QUEENSLAND WATER MODELLING NETWORK

Queensland Water Modelling Network Innovation Associates and their Research

(Industry PhD Innovation Program)

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Introduction

The Queensland Water Modelling Network (QWMN) Innovation Program includes five Innovation Associates (Associates), recruited to conduct applied research (PhD) on modelling problems proposed by industry and government partners. The Associates are jointly supervised by Queensland researchers and government and industry partners.

The program aims to provide useful water models and modelling solutions for policy, planning and management issues in Queensland, develop the capabilities of the next generation of water modelling leaders, and act to attract the best potential candidates nationally and internationally to research, live and ultimately work in the Queensland water modelling and use sector.

The Associates also act as ambassadors for the QWMN and provide an important link between undergraduate students and the water modelling sector.

This document provides an introduction to each Associate, their research, government and industry partners and an abstract of their most recent work.

Innovation Associate	**Research and Industry Partners**	**Abstract Title**
Chinenye Ani	James Cook University, The Australian Institute of Marine Science and C_2O Consulting	Investigating the impacts of the temperature dependence of *Trichodesmium* on the timing and distribution of *Trichodesmium* blooms in the Great Barrier Reef
Laura Bellis	QUT and the Queensland Department of Environment and Science	Understanding the interactions of terrestrial groundwater dependent ecosystems (GDEs) with groundwater
Chao Deng	Griffith University and Gold Coast City Council	Integration of remote sensing and modelling techniques for water resource assessment in a subtropical catchment
Cherie O'Sullivan	University of Southern Queensland and Bureau of Meteorology	Investigating modelling methods to improve water quality forecasting of ungauged Great Barrier Reef catchments
Filipe Pinhati	The University of Queensland and Seqwater	Unravelling the influence of scale and methodology on estimates of pathogen export from sub-tropical catchments

Chinenye Ani

James Cook University, The Australian Institute of Marine Science and C2O Consulting

Investigating the impacts of the temperature dependence of *Trichodesmium* on the timing and distribution of *Trichodesmium* blooms in the Great Barrier Reef

Nitrogen fixation by the non-heterocystous marine cyanobacterium, *Trichodesmium*, is believed to largely contribute to the 'new nitrogen'—important for phytoplankton growth—on the Great Barrier Reef (GBR). In recent years, the Great Barrier Reef has experienced extreme events such as marine heat waves due to climate change causing increased sea surface temperature with disastrous ecological outcomes. Extreme temperature increases have been shown to reduce *Trichodesmium* growth and nitrogen fixation. Presently, the temperature dependence of *Trichodesmium* physiological processes is exponentially parametrised by the CSIRO Environmental Modelling Suite (EMS)—simulating the physical state and water quality of the GBR. However, the exponential parameterisation of the temperature dependence of *Trichodesmium* physiological processes is no longer suitable for the continuing temperature increases on the GBR. To accurately capture the effects of extreme temperature increases occurring on the GBR, the temperature dependence of *Trichodesmium* physiological processes is optimally parameterised based on observations from published literature. The effects of the temperature dependence of *Trichodesmium* on the timing and distribution of *Trichodesmium* blooms in the GBR are investigated. Further, using emergent patterns in limited *in situ* observational data the model's performance is evaluated. We anticipate improved model predictions of *Trichodesmium* dynamics with implications for water quality management.

Laura Bellis

QUT and the Queensland Department of Environment and Science

Understanding the interactions of terrestrial groundwater dependent ecosystems (GDEs) with groundwater

Groundwater dependent ecosystems (GDEs) are defined by Richardson et al. (2011a) as *"ecosystems that require access to groundwater to meet some or all of their water requirements on a permanent or intermittent basis, so as to maintain their communities of plants and animals, ecosystem processes and ecosystem services"*. In areas of water stress evapotranspiration of groundwater from GDEs has the potential to make up a large component of a catchment water balance.

The objective of this research is to better understand the interactions of terrestrial GDEs with groundwater by collecting data, and assess how this data can be more effectively upscaled to larger areas. This upscaled information can then be utilised to reduce one of the uncertainties associated with water resource models.

The Phase 1 field program will involve collection and interpretation of multiple datasets including climate, soil type, soil moisture, groundwater level, plus ecological mapping and monitoring of vegetation using sap flow meters and dendrometers. Much of the field equipment has been loaned to the project by DES, with additional funding for several new instruments being provided by DNRME.

Water quality samples from rainfall, groundwater, soil, and vegetation will also be collected and analysed on several occasions throughout the field campaign to assist with identifying the source of water being utilised by the vegetation. Analyses will include major ions, stable isotopes, and dissolved metals such as iron.

Once the field data is collected and analysed, Phase 2 of the project aims to investigate how terrestrial GDEs can be better represented in numerical groundwater models. We hope to use the field data to generate more accurate EVT estimates based on the refined conceptualisation developed in Phase 1. In addition to field data, satellite based remote sensing datasets are likely to provide a valuable resource for upscaling of the field data.

Chao Deng

Griffith University and Gold Coast City Council

Integration of remote sensing and modelling techniques for water resource assessment in a subtropical catchment

Future climate is likely to be one with higher temperatures, less rainfall but more extreme events in South-east Queensland (SEQ) region, however, the impact of climate change on catchment water resources and the combined effect of sea level rise and climate change on flooding and inundation risks in urban estuaries remain unclear. The objectives of this work are to assess the impacts of climate change and land use change on water quantify, water quality and flood risks in the subtropical Nerang River Catchment using hydrological and hydrodynamic models, and to understand the complex ecological processes in shallow urban waters by integrating remote sensing and hydrodynamic modelling.

