#RCUK2022

Reef Conservation UK

Saturday 3rd December 2022

Zoological Society of London

Book of abstracts

Plenary I

Dr Gareth Williams

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Gareth Williams is a marine ecologist specialising in coral reef ecology. His work focuses on the interaction of organisms with their environment, often taking a macroecological approach. He is particularly interested in how human activities and natural biophysical gradients interact to drive community patterns across multiple trophic levels (from microbes to sharks) and scales (from individual reefs to entire ocean basins). Much of his work incorporates remote coral reefs free from direct human impact, providing key replication at the unimpacted end of an intact-to-degraded ecosystem spectrum. By surveying across extensive geographical areas, his research group addresses broad questions pertaining to the human, climatic and oceanographic drivers of coral reef ecosystem structure and function.

Coral reefs, the moon, and underwater obstacles

All water in the ocean is connected and moving. Depth gradients around islands affect, amplify and dissipate these surface and sub-surface currents and waves, which can originate locally or from 1000's of km away and drive ecosystem patterns and processes. Disentangling local and regional physical drivers of coral reef community structure has proved challenging. Interactions between reef communities and the surrounding ocean are complex and confounded by human activities. Despite coral reef ecologists and oceanographers working hard to understand their respective fields over the last several decades, the two disciplines are historically siloed. Here I will discuss the advances we have made in understanding coral reef community dynamics by throwing some oceanography into the mix and extending the concept of ‘biological oceanography’ to ‘ecological oceanography’. This approach has revealed fascinating connections across scales between coral polyps, reef seascapes, major ocean currents, and our moon.

Plenary II

Dr Pasita Chaijaroen

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Her research interests span environmental, health, and labour issues in Southeast Asia. In her recent works, Pasita explores the socioeconomic impacts of weather variations and coral bleaching in Indonesia as well as the effects of the change in compulsory schooling law on women in Thailand. Pasita obtained her BA in Economics from Chulalongkorn University in Thailand and her PhD in Economics from University of Washington, Seattle. Prior to her relocation back to Thailand, she was an assistant professor of economics at the College of William & Mary.

How does coral bleaching affect people? Evidence from the 1998 coral bleaching in Indonesia

Coral reefs are deeply connected with human livelihoods; reef deterioration can have tremendous effects on coastal communities. This talk will illustrate such effects through evidence from the 1998 coral bleaching in Indonesia. By comparing affected fisheries-dependent households to those not affected, I showed that the affected group experienced a significant decrease in income and reduced their consumption in 2000. While the affected group could eventually mitigate most of the negative effects by 2007, this adaptation took time, and they could not fully offset some of the effects. The economic setbacks from coral bleaching also posed further threats to the other dimensions of the affected group's lives. The affected women were found to increase their fertility, yet their children's development was inferior to the other children's. Specifically, the affected children were more likely to be severely stunted and fail a grade in school. These findings together suggest that the 1998 coral bleaching had long-lasting adverse effects on coastal communities in many dimensions. Comprehensive policy interventions are therefore needed to alleviate these negative effects and facilitate community adaptation.

Session I:
Reefs under the microscope

Talk

A window into biomineralization in giant clams: opportunities and challenges

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Giant clams (Tridacnidae) are iconic reef dwellers that fulfil critical roles in tropical coral reef communities due to their contributions to the structure, complexity and ecology of reefs. They also serve as valuable bioarchives to reconstruct past oceanographic conditions in tropical regions where instrumental records are lacking. However, a broad understanding of this important reef calcifier and the physiological and environmental controls on shell biomineralization is lacking and understudied relative to other calcifiers (e.g. hard corals). Here, we present an overview of our work on the architecture of Tridacna squamosa giant clam shells collected from a gradient of turbidity in the Coral Triangle to gain insight into processes controlling shell formation that may inform us on biomineralization under changing oceanic conditions. We use a suite of novel imaging techniques (petrography, scanning electron microscopy (SEM), electron backscatter diffraction (EBSD) and X-ray diffraction (XRD)) to record fine-scale intra- and inter site differences in daily growth rate, microstructure and crystallographic habits on a micro- to angstrom scale. Results hint at distinct biomineral formation mechanisms for specific layers within the shell that likely reflect differences in biologically mediated mineralization processes and external forcings by the ambient environment. We frame these findings by conceptualizing different models of biomineralization pathways between different parts of the shell and compare to other reef calcifiers, focusing on corals. Our work suggests that Tridacna squamosa is a resilient calcifier under changing oceanographic conditions due to its dynamic behaviour and looking to the future, stressors related to overexploitation need to be a priority management of this important reef calcifier.

Building ‘Genomic Seascapes’ to enable effective marine conservation

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Illegal, unregulated and unreported (IUU) fisheries have decimated marine populations around the globe, including several marine protected areas. In ecological consequences, apex predators such as sharks have been one of the most impacted taxa, leading to severe distress in marine ecosystems, from effects of trophic downgrading. In socioeconomic consequences, developing countries have suffered massive economic losses due to rampant distant water and illegal fishing activities. Key barriers to effective conservation and management of ecosystems include: 1. Data deficiencies leading to a lack of population benchmarks in assessing baseline health, and impact of fisheries on species stability. 2.Limited surveillance capacity in our oceans enabling illegal fisheries to disproportionately impact species populations. 3. Lack of capacity among vulnerable nations to benchmark and protect marine species populations in their EEZs from illegal fisheries and thus maintain healthy ecosystems and associated ecosystem services. The current revolution in genomics has provided us with a rare opportunity to develop a novel ocean exploration and surveillance toolkit, to address the knowledge gaps described above and to build capacity for biodiversity and fisheries monitoring. We present research using three genome sequencing platforms to create a “Genomic Seascape”, which will track diversity and stability of shark populations and illegal fisheries in the Indian and Pacific Oceans (IO and PO). We discuss species identification and distribution assessments in IO and PO, 2.) building a robust framework for benchmarking population structure, stability and connectivity of reef shark populations and for tracking illegal fisheries in the IO, and 3.) building genomics capacity for robust monitoring of biodiversity and fisheries in developing nations of IO and PO to enable sustainable and effective conservation outcomes through equity and inclusion marine conservation.

