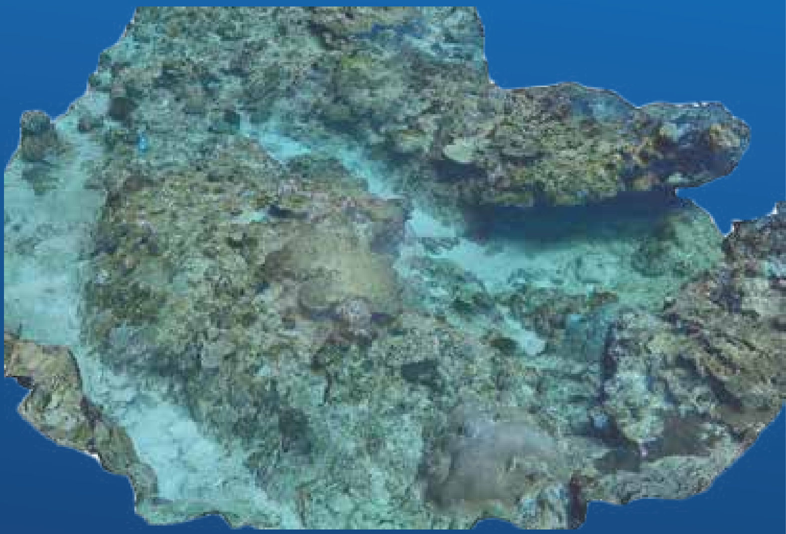
News from ORI Coral Researchers

Coral Awareness Week - July 2020

Predicting local coral reef responses to global warming in the Anthropocene

by
Dr Sean Porter and Tanja Hanekom



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SAAMBR INCORPORATING OCEANOGRAPHIC RESEARCH INSTITUTE uShaka SEA WORLD

Helping people to care for our ocean

Predicting local coral reef responses to global warming in the Anthropocene

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South Africa has exceptionally rich marine biodiversity around its entire coastline. In the north-eastern tropical parts of the country, this is exemplified by Africa's southern-most coral reefs, located in the iSimangaliso Wetland Park World Heritage Site. These beautiful coral reefs are rich natural assets and support the livelihoods of many people in the area, as they are world class diving estinations (Figure 1).

Although they are well protected from local threats, they are vulnerable to global-scale threats such as climate change – especially global warming.

Figure 1. An example of a stunning high-latitude coral reef in the iSimangaliso Wetland Park World Heritage Site.

Figure 2. Shenyang, China in November 2015, where atmospheric pollution from the burning of fossils fuels is particularly bad (source: http://berkeleyearth.org/).

Anthropogenically induced climate change is one of the key defining characteristics that typifies the Anthropocene epoch we find ourselves in – a period during which human activity has been the dominant influence on climate and the environment. Unfortunately, the marine environment and coral reefs in particular, have not been spared from the negative impacts of human activities. Ocean warming and marine heat waves have become more intense and regular since the industrial era and have been directly linked to greenhouse gas emissions from the combustion of fossil fuels. Air pollution in Europe is equivalent to smoking two cigarettes per day, and in parts of India and China, it is equivalent to smoking a pack a day (Figure 2)!

Coral reefs are very sensitive to abnormally warm temperatures, which are predicted to occur more frequently in the next hundred years due to climate change. In fact, 2017 was the third warmest year on record, 2019 was the second-most and 2016 was the warmest year ever recorded. Coral reefs act like the caged canaries miners used to carry with them to warn them of noxious gases; corals similarly act as an early warning sign of adverse conditions – in this case global warming. Abnormally warm water temperatures cause corals to lose their colour, bleach and die, a phenomenon known as coral bleaching (Figure 3). This has devastating socio-economic impacts and directly affects people's livelihoods (e.g. fisheries, ecotourism, coastal erosion, etc.).

Figure 3. Coral bleaching on a reef in Zanzibar, Tanzania, during 2016, the hottest year on Earth ever recorded.

Baseline information on reef growth (biogenic accretion and dissolution of coral reefs) in South Africa and in the western Indian Ocean does not exist, and the effects of climate change on these processes at the individual coral colony level and at the community level are largely unknown. Therefore, laboratory experiments were conducted on typical South African corals and coral communities with the aim of measuring calcification (accretion and dissolution), growth and the ability to acquire energy (photosynthetic efficiency) under current and future global warming temperatures predicted to occur with regularity within the next 80 years. See SAAMBR video of experimental setup.