A catchment hydrological model (SWAT) gave satisfactory performance in simulating discharge, loadings of sediment and nutrient, and reservoir volumes for the period of 2008 – 2019 in Upper Nerang River catchment controlled by Hinze Dam, indicating the key hydrological processes were well represented. Under both emission scenarios of RCP 4.5 (median) and RCP 8.5 (high), there were expected with more extreme flows, in terms of magnitudes, for this catchment in the near future. Except slightly increases in discharges, loadings of sediment and nutrients by 2050s under RCP 4.5 emission scenario, these variables were expected to decrease under the rest scenarios. Reservoir volume has been projected to reduce by -13.7% ~ -39.3%, and it may fail in satisfying the increasing public water demands under a high emission scenario of RCP 8.5. However, the impact of variations in catchment fluxes of flow and nutrient loadings on water quality in Hinze Dam under future climatic conditions remains unclear.

Future work includes setting up a one-dimensional lake water quality model to combine the catchment model outputs for simulating the trophic state in this reservoir regarding to the reduced nutrient loads and reservoir volumes in response to climate change, promoting field spectrum measurement and water quality sampling to calibrate water quality retrieving models for satellite imagery products, setting up and calibrating a hydrodynamic model for the urban estuary to achieve these abovementioned goals.

Cherie O'Sullivan

University of Southern Queensland and Bureau of Meteorology

Investigating modelling methods to improve water quality forecasting of ungauged Great Barrier Reef catchments

Deteriorating water quality associated with sediment and nutrients poses a high risk to the Great Barrier Reef (GBR), one of Australia's iconic natural assets. Thus Australian and Queensland Government's Reef 2050 Water Quality Improvement Plan has set targets for improving the water quality entering the Great Barrier Reef (GBR) lagoon. Concurrently, Target 14.1 of the United Nations Sustainable Development Goal (SDG) also calls for nutrients entering marine systems to be reduced by 2030. Better understanding loads, sources and transport of sediment and nutrients assists decision makers prioritise and communicate necessary measures to manage the health of the Reef, and demonstrate progress towards these water quality targets and obligations. Catchment scale water quality simulation models are used to facilitate the quantification of nutrients entering the reef from its contributing catchment systems. In GBR catchments, 18 of its 35 catchments are ungauged, so lack observed water quality data, equating to 30% of the flows that enter the Reef. In lieu of the observed data, transfer of information from gauged to ungauged catchments allows for water quality and quantity estimate models to function for these ungauged catchments, to inform end users.

My research improves knowledge of suitable catchments to transfer data between via classifying GBR catchments based on physical as well as biological drivers of nutrients using machine learning classification techniques. Machine learning is used because it evaluates data in new ways, so offers innovation to transfer of information from gauged to ungauged catchments. Using innovative artificial intelligent techniques, findings of my research are intended to advance principles for modelling ungauged catchments, and reduce uncertainties associated with regionalisation and nutrient simulations for ungauged catchments. Inclusion of my research outputs to Bureau of Meteorology operational procedures can help better inform data inputs to the eReefs visualisation tool, which is designed to improve communications to the public regarding catchment influences of land towards Great Barrier Reef water quality. Reduced uncertainty within these tools also reduces uncertainty in quantification of progress towards targets of the Reef 2050 Water Quality Improvement Plan and SDGs.

Filipe Pinhati

The University of Queensland and Seqwater

Unravelling the influence of scale and methodology on estimates of pathogen export from sub-tropical catchments

Many quantitative microbial risk assessment (QMRA) projects rely on linked numerical models of catchment and reservoir dynamics to provide information on potential pathogen concentrations. But contemporary modelling approaches do not specifically represent ponds and farm dams (collectively referred to as small reservoirs (SR) herein). Despite their ubiquitous occurrence in Australian catchments, with 2 million SR storing more than 8 million ML of water, the role of SR in of the transport of pathogens is generally not specifically considered in modelling studies that underpin many QMRA projects. Large reservoirs have been identified as a key drivers of natural pathogen inactivation and it is possible that SRs function in a similar way. Conversely the shallow depth of SR might enhance resuspension of sediments and pathogens during high flow events, thus acting as an apparent source of pathogens.

This research seeks to explore the role of SRs in pathogen transport and fate in sub-tropical water supply catchments. Specifically, it aims to investigate the variation in estimates of pathogen export from catchments when different modelling approaches are applied. Three types of model approaches are being compared:

1. A traditional SWAT catchment model to predict pathogen export, ignoring SR;
2. A SWAT catchment model with SR represented in the system; and
3. A coupled modelling approach that uses SWAT coupled with AEM3D aquatic model of SRs linked in a chained configuration.

SWAT was selected as it is a physical, process-based catchment model that provides pathogens and reservoirs modules, making it directly relevant to the research. The AEM3D model is physical process-based aquatic model with a water quality module that provides the ability to simulate fate and transport of pathogens in the aquatic environment.

This research will provide one of the first comparisons of pathogen fate and transport at different scales, providing information about the advantages and disadvantages of modelling SRs in a cascading sequence compared to traditional approaches. This information will directly inform the commissioning of future pathogen fate and transport modelling activities that aim to inform QMRA projects.