Smart Grains: a novel Artificial Intelligence approach for sediments classification in turbid vs. clear-water reefs

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Turbid-water environments have been recognised as potential refugia for corals, with the ability to provide long-term mitigation from unfavourable conditions. Reef sites with varying turbidity, Blue Lagoon (clear-water), Triangle (intermediate turbidity), and Sakar (turbid-water) in Darvel Bay, Malaysia, have been analysed for differences in their carbonate grain composition in samples collected at 10 m depth. An artificial intelligence program was trained and utilised to segment and classify grains in the size range 0.5 mm to 1.4 mm in different environmental settings. Over 1650 microscope images containing nearly 25,000 grains have been classified to establish the proportion of carbonate grains, in addition to the relative abundance of bryozoans, calcareous coralline algae (CCA), corals, echinoderms, foraminifera, and molluscs. Preliminary analyses of 7,763 grains from the two contrasting sites (clear-water Blue Lagoon vs. turbid-water Sakar) show that the clear-water reef sediments were dominated by the autotrophs, CCA (38.35 %) and symbiont-bearing foraminifera (30.64 %), whereas heterotrophs such as molluscs were the dominant constituent of turbid-water reef sediments of Sakar, accounting for 46.76 %. The segmentation task proved more successful than the classification task, which has lower accuracy and performance. Different sediment size fractions were tested in Blue Lagoon samples. There were no significant differences in composition, though there was a trend of higher abundance of foraminifera in the fraction 1.0 mm - 1.4 mm, whereas molluscs were more abundant in the 0.5 mm - 1.0 mm fraction. Further training of the AI with a larger set of samples from a mosaic of reef sites in the Coral Triangle region such as Semporna Reefs and the Spermonde Archipelago will allow better accuracy, precision and a wider application of this tool.

Effects of nutrient and temperature stress on the coral microbiome

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Shallow-water coral reef ecosystems are facing a global decline as a result of climate change, pollution, overfishing and habitat destruction. Heat stress and deteriorating water quality have been identified as major causes of coral bleaching, disease and subsequent mass mortality in reef-building scleractinian corals. Reef-building corals are described as a holobiont, comprising the host cnidaria, endosymbiotic dinoflagellates and a highly diverse and abundant community of bacteria, archaea and fungi known as the coral microbiome - living on and within the coral skeleton, tissue and mucus. Whilst intense research effort has focused on the symbiosis between host and dinoflagellates, the exact function of the coral microbiome in the coral holobiont is less understood. Furthermore, it is unclear how environmental parameters shape the structure of the coral microbiome. We have used physiological monitoring and metabarcoding of the 16S rRNA gene to investigate the effects of environmental stress on reef-building corals and their microbial communities, within a closed experimental mesocosm. Our work examines the influence that a combination of nutrient limitation and increased water temperature exerts on the functioning of the coral holobiont and contributes critical knowledge to the understanding of microbial population dynamics in corals. Investigating how environmental stressors shape the coral microbial community, especially when associated with incidences of coral diseases and bleaching, will help determine the effects of nutrient and temperature stress on coral reef ecosystems under a changing climate.

Fine-scale temporal variation in coral reef community composition detected by environmental DNA

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The use of molecular methods in ecology and conservation has exploded in recent decades, with environmental DNA (eDNA) becoming a recognised technique to assess biodiversity in diverse ecosystems. However, significant gaps in our knowledge remain regarding how eDNA exists and persists in the environment that influence our interpretation and the conclusions we can draw from these data. The turnover of detectable eDNA is influenced by DNA release, transport and persistence and a wide range of detection times have been reported. The possibility that the time of sampling may impact detected community has not been widely investigated in marine systems. Here, we test the ability of eDNA metabarcoding methods to detect changes in marine eukaryotic communities over a fine temporal scale at two lagoonal sites in the Chagos Archipelago, Western Indian Ocean. Communities were significantly different between sites and time of sampling, indicating that eDNA sampling provides only a snapshot of communities. The abundance of Copepoda reads increased significantly between 7pm and 1am. Phytoplanktonic Dinoflagelatta reads peaked at 1pm and significantly decreased overnight. These changes match expected community shifts due to the diurnal vertical migration of zooplankton to depth avoid predation during the day and therefore increased predation of phytoplankton in the surface layer at night. This highlights potential bias introduced by inconsistent sampling times and the importance of considering target organism ecologies when designing sampling strategies in marine environments.

Poster

Foraminifera as carbonate sediment producers and bioindicators of coral reef habitat variations over time and space

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The production of carbonate sediments by coral reef organisms is an essential driver of tropical beach and island formation and maintenance. Low-lying islands especially rely on rates and types of biological sand supply. The ongoing degradation of coral reef ecosystems may however diminish this important geo-ecological function. Benthic foraminiferal shells ('tests') are abundant components of many reef sediments and can locally contribute significantly to reef carbonate sediment production. They also serve as sensitive bioindicators that allow us to reconstruct past and recent environmental conditions, assess ecosystem 'health' status or recovery potential. Here we examine spatial and temporal patterns in benthic foraminifera communities across the Chagos Archipelago, Indian Ocean, to a) quantify their contribution to sedimentary carbonate production states across reef zones and islands of three atolls, and b) to detect temporal and spatial variations potentially related to changes of the benthic community or local inputs of seabird-derived nutrient subsidies. Initial results reveal large variability of foraminiferal carbonate production across depths, but indicate greater contribution to reef sediments on outer reef slopes compared to lagoons. Furthermore, foraminiferal productivity appears to be slightly higher around islands with large seabird populations, possibly due to guano-derived nutrient runoff or linked to higher microhabitat and substrate availability within the local reefs (e.g. more calcareous algae). Comparison of contemporary foraminiferal assemblages at Peros Banhos atoll to data collected in 1979 reveals long-term community shifts from species common in coral-dominated habitats (e.g., *Amphistegina* spp.) to those indicating more algae-dominated realms (e.g., *Neorotalia* spp.), likely reflecting changes in benthic communities following two major coral bleaching events. Yet, application of the FoRAM Index, a bioindicator metric for water quality derived from the foraminifera community, suggests that the absence of local human pressures in this marine protected area ensures favourable conditions for reef calcification and high post-disturbance recovery potential.