The results showed suppressed growth in hard coral and especially soft coral under future predicted temperatures by as much as 20-85% respectively, over a month-long period. Concomitantly, photosynthetic efficiency also declined by approximately 20%, in both hard and soft coral. At the coral reef community level, net community calcification also decreased, by 40%. Hard corals began to bleach and die after a month of being exposed to temperatures predicted to occur within the next 80 years and soft corals also showed obvious signs of thermal stress with increased mucous secretion.

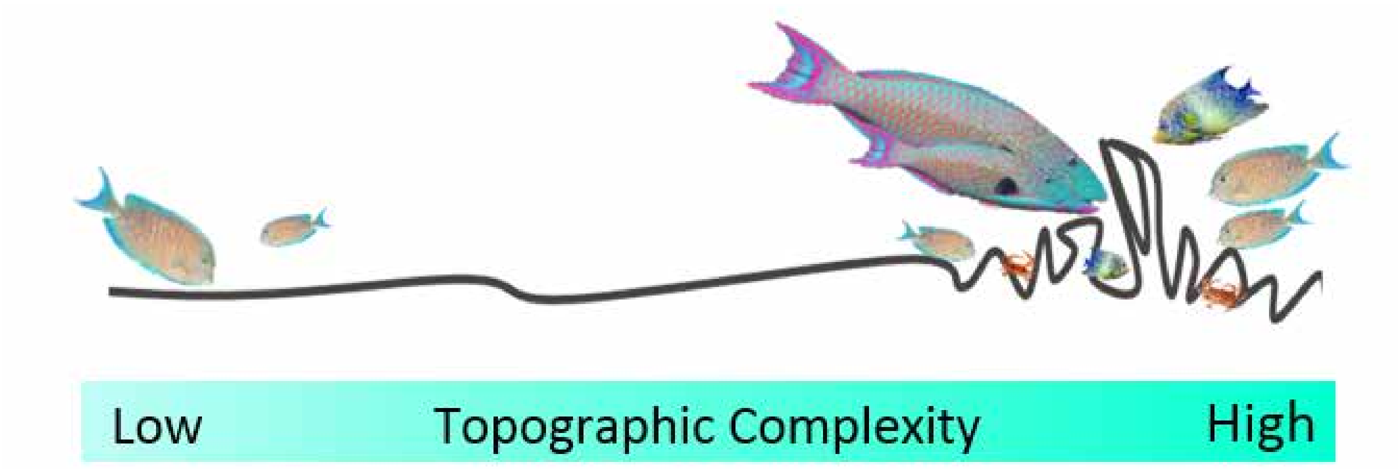
The results indicated that predicted future increases in temperatures within the next 80 years will severely affect our local coral reefs in South Africa, despite their high-latitude location where temperatures are relatively cooler compared to the tropics (Figure 4). This will negatively impact coastal livelihoods dependent on these reefs for ecotourism and will impoverish our natural heritage. We have already started seeing some of the effects of global warming on our local reefs, with cases of mild coral bleaching already having been documented.

Figure 4. Local coral reefs such as this one in the iSimangaliso Wetland Park World Heritage Site are predicted to become increasingly vulnerable to global warming.

The Paris Agreement on climate change aims to keep global temperature rise to below 2°C. At the current rate of global warming, the Earth's long-term average temperature will reach 1.5°C above the 1850-1900 average by 2035 and 2°C by 2065. Significant action is therefore required to reduce human activities that contribute to greenhouse gas emissions soon if the goal of the Paris Agreement is to be realised and the future of coral reefs safe guarded from global warming.

Virtual Reefs
Recreating Sodwana Bay's coral reefs in 3D
by
Samantha Hofmeyr and Dr Dave Pearton

Off the coast of northern KwaZulu-Natal in the clear, blue, warm waters of the iSimangaliso Wetland Park World Heritage Site, lie the vibrant, highly diverse coral reefs of Sodwana Bay. These reefs are a hotspot for diving and other recreational activities, and they support the livelihoods of many people. Globally, coral reefs support more than a quarter of all marine organisms and they are essential for the livelihoods of around 275 million people. One of the first things you notice when diving on a reef is its incredible diversity and complexity, it has a multitude of little nooks and crannies, crammed with all sorts of life. This forms network of complex, three-dimensional ecosystems created, in part, by the varying structures of the corals themselves. Importantly, more complex topography (physical structure), means more habitat area, breeding, feeding and nursery spaces for reef organisms, contributing to the great diversity and productivity found on coral reefs. Many local and global threats to these ecosystems are increasing in intensity and frequency as the human population grows. These disturbances (including overfishing, pollution, and climate-change driven coral bleaching) are causing large scale loss of live coral cover and thereby reducing topographic complexity and the corresponding services.

