiple coral life history or functional groups would increase parameter requirements while suitable long-term, spatially extensive datasets for parameterisation and validation remain limited. Robust representation of coral functional diversity would require consistent large-scale observations linking coral community composition and trait variability with water-quality drivers, which are not yet available at the spatial and temporal scales necessary for Reef-wide biogeochemical modelling.

Photosynthetic growth is determined by concentrations of dissolved nutrients (nitrogen and phosphorus) and photosynthetically active radiation. Overall, the model contains 23 optically active constituents (Baird et al., 2016, 2020). The biogeochemistry model also considers ultrafine sediment particles and their impact on matters such as water clarity (Baird et al., 2020).

The model is currently forced with freshwater inputs from rivers along the GBR that enter at the river mouths (Figure 3). River flows for 65 rivers are obtained from Queensland Department of the Environment, Tourism, Science and Innovation (DETSI) Great Barrier Reef SOURCE Dynamic Sednet model. There are an additional 36 rivers entering as point sources along the coast (i.e. fluxes with load but no flow). The nutrient and sediment loads for all 101 rivers are from the SOURCE catchment model through DETSI and the Queensland Department of Natural Resources and Mines, Manufacturing and Regional and Rural Development. For rivers outside the GBR region, flows are from the gauging stations supplied by the Queensland Government's gauging network. Nutrient concentrations flowing in from the ocean are obtained from the CSIRO Atlas of Regional Seas (CARS) 2009 climatology (Ridgway et al., 2002). 90% of nutrient and sediment loads are delivered with flow and the remaining 10% are as fluxes.

River pollutant loads were obtained from the QLD DETSI GBR SOURCE Dynamic Sednet model outputs (Ellis and Searle, 2013) up to 1 November 2024 (Figure 3). These provide daily time series prediction of pollutant loads and pollutant generation models are used that estimate daily loads through varying monthly concentrations. These monthly concentration outputs allow the model predictions to be extended by providing daily rainfall run-off model inputs (i.e., the run-off of the day), without the need to update many thousands of farm-scale sub-models from the associated paddock and catchment models.

Figure 3 River entrances in blue along the GBR with marine monitoring sites used to compare and validate the marine model in black. Outline of GBR1 (hashed: note GBR4 is used in report card) and the GBR World Heritage Area (blue). Coral mapping in brown. The 6 NRM (land) catchment areas shown as outlines.

Data assimilation/ reanalysis

The eReefs model can be run without ingesting observations from the marine environment which is referred to as a non-assimilating simulation. However, optimally configured data assimilation systems provide the best estimate of the biogeochemical state of the Reef by combining model predictions with observations (Jones et al., 2016). The assimilation of observations improves the model's predictive skill (Skerratt et al., 2019). Data assimilation methods can be thought of as using a model to dynamically interpolate between observations.

For shallow inshore waters, using remote sensing observations to estimate in-water properties is challenging due to the interactions between chlorophyll-*a*, sediment, coloured dissolved organic matter and benthic communities, which all absorb and scatter light in the blue, green and red wavebands. Instead of using remote sensing to estimate in-water properties, the water quality metric is based on the optical calculations of the biogeochemical model, which simulates the normalised remote-sensing reflectance. The data assimilation system uses the mismatch between observed and modelled remote-sensing reflectance to constrain the biogeochemical model (Jones et al., 2016).

The use of data assimilating biogeochemical models to quantify the state of marine ecosystems is becoming an important management tool globally (Jones et al., 2016; Fennel et al., 2019 Higgs et al 2026). The eReefs Project has developed a sophisticated data assimilating system (Figure 1) based on the eReefs 4 km configuration of a coupled hydrodynamic - biogeochemical model. The output of such a data assimilating system is described as a reanalysis. A biogeochemical reanalysis was used to estimate spatially and temporally resolved water quality properties for the previous Great Barrier Reef (GBR) Water Quality Report Cards (Robillot et al., 2018, Baird et al, 2020). For naming see Table 1.