Novel estimates of endolithic bioerosion from remote reefs in the Central Indian Ocean

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Bioerosion of calcium carbonate is a fundamental process that impacts reef accretion, and structural complexity. Previous work has shown that bioerosion rates on reefs are dependent upon local factors and are spatially variable. Besides grazing fish and sea urchins, organisms that bore into the reef substrate, known as endoliths, such as sponges, worms and molluscs play a large role in carbonate removal in some regions. Similarly, unicellular algae and fungi penetrate dead reef substrate and can result in bioerosion rates of comparable magnitude. Here we provide the first rate data for both macro- and micro-endolithic bioerosion in the remote Chagos Archipelago, Indian Ocean. We deployed experimental Porites blocks in 5 and 10 m depth for one or three years and quantified bioerosion rates, as well as the contribution by different bioeroders. Macrobioerosion was quantified using computer tomography, and microbioerosion was analysed using scanning electron microscopy. Macrobioerosion rates after three years of exposure were higher at 5 m (0.086 ± 0.026 kg m^{-2} yr^{-1}), than 10 m depth (0.066 ± 0.016 kg m^{-2} yr^{-1}). Worms were important bioeroders at both depths after one year, while sponges and molluscs became dominant after three years. Conversely, microbioerosion rates were higher at 10 m (0.313 ± 0.049 kg m^{-2} yr^{-1}) than at 5 m depth (0.187 ± 0.028 kg m^{-2} yr^{-1}),with the main trace types at both depths being caused by the cyanobacteria *Mastigocoleus testarum* and *Plectonema terebrans*. These data provide an insight into how different endolithic processes interact to influence overall reef carbonate budgets, and how these may vary with depth. Further study is needed to identify the environmental drivers of bioerosion in the region, so that spatial variability can be better understood and to improve estimates of local carbonate budgets.

Session II:
Reef ecology and behaviour

Coral reef connectivity across the southwestern Indian Ocean

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Coral larvae can be transported over great distances by ocean currents, establishing ecological and genetic connectivity between distant coral reefs. Understanding these patterns of connectivity and how they vary through time is essential for effective marine spatial planning, particularly in the southwestern Indian Ocean, which is an under-studied region. Here, we present results from a high-resolution (2km), multidecadal ocean simulation spanning almost all shallow-water coral reefs across the southwestern Indian Ocean, coupled with a larval dispersal model incorporating species-specific competency, mortality, and recruitment. These results are being made fully available, and can be adjusted for different biological parameters. We demonstrate that coral reef connectivity in this region is enormously variable over timescales ranging from daily to interannual, and discuss how coral spawning times correspond to connectivity seasonality. We also describe the role particular coral reef sites may play in maintaining local and regional reef resilience across the southwestern Indian Ocean through the use of network theory, and introduce a new online platform which we hope will be useful for communicating ecological connectivity data to policymakers and the public.

Benthic functional diversity in deep-sea coral reefs across a habitat complexity gradient in the Rockall Bank, NE Atlantic

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There is a growing need for ecological indicators, such as measures of functional diversity (FD), to inform marine ecological understanding and policy. Although baseline studies provide valuable biodiversity information, there is a need to understand the nuance of functional services provided by resident benthic fauna within an ecosystem. The use of functional indices is essential to understanding the relationships between benthic ecosystem functioning and community resilience, anthropogenic impacts and changing oceanic conditions. This study aimed to address knowledge gaps in benthic FD and use FD indices to better understand benthic macrofaunal community assemblages associated with *Desmophyllum pertusum* cold-water coral reefs in the Logachev Mound Province, of the Rockall Bank (UK). Habitat complexity gradient (coral framework L m2) was defined across four biotopes: coral rubble, low coral framework, dead coral framework and live coral framework, from boxcore samples collected from two-cross mound transects from the Haas Mound, to draw comparisons between habitat to heterogeneity and FD of benthic assemblages. FD was assessed through functional trait analysis (FTA), using a selection of functional traits assigned to taxa families to calculate FD indices. FD indices were significance tested and PERMANOVAs were performed on trait data. Pearson's rank correlation was conducted to verify the relationships between FD and habitat heterogeneity. The study hypothesis that FD indices positively corresponds to increased habitat complexity, was accepted. The findings highlight the usefulness of using trait-based approaches as a tool for assessing ecosystem functioning and enhance our understanding of ecosystem resilience and services in deep-sea coral habitats. More baseline data regarding keystone benthic species is required, to give a more comprehensive understanding of the effect of functional diversity. This will aid in the development of specific and effective management strategies.

Don't listen to your elders - ecological trap following habitat loss in a coral-associated reef fish

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Habitat loss governs the distribution of species on a coral reef by altering the availability of resources. Many threats facing coral reefs have a species bias, resulting in a mosaic of dead and live corals, however species responses to patchy disturbances remains poorly understood. Here we investigate how an ongoing outbreak of the crown-of-thorns starfish affect the distribution of a common coral-associated reef fish, the lemon damsel, *Pomacentrus moluccensis*. We found that densities of adult *P. moluccensis* on remnant live corals increased with the proportion dead coral in the surrounding area, leading to crowding on severely degraded reefs. In areas where less than 50% of coral colonies were alive, adults started associating with dead coral colonies to a greater extent. We hypothesise this may be due to density dependent habitat selection, where some individuals relocate to less crowded dead coral colonies. Indeed, when presented with the choice of two colonies in a choice experiment, fish were more likely to choose a near empty alternate colony when the other colony was severely crowded with conspecifics. While this habitat choice may not have direct fitness consequences to a large adult, here we demonstrate that it creates an ecological trap for juvenile fish. Juvenile *P. moluccensis* use the cue of conspecific adult presence to determine recruitment habitat, a historically reliable indicator of habitat quality, and select dead corals to a greater extent than on healthier reefs. This suggests that the cue of a conspecific is a greater attractant than the cue of live coral itself. This poor choice likely contributed to a 54% decline in *P. moluccensis* 12 months later. This is a first demonstration of an ecological trap on coral reefs, and adds to the growing body of work outlining how reef fish communities are affected by disturbances.