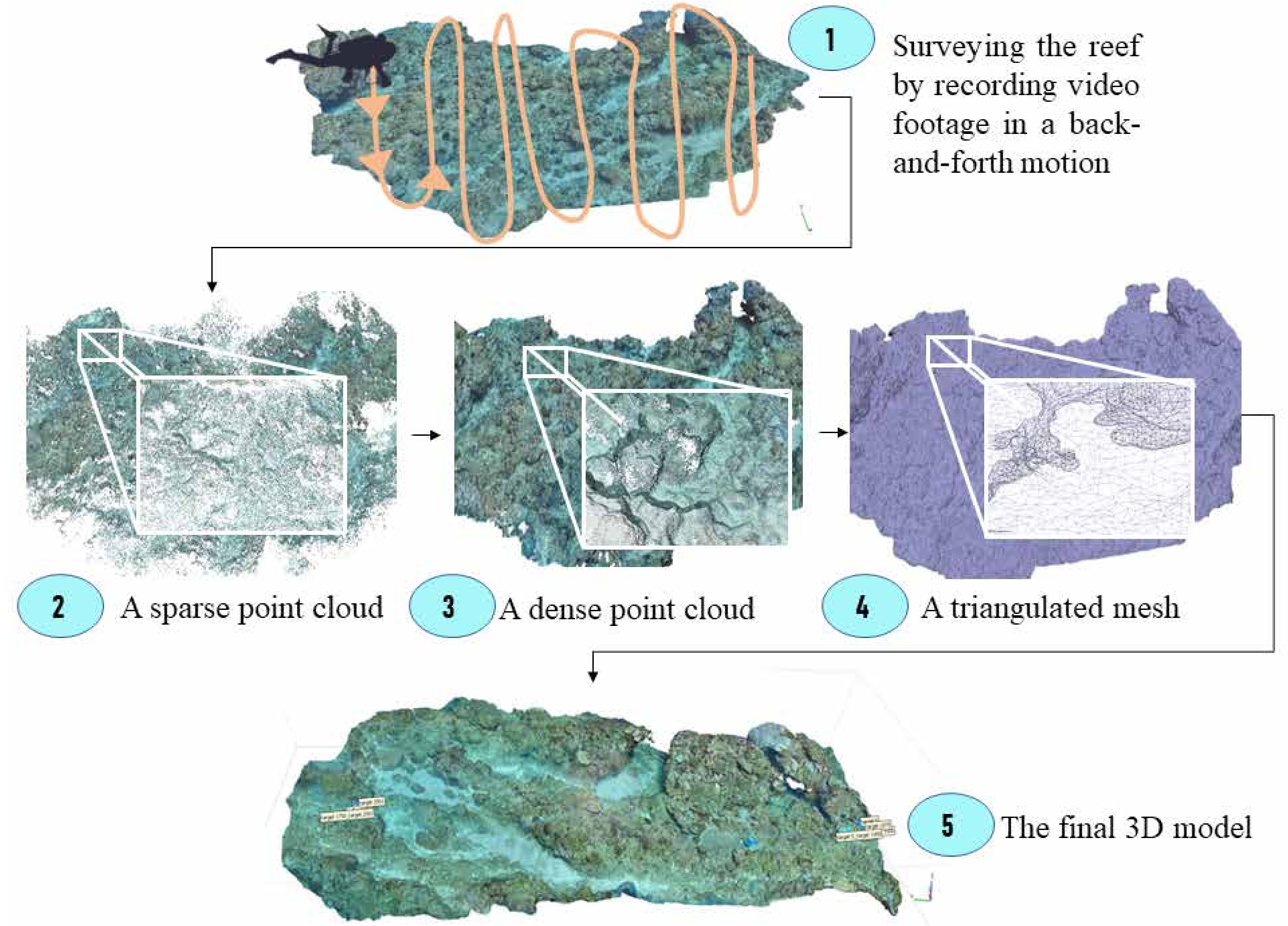


The association between the complexity of the reef and fish abundance and diversity.