For the GBR, only remote sensing platforms provide the density of observations required to undertake a large-scale data assimilation (see <eReefs home page | eReefs>). The data assimilation system combines model simulations with data obtained from the European Space Agency (ESA) Sentinel-3A and 3B ocean colour sensors and Visible Infrared Imaging Radiometer Suite (VIIRS) sensors (Figure 1). Specifically, the data assimilation system uses the mismatch between satellite-derived remote-sensing reflectance and the simulated remote-sensing reflectance in a 100-member ensemble of simulations to alter the state of the biogeochemical model ensemble thus providing a better estimate of water quality than can be obtained from either models or observations alone.

For more information on the eReefs simulations see biogeochemical -simulation naming protocol (https://research.csiro.au/ereefs/models/models-about/biogeochemical-simulation-naming-protocol/)

The data assimilation technique used in this report is described as an Ensemble Kalman Filter (EnKF). We utilized a 100-member ensemble, which was informed by observed ocean colour data collected by the Sentinel-3A/B and VIIRS satellites. The system is described in detail in Jones et al. (2016). When the ocean colour data is assimilated, it means that the data is incorporated or ingested into the model. In this case, the model incorporates the ocean colour data from satellite observations to update and adjust the relevant variables in order to improve the accuracy of the model's predictions. The model adjusts several optically active in situ variables, including phytoplankton concentration, in all the ensemble members in a way that aligns with the internal properties of the biogeochemical model. The model's performance was then evaluated against in situ observations of chlorophyll-*a* concentration (monitored water samples and sensor networks), which allowed us to quantify the system's accuracy.

Member selection and assessment

The water quality indices are calculated from a subsample of the 100-member ensemble. Ensemble members exhibiting non-dynamical behaviour are first excluded. From the remaining members, we retain only those that demonstrate lower root-mean-square error (RMSE) and bias, based on independent in-situ observations that are not assimilated, relative to the non-assimilating control simulation. Two set of independent observations are used: non-assimilated ocean colour data and in-situ observations.

The members selected using in-situ observations showed improved statistics in comparison with the non-assimilating control run. In this case, three members were used. The estimate of the biogeochemical state used in the report card is the mean of these three members.

The reduction of the 100-members to three selected members is a limitation of this round of Reef Water Qualit Report Card. Justification is given in the following section.

Behaviour of the Data Assimilation system during the 2022–2024 marine water quality assessment (Reef Water Quality Report Card 2023–2025)

This report card period was also the first time the data assimilation (DA) system has been applied over a sequence of very wet, high river flow years. Previous Reef Water Quality Report Card periods were comparatively dry, so the DA system has not previously been applied under sustained, high river discharge conditions. These wet years provide an opportunity to evaluate how the assimilation framework performs in the presence of large long-lasting dispersed river plumes and strong optical gradients.

This is the first time we discarded a large number of members due to unrealistic behaviours: the DA system introduced relatively large increases in phytoplankton biomass, contributing to an unrealistic positive chlorophyll-*a* bias. The 100-member dynamic ensemble is generated and run with perturbations made to model parameters, initial conditions and boundary conditions (including river boundaries). During high flow conditions, the ensemble spread near the river mouths was dominated by phytoplankton uncertainty. Thus the assimilation system updated phytoplankton biomass near river mouths during high flow events.

In addition, the non-assimilating control run is skilful during high flow periods. The skilful control run combined with a smaller ensemble pool of dynamical consistent run left a small subset of improved members in comparison with the control run and previous reporting.

This assessment highlights the importance of reviewing both the optical parameterisation and the way plume perturbations are generated within the DA ensemble framework when applied to extended wet periods. Comparison of simulated true-colour imagery with Sentinel true-colour composites in the future will help identify the dominant sources of discrepancy for the next reporting period.