Functional impact and trophic morphology of small, sand-sifting fishes on coral reefs

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Oligotrophic tropical coral reefs are built on efficient internal energy and nutrient cycling, facilitated by tight trophic interactions. In the competition for available prey, some small fishes have evolved to feed on apparently barren sand patches which are prominent in many reef habitats. One strategy for obtaining prey from a particulate matrix is to sift out small prey items from the sediment (often called 'winnowing'). Yet, the trophic link between small winnowing consumers and their prey are poorly resolved, let alone the morphological specialisations that enable this foraging behaviour. We used aquarium-based feeding experiments to quantify the impact of winnowing by two goby species (*Valenciennea sexguttata* and *V. strigata*) on meiobenthos abundance and diversity, and confirmed ingestion of meiobenthos using gut content analysis. To identify potential morphological structures involved in winnowing, we investigated the gobies' feeding apparatus with electron microscopy (SEM) and µ-computed tomography (µ-CT). After four days of sifting through the sand matrix, the two species significantly reduced meiobenthic prey abundance by 30.7 % ± 9.2 SE (*V. sexguttata*) and 46.1 % ± 5.1 SE (*V. strigata*). The reduction in the most abundant prey groups (copepods and annelids), suggest selection by size, shape and density of prey items. Furthermore, gut content analysis confirmed that winnowing gobies can efficiently separate meiobenthic prey from heavier inorganic particles (sand), likely facilitated by a specialised epibranchial lobe, pharyngeal jaws and highly abundant papillose taste buds in the oropharyngeal cavity. Our results provide important background on the trophic link between meiobenthos and winnowing gobies on coral reefs. The revealed specialisations of the goby feeding apparatus facilitate sand-sifting foraging behaviour and access to microscopic prey and an otherwise inaccessible trophic niche. By obtaining nutritious and highly abundant prey from seemingly barren sand, we suggest that winnowing gobies act as an important conduit for sand-derived energy to higher trophic levels.

Assembly rules of coral reef fish communities along the depth gradient

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Coral reefs are home to some of the most studied ecological assemblages on the planet. However, differences in large-scale assembly rules between shallow and deeper (mesophotic) reefs have not been studied using empirical quantitative data and both taxonomic and functional diversity measures. Consequently, little is known about the small- and regional-scale effects of depth on coral reef assemblages. Using a large pan-oceanic dataset of underwater surveys, we found that the influence of classic biogeographic drivers on the species richness of coral reef fishes changes significantly with depth, shaping distinct assembly rules for mesophotic coral ecosystems. We show that a general pattern of decreased species and functional richness of reef fish assemblages with depth results from convergent filtering of taxonomic composition and trophic strategies on deeper reefs across ocean basins, and that small-scale deep-reef communities are less influenced by regional factors than shallower reefs.

Redrawing the lines of battle in coral reef fish communities

Sally Keith[1]

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Coexistence of competing species in ecological communities is made possible by co-evolved 'rules of engagement'. During competition, these rules enable contest resolution through avoidance or signals, without the need to escalate to direct attacks, which prevents unnecessary energy loss for both individuals. However, rapid environmental change can disrupt established competitor hierarchies as the effect of resource loss differs between species, and can even create completely new species combinations through the formation of novel ecosystems. In these scenarios, the lines of battle need to be redrawn or, in the worst case, established from scratch. Reef fish communities are restructuring globally as species alter behaviour, shift geographic distributions or die. Resolving how, when and why decisions of whether to fight can tip the energetic balance of individuals and populations towards lethal outcomes, and how it could scale up to restructure communities and ecosystems, is necessary to provide realistic predictions on future impacts of global environmental change. Tests of theory underlying animal behaviour are often confined to the laboratory or conducted in the field at a single geographical location. Lab-based approaches allow for the resolution of clear mechanistic links but are constrained in their extrapolation to real-world systems where behaviour operates under complex abiotic and biotic environmental conditions. Field studies in single locations allow deep understanding, yet it is difficult to know if their conclusions are generalisable across broad spatial extents or specific to that location. These traditional approaches to understanding animal behaviour can be strongly complemented by harnessing a macroecological approach to reveal if, when and how behavioural theory holds regardless of differences in location, environmental conditions and biogeographic history. Here, I show examples of how we are harnessing this approach to understand changing 'rules of engagement' in reef fishes and their implications for coexistence in response to coral bleaching, habitat degradation, overfishing and invasive species.

Classification and comparison of species interactions under varying environmental conditions within coral reef communities

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Species interactions play a key role in community structure and ecosystem function. For example, plant-pollinator interactions underpin ecosystem services. Additionally, interactions among herbivores and plants determine ecosystem structure. However, how interaction within communities differ under contrasting environmental conditions is unknown. Here, we compare interspecific and intraspecific species interactions and co-occurrence networks in coral communities with varying coral cover on high latitude (warm temperate, Kochi) and low latitude (sub-tropical, Okinawa) reefs in Japan. We characterise species interactions for fishes and their habitat-building benthic organisms based on video surveys among varying coral cover sites, with minimal human interference. We find that the lower latitude and high coral cover sites have more interspecific interactions, suggesting that more resources in low latitudes support a higher diversity and thus increase the chance of interactions. We also observe that degraded sites have higher counts of conflict, perhaps due to resource limitations. We further note increased counts of herbivory in low latitudes, classified as conflict, relative to high latitude reefs due to a larger abundance of turf. This study provides new insights into species interactions on coral reefs, and the potential impact of habitat stressors on these interactions. This research aids in our understanding of the wider implications of increased stress on coral reef communities and their interactions.

The role of echinoids in turbid reefs of the Coral Triangle (SE Asia)

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Turbid reefs have been proposed as refugia due to their reduced vulnerability to bleaching events. Establishing the role of important reef species in turbid waters will aid our understanding of reef survival in future. Echinoids within the family Diadematidae are common reef dwellers known to play different roles, including mitigating space competition through grazing of macroalgae, and eroding the reef substrate, increasing topographic complexity and promoting coral recruitment. Following their death, their calcareous tests break apart and erode to become part of the sediment substrate. We investigated populations of echinoids in turbid reefs in Darvel Bay, Malaysia, to assess which factors influence their distribution, as well as their contribution on bioerosion rates and as part of the sediment composition. Echinoid populations differed significantly across sites, with fewest at the most (1.5 individuals m^{-2}) and least (0.37 ind m^{-2}) turbid reefs, and medium turbidity reefs having the most (10-13 ind m^{-2}) at a depth of 5 m. Bioerosion was sufficiently low at all sites to not be having a destructive impact on the reef, 0.78 kg $CaCO_3$ m^{-2} $year^{-1}$ on average. Echinoid abundance and proportion of echinoid material in the sediment positively correlated, indicating that echinoid populations have remained stable over time, which we confirmed using historical data from the region. The lack of relationship between turbidity and echinoid abundance indicates that echinoids can thrive in the mosaic of clear and turbid reefs in Darvel Bay, so shall be an important factor in maintaining reef health and growth in the region.