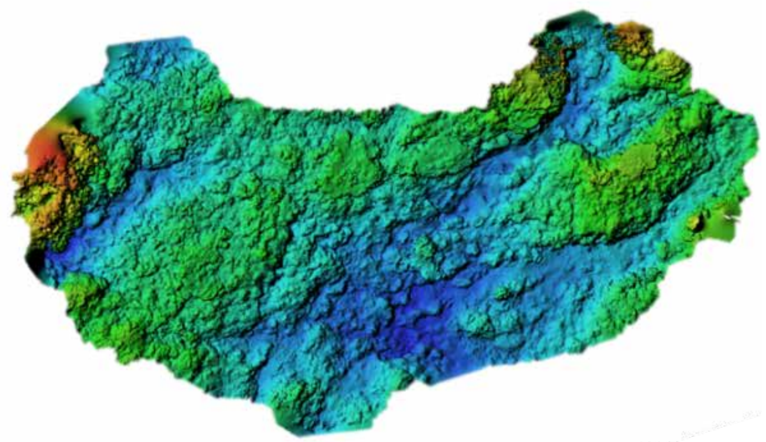
Reef health is generally documented by monitoring programs using two-dimensional (2D) photographs to measure the abundance and cover of corals over time. Technology and computing power has advanced so rapidly in recent years that we can now create three-dimensional (3D) models of an area using basic action cameras such as a GoPro. In years past this would have required a room-sized mainframe to do this, but now it can be done with a reasonably powerful desktop computer. We are using these models to monitor the coral reef ecosystems of Sodwana Bay in 3D space. This will allow us to better assess reef health, by including measurements of 3D structure and topographic complexity.

We are creating 3D models of the Sodwana Bay reefs using Structure-from-Motion photogrammetry, which uses images taken from video footage of the coral reef. The software identifies a specific point from multiple angles in several images at a time, to identify where the point lies in 3D space. The software identifies thousands of points in this manner and creates what is called a sparse point cloud, followed by a dense point cloud, and then a triangulated mesh is textured to create the model.

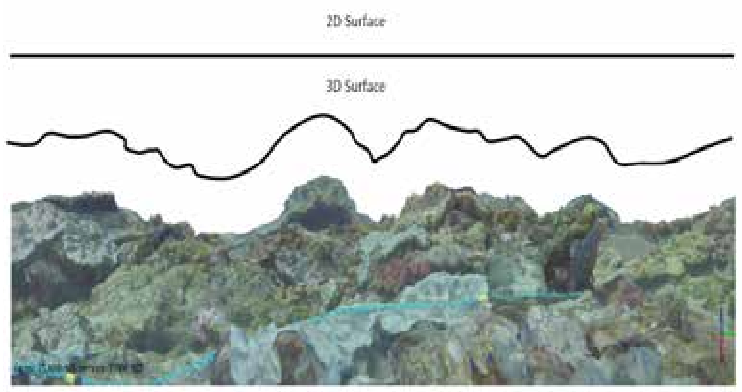
The process of creating a model using Structure-from-Motion software.



We tested the utility of these models through a series of analyses that determine how accurately and efficiently it can measure basic characteristics of the reef community such as coral cover. We further evaluated how photogrammetry may contribute to monitoring through 3D topographic metrics such as rugosity. Rugosity is the ratio between the 2D and 3D surface area of the reef and tells us how complex the structure in that area is. We used the digital elevation models derived from the 3D models, which gives us depth information, to measure the 2D and 3D area of the reefs and calculate rugosity.

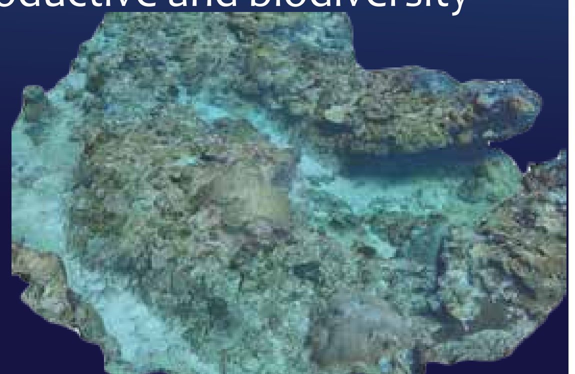


The digital elevation model that shows depth information.