How the metric is calculated, and information reported

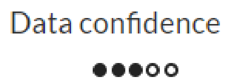
The Reef Water Quality Report Card marine water quality metric is calculated as follows:

- Chlorophyll-*a* concentration and secchi depth data are extracted from the assimilated eReefs biogeochemical model at a 4km spatial resolution and daily temporal resolution (midday snapshot) for the entire Reef.
- The data is partitioned temporally into water years (from 1 October to 30 September of the reporting year) and spatially into zones representing combinations of regions and cross-shelf water bodies (i.e. open coastal, mid-shelf and offshore waters; defined in GBRMPA, 2010). The enclosed coastal water body is excluded due to limitations associated with the 4 km model resolution near the coastline. For the report card only the open coastal water bodies zone is used as this is the area of river influence.
- The site-level data (4 km x 4 km) for chlorophyll-*a* and secchi depth are standardised to indices on a continuous scale of zero (very poor) to 100 (very good). This is done by assessing individual values relative to the appropriate water quality guideline value according to a ‘modified amplitude indexation routine’ (fsMAMP: base 2 logarithm of the ratio of observed value to threshold).
- Scores for each parameter are aggregated (averaged) temporally over the water year into annual scores and spatially in the open coastal reporting zone. The resulting scores for chlorophyll-*a* and secchi depth are then averaged to generate a single annual marine water quality index score for each region.
- All scores are mapped and compared with the previous report card as to whether the region in the current 2023–2025 report card is improving, declining or no change (see Table 2).

Table 2: Marine water quality index score to gauge condition

Condition	Score
Very poor	0–20
Poor	21–40
Moderate	41–60
Good	61–80
Very good	81–100

Semiquantitative confidence ranking



A multi-criteria analysis was used to score the confidence in each indicator used in the report card, from low to high. The approach combined expert opinion and direct measures of error for program components where available. Marine modelling received a three-dot confidence ranking.

References

Australian Institute of Marine Science (AIMS). (2016). Great Barrier Reef Marine Monitoring Program for Inshore Water Quality - Chlorophyll Fluorescence and Turbidity Time-series Data. https://doi.org/10.25845/CMVM-ZT18

Australian Institute of Marine Science (AIMS). (2017). AIMS Physico-Chemical and Nutrient Database. https://doi.org/10.25845/5c09b551f315b, accessed 13-Nov-2023.

Baird, M. E., J. Andrewartha, M. Herzfeld, E. Jones, N. Margvelashvili, M. Mongin, F. Rizwi, J. Skerratt, M. Soja-Wozniak, K. Wild-Allen, T. Schroeder, B. Robson, E. da Silva, M. Devlin (2017) River plumes of the Great Barrier Reef: freshwater, sediment and optical footprints quantified by the eReefs modelling system. In Syme, G., Hatton MacDonald, D., Fulton, B. and Piantadosi, J. (eds) MODSIM2017, 22nd International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2017, pp.1892-1898. ISBN: 978-0-9872143-7-9. https://www.mssanz.org.au/modsim2017/L22/baird.pdf

Baird, M. E., K. Wild-Allen, J. Parslow, M. Mongin, B. Robson, J. Skerratt, F. Rizwi, M. Soja-Woźniak, E. Jones, M. Herzfeld, N. Margvelashvili, J. Andrewartha, C. Langlais, M. Adams, N. Cherukuru, S. Hadley, P. Ralph, T. Schroeder, A. Steven, U. Rosebrock, L. Laiolo, M. Gustafsson, and D. Harrison (2020). CSIRO Environmental Modelling Suite (EMS): Scientific description of the optical and biogeochemical models (vB3p0). Geoscientific Model Development.13:4503-4553. https://doi.org/10.5194/gmd-13-4503-2020

Baird, M. E., M. Mongin, J, Skerratt, N. Margvelashvili, S. Tickell, A. D. L. Steven, C. Robillot, R. Ellis, D. Waters, P. Kaniewska, J. Brodie (2021) Impact of catchment loads of nutrients and sediments on marine water quality on the Great Barrier Reef: An application of the eReefs marine modelling system. Mar. Poll. Bull. 167, 112297 https://doi.org/10.1016/j.marpolbul.2021.112297 .

Baird, M. E., Margvelashvili, N and Cantin, N (2019) Historical context and causes of water quality decline in the Whitsunday region. CSIRO Report to Department of Environment and Energy.

Baird, M. E., P. J. Ralph, K. Wild-Allen, F. Rizwi and A. D. L. Steven. (2013). A dynamic model of the cellular carbon to chlorophyll ratio applied to a batch culture and a continental shelf ecosystem. Limnol. Oceanogr. 58, 1215-1226.