Between the Cracks: uncovering patterns of cryptic biodiversity in South African reefs and benthos using ARMS and metabarcoding

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The East Coast of South Africa is a remarkably biodiverse region and comprises a number of distinct biogeographic regions along a unique latitudinal and climate gradient. They are thus uniquely positioned to serve as sensitive models for the potential effects of climate change on a larger scale. In order to detect these potential changes a detailed and comprehensive knowledge of baseline biodiversity is required. We used a combination of standardised sampling techniques such as Automated Reef Monitoring Structures (ARMS), benthic grabs and plankton nets to study cryptobiota associated with coastal reefs and their surrounding habitats. These little studied organisms are are a critical, but poorly understood, component of functional biodiversity and ecosystem productivity.

ARMS were deployed on coral and rocky reefs along a biogeographical gradient along the coast of Kwazulu-Natal on the east coast of South Africa. After a prolonged soak they were retrieved and processed for traditional taxonomy and barcoding (for the larger samples) and metabarcoding for microscale organisms. In parallel, soft benthos was sampled using grabs and reef associated plankton via plankton nets. Visual assessment of the ARMS and benthic macrofauna revealed a wide variety of organisms from a diverse range of phyla, including a number that appear to be new species. Metabarcoding of the samples using short COI and 16S barcodes shows a truly astounding level of biodiversity in these samples covering numerous phyla and families. Many of the sequences are not represented in current databases, showing that we have barely scratched the surface of the biodiversity present in these ecosystems. We are currently using long range sequencing to generate longer and more informative barcodes to improve the phylogenetic resolution as well as sequencing as many identified organisms as possible to improve the databases.

The effects of dead-in-place *Pocillopora* corals on coral reef community structure

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Coral bleaching events are increasing in frequency and intensity, resulting in high coral mortality and leaving colonies dead in their growth position. Detached dead colonies can propagate damage and create patches of bare space suitable for settlement, while dead-in-place colonies provide refuges for encrusting algae and invertebrates. In Moorea, French Polynesia, live *Pocillopora* spp. covered 69% of the forereef (10 m depth) in early 2019, but bleaching that year reduced coral cover to 13%, leaving many dead-in-place colonies; these were rapidly colonized by the alga, *Lobophora veriegata*, which can inhibit coral recruitment. This study assessed: (a) the role of dislodgement of dead colonies in creating vacant patches suitable for coral recruitment, and (b) the effects of the colonization of dead *Pocillopora* by *Lobophora* on the diversity and abundance of invertebrates associated with the coral skeleton. Corals at 10 m depth were sampled 37 months after the bleaching event, and the abundance of motile invertebrates was compared between live and dead *Pocillopora* colonies, with photography used to quantify *Lobophora* on dead corals and colony dislodgement. Motile invertebrates were five times more abundant, and represented by twice as many taxa, in dead corals covered with *Lobophora* than in live corals, with the most common invertebrates being amphipods. During three months of the Austral winter, since corals were first tagged, *Lobophora* cover increased on dead corals, but none of the tagged colonies were dislodged. Together these results suggest that dead-in-place *Pocillopora* encrusted with algae can suppress colony dislodgement but augment the abundance and taxonomic richness of mobile invertebrates compared to live colonies. While dead corals provide structure and habitat for a variety of invertebrates, the colonization of their surfaces by encrusting algae might impede the reef recovery if it modulates colony dislodgement and the creation of vacant benthic space suitable for coral recruitment.

Avoiding the enemy: farming damselfish create landscape of risk

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Consumption of algae by herbivorous fishes is critical in maintaining coral reef function and preventing phase-shifts from reef-building organisms to macroalgal-dominated states. Existing understanding of when this is compromised hinges around abundance of herbivores on the reef. However, this idea assumes that fish use all areas of the reef equally and therefore fails to consider the importance of movement behaviour. Territorial behaviour of farming damselfish is known to affect the abundance, foraging rates and diet of roaming herbivorous fish, yet their effect on fine-scale space use is unknown. If damsels create 'no-go' zones because other herbivores choose to avoid their aggressive forays, this could impact the ability of fish to control macroalgal overgrowth on the reef with ecosystem scale consequences. Landscapes of risk are a useful way to understand how the distribution of one species can affect that of others, and is often used to predict and explain changes in the behaviour and habitat use of prey in response to predation risk. We adapted this framework to test the extent to which territorial farming damselfish (*Stegastes* spp.) aggression can alter how other herbivorous fishes use the reef. We used static camera with mobile stereo-video systems to map multiple landscape types including physical, threat and response. We plotted the distributions of farming damsels and other herbivores, and tested whether other fish maintained greater distances from damselfish territories than would be expected by chance by comparison of observed distributions with those that were randomly generated. We anticipate that results will indicate the potential importance of the role for aggressive behaviour in mediating coral reef resilience into the future.

Influence of upwelling on coral reef benthic communities: a systematic review and meta-analysis

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Highly competitive coral reef benthic communities are acutely sensitive to changes in environmental parameters. Physical oceanographic processes that induce upwelling alter temperature and water column nutrient concentrations, and therefore act as drivers of community structure on tropical reefs. Much research has quantified environmental parameters associated with upwelling, and benthic community structure on coral reefs is likewise well studied. In contrast, there remains a lack of understanding surrounding the impacts of upwelling on reef communities. This study employed a systematic review to assess existing literature linking upwelling with reef community structure, and used meta-analysis to quantify the impact of upwelling on the percent cover of coral reef benthic groups. We show that upwelling has context-dependent effects on the cover of hard coral and fleshy macroalgae with effect size and direction varying with depth, ocean basin and, most notably, with proximity to human population centres. Fleshy macroalgae were found to increase by 110% on inhabited reefs yet decrease by 56% on remote reefs in response to upwelling. Hard coral cover was not significantly impacted by upwelling on inhabited reefs but increased by 150% in remote locations. As such, we provide evidence that proximity to human population settlements can be a major predictor of reef response to upwelling. This review highlights the variable impacts of upwelling on coral reef benthic communities, facilitating adaptive and nuanced reef management which considers the influence of changes in environmental parameters on reef assemblages.