The side view of a reef, indicating the difference in 2D and 3D surface area.

Creating these 3D models allows us to monitor large areas of reef and provide measurements of ecologically important parameters like topographic complexity. It can be used to further study the relationship between the structure of corals and the topographic complexity of the reef to aid in habitat mapping and analysis and monitoring recovery after disturbances. We hope to use these models as a visual tool for education for anyone who can't experience these amazing ecosystems first hand by using virtual swim-throughs over the reef in 3D space or virtual reality dives (see the swim through video). Additionally, the collection of video footage is a simple task that provides an opportunity for citizen science and public involvement in the monitoring of these productive and biodiversity rich ecosystems.



Peering into the dark
by
Dr Dave Pearton

The diving at Sodwana Bay is justly regarded as some of the best in the world, but it also ranks as some of the most challenging, with "exciting" beach launches through the waves that raise the adrenaline of tourists more used to calm tropical lagoons. This is doubly the case when the sun sets and a diver's world is reduced to the small beam of light from a torch with the knowledge that things (potentially with sharp teeth) wait, unseen, in the darkness. This, and the variable weather, makes it difficult to study phenomena that occur exclusively at night, such as the annual mass coral spawning taking place each summer.

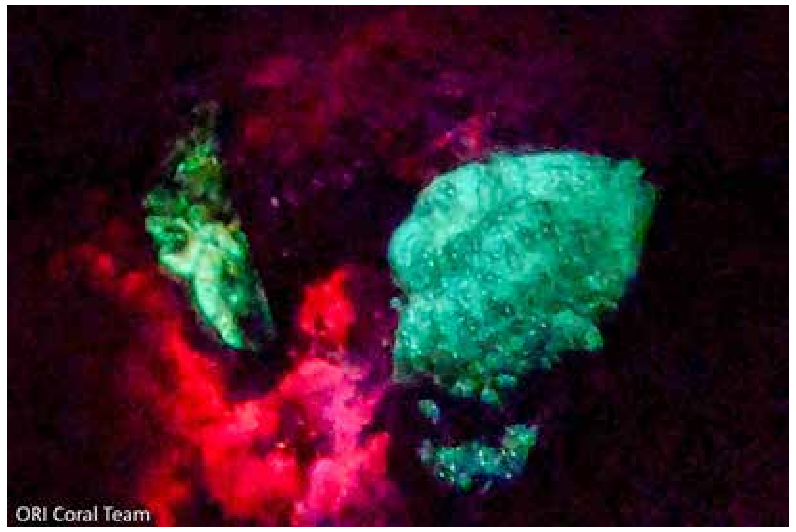
Sodwana Bay corals – colonies like this all spawn on a single night of the year simultaneously all over the reef. When they do and how they co-ordinate it is still unknown.

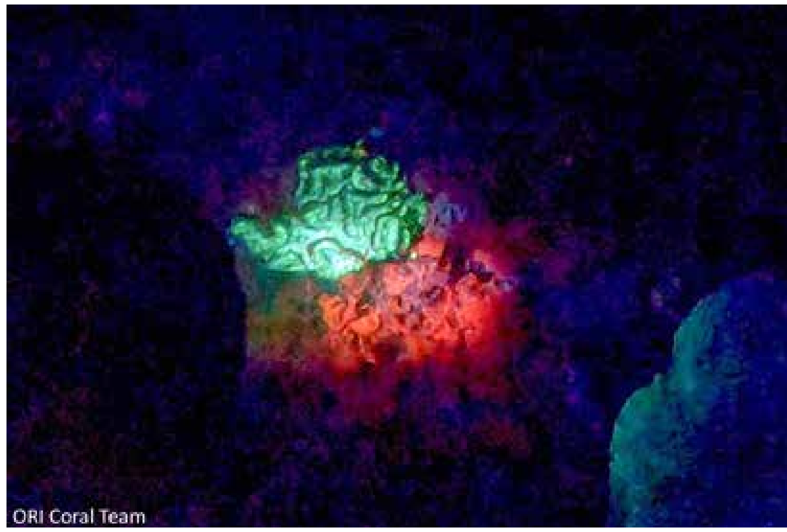
ORI scientists and students, led by Dr David Pearton and Dr Michael Schleyer, travelled to Sodwana after the full moon in February as part of a research project to learn more about this critical process. The annual spawning ensures that new coral recruits are available to maintain the health and resilience of the reefs, both in Sodwana as well as, potentially, all along the KZN coast. The weather this season, unfortunately, put paid to any night dives that would allow direct observation of spawning activity. Fortunately, there are indirect ways of looking at these phenomena. Improvements in gene sequencing technology have opened up new methods of determining the identity and timing of which species are spawning by looking for the microscopic eggs and larvae hidden in the plankton above the reef using genetic metabarcoding. To do this, plankton tows were conducted each morning and these will subsequently genetically sequenced en masse, and powerful computer algorithms and databases will enable us to detect and identify the few coral larvae present in the tens of thousands of other organisms that make up the plankton.

