Title of Project: Ecology of an important coral predator: eDNA as a novel tool to investigate different life-history stages of Crown of Thorns Seastars (*Acanthaster cf. solaris)*

Names of supervisors:

Name	Affiliation (AIMS or JCU)
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Brief description of the project

Crown of Thorns Seastars (CoTS) are important coral predators. On the Great Barrier Reef, CoTS outbreaks may have been responsible for over 40% of the recent coral cover decline. The reasons for these outbreaks are still under debate, possible explanations range from bottom-up ('nutrient limitation hypothesis') to top-down hypothesis ('predator removal hypothesis'). At least to some degree, the confusion about the causes is due to a lack of knowledge on the ecology of CoTS, especially of early life history stages: Planktonic larval stages are hard to distinguish from other echinoderm species and post settlement juveniles are cryptic. Our team has recently developed molecular probes which allow detection and quantification of larval stages, and potentially also juveniles. These 'eDNA' tools open new alleys to investigate the ecology of larvae and juveniles of CoTS, such as temporal and (large and fine scale) spatial distribution.

This project would suit someone who: We seek a highly motivated student with both genetic laboratory and ecological skills who is interested in using these tools along with the development of further methods to shed more light on the ecology of CoTS and contribute to new management solutions.

Key words: reef-degradation, crown-of thorns-seastar, molecular tools, eDNA, echinoderms

Title of Project: Modelling plastic pollution in the Great Barrier Reef

Names of supervisors:

Name	Affiliation (AIMS or JCU)
Barbara Robson*	AIMS
Frederieke Kroon	AIMS

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Brief description of the project

Plastic pollution in marine environments is a growing concern globally. Research to understand the extent and nature of plastic pollution is an emerging hot topic and the impacts of microplastic pollution in particular (i.e. plastic particles less than 5mm) are not yet well understood. Recent AIMS research has demonstrated that microplastic pollution is widespread, even in the Great Barrier Reef. In this project, the student will develop numerical models to trace the path and track the distribution of microplastics in the Great Barrier Reef, building on existing hydrodynamic and biogeochemical models, including previous GBR microplastic modelling, by considering the implications of microplastic buoyancy and particle shapes as well as interactions with other organic materials such as biofilms. The models developed will be used to put measured microplastic concentrations into context in order to address such questions as:

- What is the total mass of microplastics in the Great Barrier Reef?
- Where do microplastics in the Great Barrier Reef come from, and where do they end up?
- Are there regions where microplastics can be expected to accumulate?
- Do different microplastics behave differently in the marine environment?
- What might the variable distribution of microplastics in the marine environment mean for marine food webs?

This project would suit someone who: The successful applicant should have an interest in marine science, a strong quantitative background and some prior programming experience (e.g. in compiled language such as C++ or Fortran as well as an interpreted language such as R, Python or Matlab) as well as relevant research experience such as a 1st class or 2a Honours degree. Students with a Bachelor’s degree in any sufficiently quantitative field may be considered – for example, Oceanography, Applied Mathematics, Computer Science, Meteorology or Engineering. Students with a degree in Marine Science, Environmental Science or Ecology could be considered if they have completed appropriate university-level coursework in mathematics. Some prior knowledge of fluid dynamics and/or environmental chemistry would be an advantage, but not required.

Key words: Great Barrier Reef; hydrodynamic modelling; microplastics; oceanography; plastic pollution; water quality; environment

Title of Project: Deep learning assisted underwater robot navigation

Names of supervisors:

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Brief description of the project

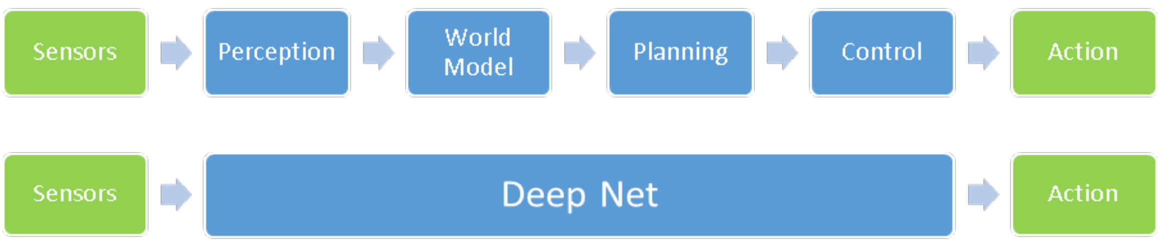
Marine robotics faces many unique challenges due to the complex and dynamic operating environment. The highly chaotic and cluttered nature of reef sites, the lack of a global positioning system underwater, reduced visibility, and imperfections in the obtained sensor data all present difficulties when designing navigation and control algorithms for autonomous underwater vehicles (AUVs).