Moonlight and darkness regime as proximate cues on coral spawning

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Coral spawning synchrony is vital for ensuring perdurance of coral populations, however, there is still much uncertainty about the environmental cues that trigger spawning to happen on a particular night, usually shortly before or after the full moon. Recent research suggests that night of spawning is influenced by rapid increases in sea surface temperature (SST) and by the increasing darkness period after sunset that takes place after the full moon. However, further empirical tests in controlled conditions are needed to find out whether a period of darkness before moonlight could be a cue for spawning time and synchrony. We conducted a field experiment in Palau to find out whether a darkness period after sunset could alter spawning synchrony of *Acropora hyacinthus*, a common widespread reef building coral. We manipulated the timing and length of darkness period prior the full moon using opaque and transparent lids to cover *A. hyacinthus* colonies for over their split spawning season (March and April), evaluating whether colonies spawned on each night of the experiment or not. We documented differences on colonies spawning time in the prolonged darkness treatments respect to these colonies kept with ambient light conditions, a novel an interesting finding for Acroporids that contrasts with previous research that suggested that spawning is supressed in the absence of moonlight for *Acropora* corals. Our results open new insights about phenological cues of coral reproduction and synchrony and should foster further discussion about the light-darkness interplay and its relevance for preventing breakdowns in coral synchrony.

Juvenile corals adversely affected by rubble bed physical dynamics

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Juvenile coral communities depend on the structural complexity of the consolidated framework upon which they grow, yet this framework is being degraded to rubble by disturbances. In Moorea, French Polynesia, much of the backreef is occupied by rubble of mostly pocilloporid skeletons that modulate coral recruitment. Using this location as a case example, we explored the implications of rubble proliferation for coral community dynamics through surveys and manipulative experiments. In the back reef, juvenile corals (pooled among taxa) were more abundant on pavement and *Porites* bommies than on rubble, but interestingly > 60% of the corals on rubble were *Psammocora* spp., while *Porites* spp. and other taxa were more common on pavement and bommies. To test the hypothesis that *Psammocora* spp. was most abundant on rubble because of fast growth, a 21-day experiment was conducted in which the growth of *Psammocora* spp. and *Porites* spp. was contrasted between treatments in which the effects of rubble and consolidation (i.e., pavement) were compared; the effects of rubble mobility were explored through cages shielding the corals from impact by moving rubble. When caged, both taxa grew equally well on rubble and pavement, however, *Psammocora* grew ~19% slower than *Porites* in both treatments. In uncaged treatments corals grew significantly slower than when caged, for *Psammocora* 37% and Porites 46%, which supports the ongoing concept that mobile rubble are less suitable substrata with respect to the growth of coral colonies that settle on these surfaces. From this study coral survival within rubble beds could not be attributed to fast growth rates, thus indicating that some corals might rely on enhanced reproductive capacity, including high fecundity and more than one mode of reproduction, to become established within physically dynamic habitats. Tropical corals adversely affected by rubble bed physical dynamics

Session III:
Reef conservation

Seascape connectivity modeling reveals potential hotspots of fish-derived nutrient provisioning to restored coral reefs

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Restoring ecological connectivity across coastal seascapes is imperative for ecosystem health, particularly as stressors operating and interacting across the land-sea interface continue to erode habitat quantity and quality. Programs seeking to restore coastal habitats have proliferated globally, yet these initiatives often overlook the opportunity to include connectivity as a spatially explicit, quantitative criterion during their planning processes. We applied a novel spatial graph-theoretic model to estimate likely movement pathways for two key reef fish species , Lutjanus griseus and Haemulon sciurus, known to supply nutrient subsidies from nearshore mangrove and seagrass nurseries to oligotrophic offshore reefs during their ontogenetic migrations. We calculated ecological connectivity estimates for sites considered by a large-scale, multi-million dollar coral restoration program in the degraded coastal seascape of the Florida Keys, USA, highlighting locations where outplanted corals are likely to benefit most from enhanced functional connectivity in the form of nutrient provisioning by the focal reef fishes. Our analyses revealed disparities between fish species with respect to their potential for beneficial interactions with outplanted corals, owing to selective patterns of habitat use across the seascape. These results highlight the need for species-specific estimates of ecological connectivity, even within trophic guilds. Overlaying connectivity model outputs pinpointed locations that may serve as multi-species connectivity hotspots. Connectivity estimates for candidate coral restoration sites were influenced more strongly by habitat composition (which likely influences fish foraging and shelter resources) than by proximity to adjacent mangrove and seagrass habitats (which serve as nurseries), emphasizing the importance of considering seascape composition and configuration in restoration design. Sensitivity analyses revealed that predicted site-specific connectivity contributions were relatively insensitive to fluctuations in species dispersal ability. Our study illustrates the utility of spatial graphs as a data- and resource-efficient technique for quantifying and communicating complex ecological connectivity information in service of spatial planning for coastal restoration.

Heritability of heat tolerance in *Acropora digitifera*

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Coral reefs are facing unprecedented mass bleaching and mortality events due to marine heatwaves and climate change. Individual variation in heat tolerance and heritability of this trait underpin the potential for coral adaptation to future climate conditions. The rate of future coral adaptation will be constrained by the magnitude of narrow-sense heritability of coral heat tolerance (h2, the proportion of phenotypic variance explained by additive genetic variance), which remains largely unresolved for adult colonies. Here, we quantify the h2 of heat tolerance in adult corals of *Acropora digitifera* using a selective breeding trial linked to long-term MARine Heatwave EMulation (MARHEM) assays of parental colonies and their offspring based on bleaching and mortality responses of replicate colony fragments. High and low heat tolerant parental colonies selected with a MARHEM assay in 2018 were selectively bred to produce 22 unique crosses (F1). The resulting offspring were reared in ex situ nurseries for three years, after which fragments of the F1 colonies were exposed to a MARHEM assay. Parent-offspring regressions were used to estimate the overall h2 of heat tolerance, and individual maternal and paternal contributions. Our results indicate a moderate level of heat tolerance heritability (h2: 0.32 ± 0.27) for *A. digitifera*, similar to the h2 of other traits in wild animal populations. Furthermore, there was a stronger maternal contribution (h2: 0.35 ± 0.27) than paternal contribution (h2: 0.16 ± 0.28) to offspring heat tolerance. Such information has practical implications for designing selective breeding programmes that can maximise logistical efficiency and genetic diversity, and to inform future projection models of coral adaptation under climate change.

