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Towards a reference GLM-AED model for wetlands in Great Barrier Reef catchments

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Abstract: Wetlands are key nature-based solutions for reducing nutrient loads to the Great Barrier Reef (GBR), but tools to assess their performance remain limited. This study applies the General Lake Model coupled with Aquatic EcoDynamics (GLM-AED) libraries to simulate nutrient dynamics in GBR wetlands. Using three case studies, wetlands were represented in a quasi-2D manner through sediment zones that captured vegetation and hydrological variability. Results show the model can reproduce nutrient reduction and seasonal dynamics, while highlighting challenges including wetland variability, uncertainty due to data limitations, vegetation representation, and sediment-water interaction. This work provides a reference configuration and identifies priorities for advancing GBR wetland modelling and management.

Keywords: *GLM-AED, Great Barrier Reef, Nutrient reduction, Wetland modelling.*

1. INTRODUCTION

Wetlands provide vital ecosystem services, notably flood attenuation, biodiversity support, and nutrient retention. Their role in nutrient reduction is particularly imortant in catchments draining to the Great Barrier Reef (GBR) (Adame et al., 2019). Excess nutrient runoff from these catchments fuels algal blooms, reduces water clarity, smothers corals, and promotes outbreaks of coral predators, all of which threaten Reef health (Waterhouse & Pineda, 2021). In this context, wetlands are increasingly recognised as effective nature-based solutions to improve water quality and, in turn, enhance the resilience of the GBR.

This work is framed in a project to develop a wetland modelling tool for assessing nutrient reduction in GBR catchments, with the ultimate goal of supporting wetland management and planning. The tool needed to capture key processes driving nutrient reduction, be computationally efficient, and remain transparent in its assumptions and limitations.

The General Lake Model (GLM) (Hipsey et al., 2019) coupled with the Aquatic EcoDynamics (AED) (Hipsey, 2022) library was selected as the modelling platform. GLM-AED is a 1D, open-source framework with a modular structure, allowing users to activate relevant physical, chemical, and ecological processes. While GLM-AED has been widely applied to lakes, its use in wetlands remains limited.

In this study, we address two guiding questions: (1) What considerations are needed to adapt and configure GLM-AED for wetland systems? (2) Can a representative parameter set be defined to establish a "generic" GLM-AED model for palustrine wetlands in GBR catchments?

2. METHODOLOGY AND RESULTS

To address these questions, we combined three sources of information: (i) monitoring data from three wetland case studies, (ii) a vegetation database of GBR wetlands developed within the project, and (iii) an in-depth literature review.

The General Lake Model (GLM) is a 1D vertical model that averages properties within water layers. While this structure can be limiting for shallow wetlands, GLM allows the bottom sediments to be divided into multiple zones, resulting in a quasi-2D representation. Each sediment zone can be parameterised separately, enabling distinct interactions with the water column. This zoning strategy was applied to represent different vegetation types typically present in wetlands; submerged macrophytes, emergent macrophytes, and standing vegetation, alongside open-water areas with no vegetation.

The Aquatic EcoDynamics (AED) modules activated included oxygen, organic matter, nitrogen, and phosphorus cycling, as well as phytoplankton dynamics, sediment–water exchanges, and macrophytes. For each wetland case study, the model was configured with four sediment zones; open water (>3 m depth, no vegetation), submerged vegetation (2–3 m depth), emergent vegetation (1–2 m depth), and standing vegetation (0–1 m depth). The vegetation database informed the depth distribution of these zones, while literature review and expert knowledge guided parameterisation. Each model was then calibrated to site-specific monitoring data.

The three case study models demonstrated consistent and reasonable performance, reproducing key processes such as flow variability, nutrient reduction, and seasonal trends in ecological dynamics. These results, together with insights from the literature, informed the selection of a preliminary parameter set that can serve as a starting point for defining a GBR reference wetland model.

3. CONCLUSIONS AND DISCUSSION

This study developed a modelling methodology and preliminary GLM-AED configuration to simulate nutrient reduction in wetlands draining to the GBR. The results show that the configuration can represent key wetland processes and dynamics, while also highlighting the considerable diversity of wetland types in GBR catchments and the associated challenges of defining a single, generic model representation. Notably, the modelling exercise demonstrates that internal biogeochemical processes are as influential as inflows and boundary conditions in determining nutrient reduction outcomes.

Several methodological insights emerged during implementation. Because wetlands are generally shallower than lakes, finer vertical discretisation was required to capture short-term stratification. Simulations showed that even shallow wetlands can stratify for days to weeks, driving shifts between oxic and anoxic conditions that many existing well-mixed wetland models overlook. The importance of high-frequency boundary data also became clear. GLM-AED requires inflows'nutrient concentrations, including speciation, at temporal resolutions sufficient to capture system variability. Continuous monitoring of inflows and outflows, alongside high-resolution water quality data, is therefore critical to improve calibration and validation. This underlines the need for enhanced and targeted monitoring, not only to better define boundary conditions, but also to support accurate representation of internal dynamics, ultimately improving confidence in wetland design and management across GBR catchments.

Vegetation emerged as a key driver of wetland function. The use of sediment zones provided a practical way to achieve a quasi-2D representation of laterally variable vegetation communities. This approach allowed distinct parameterisation of sediment–water interactions across open water, submerged, emergent, and standing vegetation zones. However, a limitation remains: GLM-AED currently assigns all active macrophyte groups to all zones, restricting the ability to represent distinct vegetation communities accurately.

Another important aspect is sediment–water interactions. The use of sediment zones enabled distinct parameterisation of fluxes across different wetland areas, but the case studies underscored how site-specific these processes can be. A more comprehensive approach would involve incorporating the sediment diagenesis module, which dynamically simulates sediment–water exchanges under varying environmental conditions.

In addition, groundwater–surface water interactions remain a critical but unexplored component in this exercise, representing another priority for future investigation.

Overall, this reference model provides a valuable starting point for simulating GBR wetlands. At the same time, it underscores the need for further model development, particularly groundwater-surface water interaction, vegetation representation and sediment-water interactions, and expanded monitoring efforts to constrain uncertainty. Together, these steps are essential for advancing the use of modelling tools, as GLM-AED, to support wetland design, planning, and management for nutrient reduction in GBR catchments.

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