With the recent advancements in machine learning, in particular large artificial neural networks with many layers ('deep learning') there is much potential to enhance the robot's capabilities beyond those achievable with present methods.

The key idea of this project is to replace individual, "traditional" modules in robotics pipelines, with deep learning based modules in order to improve the platform's performance and reliability. One could for example think of replacing traditional vision-based perception approaches [1] [2] [3] with a convolutional neural network approach that is able to "learn" to perceive the surrounding environment in varying conditions – even when the footage obtained from the sensors is highly degraded and would quickly bring traditional approaches to their limits.

Other parts of the robotics pipeline can profit from deep-learning based enhancements. Potentially this new technology could be applied to the navigation and control problem, and enhance the quality of the robots motion planning and decision making based on past experiences. It is even conceivable that the full end-to-end behavioural system could be replaced by a trained deep neural network with only raw sensor inputs, as recently demonstrated by Google DeepMind in [4] and illustrated in the figure below.

The PhD student will, in the context of this project, have the opportunity to study deep learning technologies and explore how they can be adapted for the use in guidance and



navigation of unmanned underwater vehicles to improve currently available capabilities and algorithms.

[1] Lindeberg, Tony. "Scale invariant feature transform." (2012): 10491.
[2] Bay, Herbert, Tinne Tuytelaars, and Luc Van Gool. "Surf: Speeded up robust features." *European conference on computer vision*. Springer, Berlin, Heidelberg, 2006.
[3] Mur-Artal, Raul, and Juan D. Tardós. "Orb-slam2: An open-source slam system for monocular, stereo, and rgb-d cameras." *IEEE Transactions on Robotics* 33.5 (2017): 1255-1262.
[4] Mirowski, Piotr et. al. "Learning to Navigate in Cities Without a Map" **arxiv:1804.00168, 2018**

This project would suit someone who: The ideal candidate will have a strong academic background in computer science, mathematics, engineering or a closely-related numerical discipline. They will have strong mathematical skills and demonstrated proficiency with a programming language. Knowledge of artificial intelligence and/or robotics techniques is highly desirable.

Key words: Deep learning, artificial intelligence, neural networks, robotics, marine

Title of Project: Development of Artificial Intelligence Methods for Hyperspectral Image Analysis in Coral Reef Science Applications

Names of supervisors:

Name	Affiliation (AIMS or JCU)
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Brief description of the project

The aim of this research project is to investigate the use of advanced artificial intelligence (AI) methods for hyperspectral image analysis in coral reef science applications (such as, bleaching prediction, benthic community properties, etc.). Current hyperspectral analysis methods rely on satellite and low spatial resolution (e.g., 30 to 250 metres per pixel) hyperspectral imagery, which require significant pixel un-mixing and complex atmospheric correction. Instead, the scope of this project is to use close range, millimetre resolution hyperspectral imagery from live coral tanks using AIMS hyperspectral and SeaSim infrastructure. The datasets will be used for developing a spectral library of high-quality end members as well as for temporal coral bleaching studies to identify stress indicators of bleaching before bleaching actually occurs. Due to the complexity and large amount of information inherent in hyperspectral datasets, traditional statistical analysis methods are not computationally feasible, hence AI methods (such as machine learning, neural network, deep learning, evolutionary algorithms, etc.) will be explored and evaluated. Methods developed will be further validated with field experiments. The output of this project will be valuable in bridging the gap of applying high quality hyperspectral data in coral reef science.

This project would suit someone who: Background in AI methods, spectroscopy and hyperspectral systems. Above average programming skills, i.e., able to code and modify AI algorithms. Familiarity with MATLAB would be ideal, but other programming languages are acceptable as well.

Key words: Hyperspectral imaging, hyperspectral analysis, coral reef, bleaching, neural network, deep learning, machine learning, artificial intelligence.

