INDONESIA DISSERTATION/THESIS PROJECT

AI for Coral Reef Conservation: Digital Tools for Monitoring Marine Ecosystems

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Marine conservation is entering a new era, where advances in computer science are unlocking innovative, scalable ways to monitor ecosystem health. Rather than being limited by time-intensive, manual data collection and analysis, researchers can now apply automated techniques to assess biodiversity, habitat structure and species populations with greater efficiency and precision. These tools are transforming how we understand and protect marine ecosystems - enabling faster responses to environmental change, better-informed management decisions and the potential to scale up conservation efforts globally.

This research program focuses on developing robust, field-deployable digital solutions that support long-term monitoring of coral reefs and associated fish communities. Designed specifically for use in remote marine environments without relying on cloud computing or internet access, these tools integrate machine learning, computer vision and 3D modelling techniques to deliver high-quality ecological insights. Students with good computational skills have a unique opportunity to contribute meaningfully to conservation by designing and refining methods that are both technologically advanced and practically usable in the field.

The project is based at Hoga Island in the Wakatobi Marine Reserve, Indonesia, a site with over two decades of ecological data. The site offers an ideal environment for testing automated methods under different reef conditions. By integrating field-collected data (such as underwater imagery, stereo video and photogrammetry scans) with offline machine learning models and custom analysis tools, students can generate insights into ecosystem structure, species dynamics and the effectiveness of conservation measures.

This research is structured around three core methodologies: (1) benthic classification using deep learning models trained on annotated reef imagery; (2) 3D photogrammetry to measure reef structural complexity over time; and (3) automated fish diversity, abundance and biomass estimation from video data. All approaches are designed to run efficiently on laptops or portable devices, with an emphasis on reproducibility and real-time analysis. Students working on these projects will gain hands-on experience with ecological data, contribute to conservation solutions, and develop field-ready technical tools with real-world impact.

1. Development and field deployment of offline benthic classification models

This project could focus on training and deploying deep learning models (e.g. convolutional neural networks) to classify benthic features such as coral, algae and sponge from reef imagery. Students will refine model architectures (e.g. YOLO, FasterRNN) for use on local machines with limited processing power. The goal is to produce lightweight, accurate models that can be used in the field to assist real-time or same-day ecological assessments without internet access. A key component will be testing performance across different reef sites and evaluating how generalisable the model is across habitat types.

2. Quantifying reef structural complexity using portable 3D modelling workflows

This project could use photogrammetry to reconstruct high-resolution 3D models of reef habitats, from which structural complexity metrics can be extracted. Students will design a streamlined pipeline using offline software such as Agisoft Metashape or Meshroom, optimised for laptops. They will develop scripts to compute key metrics (e.g. rugosity, surface area, volume, fractal dimension) and compare outputs between reefs. The project may also explore temporal changes using archived data and propose optimisations to improve processing speed or visualisation quality under field conditions.

3. Fish diversity, abundance and biomass estimation from video data using machine vision

This project could develop or improve offline methods for estimating fish diversity, abundance and biomass from video recordings, including stereo paired videos. Students will build or adapt computer vision tools (e.g. OpenCV, YOLO-based models) to identify, measure and count fish across frames, possibly also using using stereo calibration to compute lengths and biomass estimates. The project will include designing an efficient, user-friendly interface for in-field use and validating model performance against manually annotated datasets.

This project would require the participant to have good computer science skills. The data for the project would be collected using SCUBA diving and the participant would be taught skills in marine species identification to support the labelling of data.

Recommended reading:

Chamberlain, Jon, et al. "ImageCLEFcoral task: coral reef image annotation and localisation." CEUR Workshop Proceedings. Vol. 3180. CEUR Workshop Proceedings, 2022.

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Goetze JS, Bond T, McLean DL, et al. A field and video analysis guide for diver operated stereo-video. Methods Ecol Evol. 2019; 10: 1083–1090. https://doi.org/10.1111/2041-210X.13189

Lozada-Misa, Paula et al. (2017). Analysis of benthic survey images via CoralNet : a summary of standard operating procedures and guidelines. http://doi.org/10.7289/V5/AR-PIFSC-H-17-02

Smith, D. (2006). Wakatobi Field Report. Operation Wallacea.

Wright, Jessica, and Jon Chamberlain. 2024. " Investigating Human Impacts on Rocky Reefs Using Measures of Complexity and Relief from 3D Photogrammetry." Ecosphere 15(2): e4763. https://doi.org/10.1002/ecs2.4763

Young GC, Dey S, Rogers AD, Exton D (2017) Cost and time-effective method for multi-scale measures of rugosity, fractal dimension, and vector dispersion from coral reef 3D models. PLOS ONE 12(4): e0175341. https://doi.org/10.1371/journal.pone.0175341