HONDURAS DISSERTATION/THESIS PROJECT

HON-M01 Coral reefs in three-dimensions: using technology to explore patterns in Caribbean reef health

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Technology is revolutionising the way scientists conduct research across disciplines by improving the accuracy and efficiency of data collection, moving towards automation to remove human error, or simply allowing previously impossible questions to be answered. Tropical marine ecology has historically been dominated by research conducted by SCUBA divers and snorkellers using simple observational techniques to record data. This is especially true for coral reef monitoring programmes, which generally rely on labour intensive strategies based around simple methods to give a broad overview of reef health and community composition. This approach has the benefit of being widely accessible to research practitioners of varying levels of expertise and can give highly accurate data when conducted by experts. However, it introduces significant risk of observer bias, relies on accurate observations in the "heat of the moment" with no opportunity to verify data, and in some cases provides highly limited sampling compared to the overall area being surveyed. In recent years several new technologies have emerged that provide potential improvements on traditional coral reef survey methods. This project focuses on these technologies in three areas: (i) benthic surveys for reef health, (ii) fish surveys to assess community composition, abundance and fisheries biomass, and (iii) measurements of the underlying 3D structure of the reef as an indication of habitat complexity.

One of the most widely used ways to assess the health of a coral reef is to determine the percentage of the reef surface which is made up of healthy live corals; as ecosystem architects corals are the most important organisms on the reef. By expanding this further to look at the percentage cover of other benthic categories (e.g. macroalgae, sponge, soft coral) we can gain a better understanding of the status of a reef and what factors might be impacting it. The same data can be used to look at corals of particular interest, such as the highly threatened but ecologically important Acroporids, or to measure the diversity of the coral community. Traditionally, line transects have been used to conduct benthic surveys. A single transect tape is laid horizontally along the reef at a given depth, and what lies under the tape recorded either continuously along the transect (line intercept method) or at set intervals along the transect (point intercept method). Line intercept gives a more accurate data set but is much slower to complete, but both methods can be time consuming and means an assessment of only a thin line of reef is taken as a representation of the health of the wider reef around it. Recent advances in artificial intelligence, in particular machine learning, have opened up the possibility of automated identification which allows larger data sets to be collected more quickly and accurately. One example of this is CoralNet, an open source tool developed by the University of California. This allows users to upload photographs of coral reefs, and as they begin to analyse them the machine learning algorithms begin to teach themselves based on these identifications. As more analyses are completed by the human user, the algorithms become increasingly accurate until they are essentially as good as the expert. Approximately 5-10% of photos need to be analysed by a human before the machine learning algorithm is capable of fully taking over. This not only allows huge data sets to be collected, but its use of photographs mean larger areas of reef can be covered.

Coral reef fish are important both economically for local small-scale fisheries and ecologically because of their ecosystem roles. For example herbivorous fish are crucial in reducing macroalgal growth and allowing corals to thrive. Surveys of reef fish tend to be conducted by Underwater Visual Census, where a researcher swims along a transect and records every fish they see a set distance either side of, and above, the transect to give a pre-determined total area of reef surveyed. Generally both the total number (abundance) and the species of each fish will be recorded, although more experienced researchers may also estimate the length of each fish, although this is notoriously difficult to achieve with any accuracy due to the difficulties with estimating sizes underwater. However, the reason length is so important is that it can be used to estimate biomass, which in many ways is a much more useful measurement than simple abundance. For example, one large herbivore could consume more macroalgae than several smaller ones of the same species; abundance and biomass would lead to opposite conclusions being reached. The concept of stereo-video has been around for some time, but in recent years it has been applied to underwater surveys of fish. Two cameras mounted on a precision engineered chassis essentially function like a pair of human eyes. If the exact angle between the cameras is calibrated, the contrasting views from each camera can be used to locate exact points in three dimensions. By placing one point on the nose and one on the tail of a fish, the distance between the two points can be estimated to >95% accuracy. Divers swim along a transect filming using the stereo-video system and analyse the footage back on land. Specialist software allows only those fish within a pre-determined distance to be recorded, the species to be noted, and the length of each fish to be measured. This allows accurate biomass estimates to be made, as well as providing a permanent record of the transect for future re-analysis.

One of the reasons coral reefs are home to such high levels of biodiversity is their complex 3D structure, which provides a wealth of microhabitats for organisms to exploit. However, structural complexity of underwater architecture is traditionally challenging, and has subsequently relied on particularly basic methods to estimate. The two most commonly used techniques have been chain-and-tape rugosity and Habitat Assessment Scores (HAS). For the former, a chain of known length is laid across the reef following the contours of the surface, and the final linear distance between the two ends is then measured. The complexity of the surface is then calculated as rugosity by dividing the distance between the ends with the actual length of the chain. The more complex the surface, the shorter the final distance between the two ends, whereas for a completely flat surface the two values would be the same. HAS is a passive observational alternative, whereby a diver visually characterises five aspects of the reef's complexity along a scale, then adds up the score to get a single HAS value. More recently, 3D computer modelling allows areas of reef to be digitally reconstructed and the complexity measured mathematically to a high degree of accuracy. These models can be built from video footage using cost effective underwater cameras.

To date, these new technological approaches to coral reef surveying have been used successfully in isolation, but they have yet to be combined. Operation Wallacea scientists in Honduras are using these methods to develop and test an integrated coral reef monitoring technique that uses a combination of automated benthic surveys via machine learning, fish surveys via diver-operated stereo-video, and reef complexity measurements using 3D modelling via structure-from-motion photogrammetry. Students on this project will work with all three methods and implement this integrated approach on a range of coral reef sites as part of Operation Wallacea's Honduran reef monitoring programme. Individual dissertation/thesis projects could address a range of ecological questions, such as whether the biomass of herbivores influences the abundance of macroalgae and the health of reefs, or how the structural complexity of the reef determines fish abundance and diversity. There is also historical data for stereo-video and benthic surveys going back to 2012, and students could use these data to look at temporal trends (although note that no historical data for structural complexity exists).

Recommended Reading

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