During the trip the ORI scientists were also able to work on several other projects, including conducting the annual monitoring of corals at Nine Mile Reef. This is one of the longest continuous coral reef monitoring projects of its kind in the world and has contributed immensely to our knowledge of reef dynamics and the threats they face. They were also able to service a whole suite of instruments including temperature recorders and Acoustic Doppler Current Profilers (ADCPs) as part of the CAPTOR programme. These instruments give a detailed picture of the currents over the reefs which is essential in order to be able to model and predict where the various larvae from corals, fish and other organisms will be distributed. This is vital information to assist in the design and management of our MPAs.

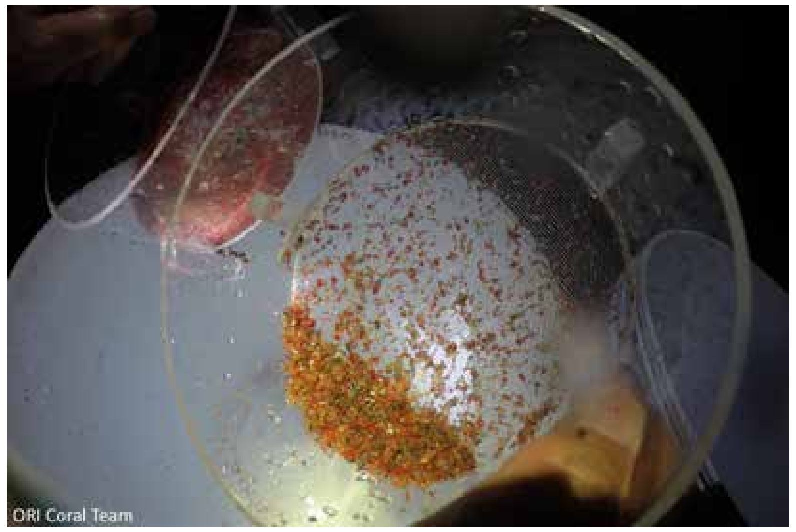
We can tell when corals are ready to spawn when we can find their brightly coloured eggs in their tissues.

The corals all spawn at night so this is the only time we can "catch them in the act". One of the most striking this about corals at night it how they will glow in the dark (fluoresce) when illuminated with blue or UV light.





Unfortunately we are often not able to dive on the reefs at night due to adverse conditions, but the corals in the tidal rockpools also spawn around this time. The best way to see them is to look for their fluorescence.



The coral eggs and sperm are released into the water where they float up to the sea surface. Once fertilized the eggs become larvae which will swim around in the plankton until they are ready to settle in a new home. By studying the plankton using advanced genetic techniques we can distinguish the tiny coral spawn from the myriad of other organisms from copepods to jellies found in the plankton.

During the day there is plenty of other work to do such as monitoring the state of the reef.

It's all in the genes: using coral genetics to assess population structure and connectivity between KZN's MPAs
by
Jessica Gilmore and Dr Dave Pearton

Corals reefs constitute a very small percentage of ocean habitat but play a disproportionately large role by providing important refuge, nursery and feeding grounds for up to 25% of marine species. They are also under huge pressure from numerous threats including climate change, pollution and overfishing. Marine Protected Areas (MPAs) are critical tools in helping to protect these vulnerable ecosystems.