Going digital: the power of mobile monitoring tools to gather octopus fisheries data and inform reef management in Indonesia

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Indonesia lies at the centre of the Coral Triangle and, with over 19,000 km2 of coral reefs along its coastlines, is home to one of the most biodiverse marine ecosystems anywhere on the planet. However, national usage of marine resources is not well understood and is largely undermanaged in Indonesia due to a dearth of available data. As demand to fish key species, such as octopus, continues to increase, Indonesia's reefs are under extreme pressure and at risk of degradation. Gathering data to monitor ecosystem changes over time is recognised as a crucial component of coral reef conservation. In 2021, NGO Blue Ventures supported the launch of a mobile tool (KoBo Toolbox) to address the data deficiency challenge facing small-scale fisheries in communities in Central Sulawesi, North Sulawesi and East Nusa Tenggara, Indonesia. In collaboration with Blue Ventures' partner organisation Yayasan Pesisir Lestari, partners Yapeka, Tananua Flores and Japesda trained community data collectors on the use of the tool, facilitating a transition from pen and paper collection methods towards agile data systems. Recording valuable octopus fishery data, namely mantle length, sex and total weight landed, using the technology has increased the accuracy and efficiency of data collection due to an integrated validation feature and a reduced number of steps to input new data into the database. The tool can also be used to produce data visualisations, which can be fed back directly to communities so that they can assess the status of their fish stocks. Understanding seasonality in production enables communities to make timely management decisions, such as implementing temporary no-take zones for sections of reef that allow stocks to replenish and the ecosystem to rebound. Digitising data collection empowers communities to take ownership in managing their own coastal resources, optimising both catch and the conservation of their reefs.

Developing a visual guide to support CITES implementation for stony coral (*Scleractinian* spp.,) in the global aquarium trade

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Use and trade of corals has existed for thousands of years as a construction material and for jewellery, but a rapid increase in the trade of live stony coral for the aquarium market led to the listing of all *Scleractinian* spp., under Appendix II of CITES (the Convention on International Trade in Endangered Species) in the mid 1980's. Over 500 taxa have been recorded in trade, almost all of which are wild-sourced (transported in water and recorded by number of pieces) originating from Indonesia and Australia and destined for sale in the United States of America. Exports of maricultured coral (source code ‚ÄòF‚Äô*) have been increasing steadily since 2003, 99% of which has been exported by Indonesia. Identification of corals in trade to species and even genus level can be extremely difficult, except for a few distinguishable taxa. Further, distinguishing maricultured coral from wild-sourced remains an important issue, as corals can be illegally traded (especially "desirable" high-value taxa that are subject to import suspensions, zero quotas or that are difficult to mariculture) or imported under incorrect source codes. In this project, we developed a practical guide to promote the identification of live stony corals in trade by inspectors who are not coral specialists. It was designed to support visual inspection processes currently undertaken in both exporting and importing countries, to verify genera listed on CITES permits or identify unlisted taxa. The guide includes genus pages describing and depicting features to help identify coral genera. These pages feature potential "look-alikes" examples of highly traded species or key information for CITES, for example, coral taxa which require identification to species level (e.g. *Euphyllia* spp). The guide was launched at the CITES 19th Convention of the Parties as an open-access resource for all parties of the convention who trade in live stony coral.

Red-Listing coral species: Progress, methods and preliminary results

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The IUCN's Red List of extinction risk is a well established and globally renown tool to predict the extinction risk of species. Coral species were last assessed in 2008 and found that one third of corals were listed under a threat category (i.e. Vulnerable, Endangered or Critically Endangered). In 2020, the coral specialist group reformed and began revising these assessments, incorporating new sources of data and recognising the increasing pressure on coral reefs from repeated bleaching, local threats and coral disease. As a global panel of scientists, we worked remotely through the pandemic to achieve this, using literature reviews, expert knowledge and global datasets.

There are several criteria under which a species could be assessed, including geographic range, number of mature individuals, quantitative extinction risk and population decline. Most corals were assessed using population decline, but because species level monitoring of corals rarely takes place, historical population decline was inferred from GCRMN data on coral cover change. Future population decline was estimated based on the average year when of annual severe bleaching is expected to occur and ocean acidification based on future aragonite saturation from IPCC predictions. Each species risk was then modified by 8 attributes that could make them more or less vulnerable to extinction, including natural rarity, thermal tolerance and popularity in the aquarium trade.

The analysis for the Indo-Pacific region is ongoing, but Caribbean species have been completed resulting in several species increasing threat status. *Dendrogyra cylindricus* has jumped two categories from Vulnerable to Critically Endangered, reflecting the devastating effects on this species from Stony Coral Tissue Loss Disease (SCTLD) in recent years. The endemic *Ctenella chagius* found only in the Chagos Archipelago & Salha da Maya bank is also being considered for Critically Endangered status, because of the dramatic decline in observations of this unique species.

Photogrammetry: A comparison of non-destructive short-term coral growth measurement methods

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The ability to measure the growth of corals at weekly intervals may better the understanding, and hence the viability, of active conservation practices such as assisted migration and experimental propagation instruments. With the possibility of repeat measurements just as important, as many coral growth measurement methods are destructive. Non-invasive methods of photogrammetry have become popular recently, as they present an opportunity to take growth measurements without killing the coral. This research explored the efficacy of a novel 6 measurement planar projection (6M) method, by comparing it to the traditional 2 measurement planar projection (2M) method and structure from motion (SfM) method. While it was found that the 6M method was the only one that was significantly different from the true volumes of the plasticine coral proxies used, it was inferred from the results that this difference was due to outlier values. Since the 6M method more accurately measured the majority of morphologies studied, compared to the 2M method, it is suggested that in future research the 6M method be used in its place. However, when debating the use of either the 6M or SfM methods, it is best to assess what the personal needs of the project are. If large sample numbers are required to be analysed, the 6M method is suggested to be better as the time required for image acquisition, image processing, and measurement were all significantly shorter than the SfM method. But if accuracy is what is most important for a small sample number, the SfM method showed notably more accurate measurements in relation to the true volume. This study determines that the 6M method does have a role to play in the field of coral conservation, even if it is not the most accurate.