Baird, ME, Cherukuru, N, Jones, E, Margvelashvili, N, Mongin, M, Oubelkheir, K, Ralph, PJ, Rizwi, F, Robson, BJ, Schroeder, T, Skerratt, J, Steven, ADL, Wild-Allen, KA 2016, 'Remote-sensing reflectance and true colour produced by a coupled hydrodynamic, optical, sediment, biogeochemical model of the Great Barrier Reef, Australia: Comparison with satellite data', *Environmental Modelling and Soft*ware, vol. 78, pp. 79–96.

Blondeau-Patissier, D., Brando, V. E., Oubelkheir, K., Dekker, A. G., Clementson, L. A., and Daniel, P. (2009), Bio-optical variability of the absorption and scattering properties of the Queensland inshore and reef waters, Australia, J. Geophys. Res., 114, C05003, doi:10.1029/2008JC005039.

Ellis, R, Searle, R 2013, 'An integrated water quality modelling framework for reporting on Great Barrier Reef catchments', in J Piantadosi, RS Anderssen and J Boland eds, *MODSIM2013, 20th International Congress on Modelling and Simulation*, Modelling and Simulation Society of Australia and New Zealand, December 2013, pp. 3183–89 https://www.mssanz.org.au/modsim2013/L21/ellis.pdf

Fennel, K., M. Gehlen, P. Brasseur, C.W. Brown, S. Ciavatta, G. Cossarini, A.M. Crise, C. Edwards, D. Ford, M.A.M. Friedrichs, M. Gregoire, E. Jones, H.-C. Kim, J. Lamouroux, R. Murtugudde and C. Perruche (2019) Advancing marine biogeochemical and ecosystem reanalyses and forecasts as tools for monitoring and managing ecosystem health, Frontiers in Marine Science, 6:89 doi:10.3389/fmars.2019.00089.

Great Barrier Reef Marine Park Authority 2010, *Water Quality Guidelines for the Great Barrier Reef Marine Park*, Great Barrier Reef Marine Park Authority, Townsville, Queensland.

Herzfeld, M 2006, 'An alternative coordinate system for solving finite difference ocean models', *Ocean Modelling*, vol. 14 (3-4), pp. 174-196.

Herzfeld, M 2015, 'Methods for freshwater riverine input into regional ocean models', *Ocean Modelling*, vol. 90, pp. 1–15.

Higgs, I., Bannister, R., Skákala, J., Carrassi, A., & Ciavatta, S. (2026). Hybrid machine learning data assimilation for marine biogeochemistry. Biogeosciences, 23, 315–344, https://doi.org/10.5194/bg-23-315-2026

Jones, E, Baird, ME, Mongin, M, Parslow, J, Skerratt, J, Lovell, J, Margvelashvili, NY, Matear, R, Wild-Allen, KA, Robson, BJ, Rizwi, F, Oke, P, King, E, Schroeder, T, Steven, ADL and Taylor, J 2016, 'Use of remote-sensing reflectance to constrain a data assimilating marine biogeochemical model of the Great Barrier Reef', *Biogeosciences*, vol. 13, pp. 6441–6469.

Jones, E., M. Baird, M. Mongin, J. Parslow, J. Skerratt, Lovell, J. N. Margvelashvili, R. Matear, K. Wild-Allen, B. Robson, F. Rizwi, P. Oke, E. King, T. Schroeder, A. Steven, and J. Taylor (2016) Use of remote-sensing reflectance to constrain a data assimilating marine biogeochemical model of the Great Barrier Reef. Biogeosciences 13, 6441–6469.

Langlais C. 2026. Improved hydrodynamics and ocean circulation in the eReefs model. (in prep).

Margvelashvili, NY 2009, 'Stretched Eulerian coordinate model for coastal sediment transport', *Computers and Geosciences*, vol. 35, pp. 1167-1176.

Margvelashvili, NY, Herzfeld, M, Rizwi, F, Mongin, M, Baird, ME, Jones, E, Schaffelke, B, King, E and Schroeder, T 2016, 'Emulator-assisted data assimilation in complex models', *Ocean Dynamics*, vol. 66(9), pp.1109-1124.