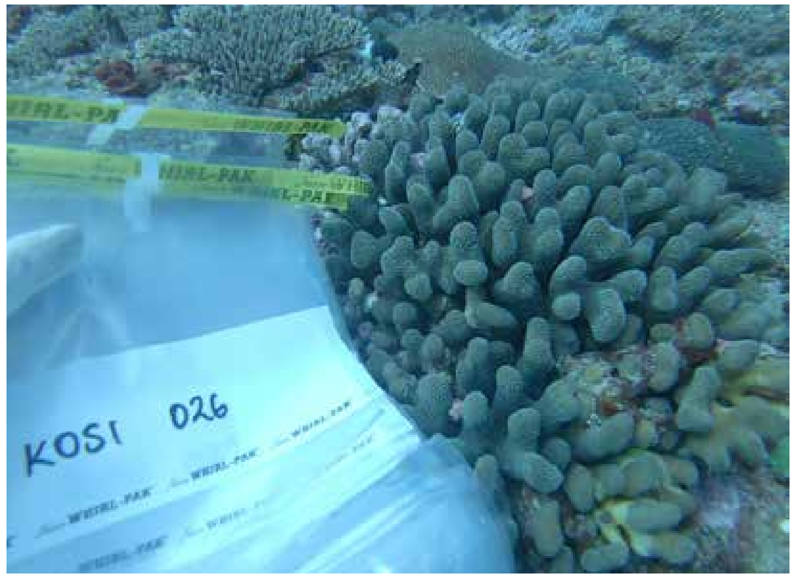
One of the most important criteria for the success of MPAs are whether they provide sufficient protection for a variety of ecosystem while maintaining population connectivity. One way to ensure this is to design MPA networks of interconnected areas that are more resilient than the single MPAs would be on their own.

The Connectivity And disPersal beTween prOtected aReas (CAPTOR) project funded by the National Research Foundation (NRF-DST) and ACEP (African Coelacanth Ecosystem Programme) seeks to determine whether the network of new and existing MPAs along KZN and Eastern Cape coast fulfils this criterion. For this component of the larger CAPTOR programme we are looking at whether the current MPA network in KZN does this effectively for critical habitat forming benthic species.

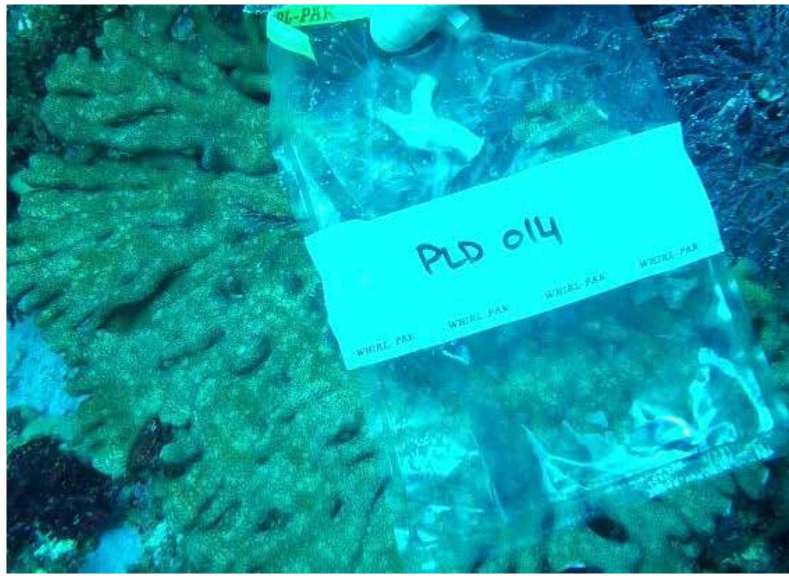
In this case we are studying a hard coral (*Stylophora pistillata*) and a soft coral (*Sinularia brassica*) which were known to be present in all of our sample locations. Samples have been collected using SCUBA and Remotely Operated Vehicles (ROVs) at three MPAs (iSimangaliso Wetland Park, Aliwal Shoal and Pondoland) as well as representative reefs located in the "gaps" between MPAs. We have used modern genetic methods, including some cutting edge genetic sequencing techniques, to look at how populations of corals in these different areas are related to each other and whether coral larvae can move between areas. This study has revealed a fascinatingly complex picture where populations that are physically close to each other are not necessarily the most related and where coral larvae can move over 300 km from the warm subtropical iSimangalio Wetland Park to the much cooler Aliwal Shoal MPA.

ROV on RV Phakisa

S. pistillata - Kosi Bay



S. pistillata – Pondoland



S. brassica, Leadsman Reef, iSimangaliso Wetland Park

Sampling image of Jessica Gilmore and Mike Schleyer, Leadsman Reef, iSimangaliso Wetland Park