Title of Project: Biogeochemical modelling of tropical marine ecosystems in the context of climate change

Names of supervisors:

Name	Affiliation (AIMS or JCU)
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Brief description of the project

Modelling of marine ecological responses to climate change is often done poorly, using models that were designed for current conditions and evaluated against historical observations. Robust modelling of climate change futures requires not only setting appropriate boundary conditions (such as meteorological and hydrological conditions and ocean currents) but also re-evaluation of the algorithms and assumptions built into the model itself. For example, most models (including the eReefs models for the Great Barrier Reef) assume that process rates including plankton growth rates increase as temperature increases. This is generally true for temperatures <30C, but the assumption fails as temperatures continue to rise. Most models also fail to account for adaptation of planktonic communities in response to long-term changes in environmental conditions and do not consider how acute responses to short-term changes in temperature or pH differ from longer-term physiological responses to chronic exposure. In this project, the student would critically evaluate the eReefs biogeochemical models and improve the models so that they can more reliably be used for climate change scenarios.

This project would suit someone who: The successful applicant should have an interest in marine science, a strong quantitative background and some prior programming experience (e.g. in compiled language such as C++ or Fortran as well as an interpreted language such as R, Python or Matlab) as well as relevant research experience such as a 1st class or 2a Honours degree. Students with a Bachelor's degree in any sufficiently quantitative field may be considered – for example, Oceanography, Applied Mathematics, Computer Science, Meteorology or Engineering. Students with a degree in Marine Science, Environmental Science or Ecology could be considered if they have completed appropriate university-level coursework in mathematics. Some prior knowledge of ecology and environmental chemistry would be an advantage, but not required.

Key words: Great Barrier Reef; hydrodynamic modelling; ecosystem modelling; oceanography; climate change; water quality; environment

Title of Project: Dissolved Organic Nitrogen (DON) in Great Barrier Reef catchments

Names of supervisors:

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Brief description of the project

Dissolved organic nitrogen (DON) makes up a large proportion of the dissolved nitrogen load delivered to the Great Barrier Reef from catchments. Although DON in marine environments may be composed of thousands of different chemical forms, it is usually treated as if it were homogenous, measured only as the difference between total dissolved nitrogen and dissolved inorganic nitrogen. DON from different sources will have different chemical structures, varying bioavailability and hence varying impacts on marine ecosystems, but this variability is not well understood and we currently have very little information about the form and bioavailability of catchment-derived DON in the Great Barrier Reef. This project will draw upon recent advancements in analytical chemistry to address this knowledge gap. The student will first identify Dissolved Organic Matter (DOM) constituents in river water, then link variability to land use practices within the catchments they were obtained. This information will then be used to improve representation of dissolved organic materials and their bioavailability in river boundary conditions for the eReefs models of the Great Barrier Reef.

This project would suit someone who: The successful applicant should have a background in environmental science, experience in water quality research, and appropriate laboratory skills.

Key words: Great Barrier Reef; water quality; environmental chemistry; catchment processes

Title of Project: Trophic transfer of microplastics in tropical marine environments

Names of supervisors:

Name	**Affiliation (AIMS or JCU)**
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Brief description of the project

Marine plastic pollution has become a global environmental concern, growing exponentially over the years. After time, plastic pollution breaks down into what is known as microplastics (< 5mm in size), becoming the optimal prey range size for many aquatic species. Microplastics ingestion has been confirmed for many marine species, however there is limited evidence that microplastics transfer within the food web into higher trophic levels, and associated potential physical and/or chemical impacts of organism within the food web. This study aims to investigate potential trophic pathways of marine microplastics in food webs of tropical marine ecosystems. Field collections will be combined with controlled laboratory studies to examine levels of contamination, and transfer pathways of microplastics from zooplankton to higher level organisms within a multi-level food web. Feeding trials and experiments will be done with common plastic polymer type, chemical additives and particle sizes. The findings will contribute to a better understanding of the ecological impacts of microplastics on tropical marine environments.

This project would suit someone who: The successful applicant should have an interest in conducting research on contamination of marine environments in general, and on microplastics contamination in particular, as well as relevant research experience such as a 1st class Honours degree. Experience with analytical methods to describe microplastics (e.g. microscopy, spectroscopy) would be a distinct advantage. Relevant first-authored publications in the area of microplastics would be rated highly, as would the ability to work collaboratively and successfully in larger teams. Students with a Bachelor's degree in Marine Ecological field may be considered – for example, Marine Biology, Ecotoxicology, Ecology, and Toxicology.

Key words: Microplastic, contamination, ingestion, food web, trophic transfer, tropical coral reef.