McCloskey, G. L., R. Baheerathan, C. Dougall, R. Ellis, F.R. Bennett, D. Waters, S. Darr, B. Fentie, L.R. Hateley, M. Askildsen (2021) Modelled estimates of fine sediment and particulate nutrients delivered from the Great Barrier Reef catchments, Marine Pollution Bulletin,165,112163, https://doi.org/10.1016/j.marpolbul.2021.112163.

Ridgway, KR, Dunn, J and Wilkin, J 2002, 'Ocean Interpolation by Four-Dimensional Weighted Least Squares – Application to the Waters around Australasia', *Journal of Atmospheric and Oceanic Technology*, vol.19, pp.1357-1375.

Robillot, C, Logan, M, Baird, M, Waterhouse, J, Martin, K and Schaffelke, B 2018, 'Testing and implementation of an improved water quality index for the 2016 and 2017 Great Barrier Reef Report Cards', *Report to the National Environmental Science Programme*, Reef and Rainforest Research Centre Limited, Cairns, pp. 65.

Robillot, C., Logan, M., Baird, M., Waterhouse J., Martin, K. and Schaffelke, B. (2018) Testing and implementation of an improved water quality index for the 2016 and 2017 Great Barrier Reef Report Cards – Detailed technical report. Report to the National Environmental Science Program. Reef and Rainforest Research Centre Limited, Cairns (150pp.).

Schroeder T., Schaale M., Lovell J., Blondeau-Patissier D., Boadle D. and Baker B., (2019), Migration of the MERIS FUB Coastal Water Processor to Sentinel-3 OLCI, 5 th Sentinel-3 Validation Team Meeting, 7-9 May 2019, ESA-ESRIN, Frascati, Italy. https://www.eoa.org.au/s/20190508_S3VT_Frascati_Schroeder-djr6.pdf

Schroeder, T., Behnert, I., Schaale, M., Fischer, J., Doerffer, R., (2007) Atmospheric correction algorithm for MERIS above case-2 waters. Int. J. Remote Sens. 28, 1469–1486. http://dx.doi.org/10.1080/01431160600962574.

Skerratt J.H. and M. Mongin Technical summary of the eReefs biogeochemical (BGC) marine water quality model for the 2023 reanalysis simulation: gbr4_H3p5_BARRAr2_BRAN2020_G2G_B4p1_Cq4b_rean.

Skerratt J.H., M. Mongin, K. A. Wild-Allen, M. E. Baird, B. J. Robson, B. Schaffelke, M. Soja-Wozniak, N Margvelashvili, C. H. Davies, A. J. Richardson, A. D. L. Steven (2019) Simulated nutrient and plankton dynamics in the Great Barrier Reef (2011-2016). J. Mar. Sys. 192, 51-74. https://doi.org/10.1016/j.jmarsys.2019.192.5174

Skerratt, J. H, M. E Baird, M. Mongin, R. Ellis, R. A. Smith, A.D. L. Steven (2023) Dispersal of the pesticide diuron in the Great Barrier Reef. Science of the Total Environment. 879: 163041. https://doi.org/10.1016/j.scitotenv.2023.163041

Soja-Wozniak, L. Laiolo, M. E. Baird, R. Matear, L. Clementson, T. Schroeder, M. A. Doblin, I. M. Suthers (2020). Effect of phytoplankton community size structure on remote-sensing reflectance and chlorophyll a products J. Mar. Sys. 211: 103400. https://doi.org/10.1016/j.jmarsys.2020.103400

Steven., A. D. L., M. E. Baird, R. Brinkman, N. J. Car, S. J. Cox, M. Herzfeld, J. Hodge, E. Jones, E. King, N. Margvelashvili, C. Robillot, B. Robson, T. Schroeder, J. Skerratt, N. Tuteja, K. Wild-Allen, J. Yu. eReefs: An operational information system for managing the Great Barrier Reef J. Operational Oceanogr. DOI: 10.1080/1755876X.2019.1650589.