Poster

Identifying connectivity hotspots for herbivorous reef fishes in a tropical island system

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Seascape connectivity refers to the degree a seascape facilitates or hinders the movement of organisms, nutrients, materials, or energy. Quantifying connectivity is integral to addressing biodiversity loss and enhancing conservation outcomes, as ecological connectivity is a fundamental ecological process in facilitating ecosystem resilience. Although connectivity is understood as an integral concept for sound conservation planning, recent meta-analyses reveal only 11% of MPAs utilise connectivity as an ecological criterion. To integrate ecological connectivity within island conservation planning, remote sensing technology and computational models can be coupled with field surveys to illuminate potential functional connectivity for specific species. We coupled MaxEnt habitat suitability models with Graphab connectivity models to illuminate species-specific potential connectivity patterns. MaxEnt software has proven effective for producing spatially explicit predictions of habitat suitability for a wide range of terrestrial and marine species based on species occurrence data and remotely sensed environmental predictors. Graphab software enables ecologists to utilise habitat suitability outputs to calculate potential habitat accessibility through corridor pathways and connectivity. Here, we used remotely sensed data combined with in-situ data to quantify potential functional connectivity for two herbivorous fish species, *Chlorurus spilurus* and *Acanthurus triostegus*, within Tetiaroa atoll, French Polynesia, an area undergoing restoration aimed at remediating a restricted nutrient cycle. Structurally complex, lagoonal areas within the Tetiaroa seascape facilitated high levels of connectivity for both species. *Chlorurus spilurus* was found to have significantly higher ecological connectivity in comparison to *Acanthurus triostegus* across the entire Tetiaroa seascape, in addition to higher connectivity within local islet areas. Differences in connectivity between the species were primarily driven by depth and habitat preferences, with *Chlorurus spilurus* representing a broader preferential range for both variables. Marine conservation efforts that consider ecological connectivity for key species within their design can expect better conservation outcomes, as indicated by population assemblages and ecosystem functioning.

Spatially predictive habitat suitability mapping to inform restoration of a threatened reef-building coral species, *Acropora palmata*, in the U.S. Caribbean

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Coral reefs are experiencing unprecedented levels of stress from accelerated global warming, ocean acidification, fishing, and water pollution. In the Caribbean, multiple stressors have resulted in widespread losses of the dominant reef-building Acroporid corals, two of which are listed as threatened species under the 1973 U.S. Endangered Species Act. Therefore, active coral reef restoration through the outplanting of corals has become a management priority across the Caribbean Sea. To increase the likelihood of success, active coral reef restoration requires significant investment and careful spatial planning, and site selection for coral outplanting is an essential step in the restoration planning process that has considerable influence on the outcomes of a restoration effort. Using eight distinct biogeophysical predictors, we constructed a maximum entropy (MaxEnt) model to predict and map habitat suitability for the dominant reef-building coral species *Acropora palmata* around the island of St. Croix in the U.S. Virgin Islands. The best-performing model, which was based primarily on bathymetry and benthic habitat type, predicted approximately 3 km2 of highly suitable habitat, of which 1/3 occurred within existing MPAs. 85% of coral outplanting sites coincide spatially with predicted habitat suitability index values greater than 0.75 and 45% with values greater than 0.90. The model revealed that all three statutory MPAs with shallow water coral reefs have a considerable area (892,150 m2) of predicted high suitability seabed with potential for active *A. palmata* restoration efforts. These results support St Croix's integrated coral restoration site selection process, as well as illustrate the value of environmental modelling as a novel approach to plan and evaluate restoration projects more broadly. Further studies may build on this work by incorporating a wider array of environmental and biological predictors into the modelling process, such as outplant growth rates.

Session IV:
Reefs in a changing world

Managing nutrition-biodiversity trade-offs on coral reefs

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Coral reefs support an incredible abundance and diversity of fish species, and reef fisheries provide an important source of income, food, and dietary micronutrients, including minerals and vitamins, to millions of people across the tropics. Numerous studies have explored how fish biomass can be sustained on reefs, however, relationships between nutrients and biomass are unknown, limiting understanding of how fisheries management can maximise both biomass and nutrient availability. Moreover, it remains unclear is whether trade-offs between nutritious food (e.g. nutrient concentrations) and biodiversity can be achieved, such that protecting biodiversity may not jeopardize food security and human health. Here, using surveys of >1,700 tropical coral reef sites and nutrient content data for calcium, zinc, and iron, for which inadequate intakes are particularly prevalent across the tropics, we establish how nutrient concentrations are: (i) influenced by key socioeconomic drivers and environmental conditions; and (ii) related to fish biomass and biodiversity. We demonstrate that fish trophic composition has a strong relationship with nutrient concentrations and is a more important driver than socio-economic and environmental conditions. Specifically, nutrient concentrations increase as the relative biomass of herbivores and detritivores increases, as these species are particularly dense in calcium, zinc, and iron. Somewhat counter-intuitively, nutrient concentrations decrease as fish biomass increases, due to increased dominance of piscivores and planktivores, which have relatively low calcium and zinc concentrations, on high-biomass reefs. Our study reveals that both functional and phylogenetic diversity of fish communities are negatively associated with nutrient concentrations. More importantly, reefs with more IUCN-listed threatened species have lower nutrient concentrations, suggesting that opportunities may exist to sustain the essential supply of nutrients from reef fisheries to coastal communities without compromising efforts to reverse biodiversity loss.

Local thermal refugia associated with unanticipated coral heat tolerance variability across taxonomic scales

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Coral reefs that consistently avoid heat stress, or "thermal refugia", have been put forward as potential safe havens for corals under climate change. However, the extent of their local-scale protective capacity for corals across taxanomic scales is yet unknown. Here, we find that 13% of reefs in Palau, Micronesia, are located in persistent thermal refugia in the north and 18% are located in southwestern hotspots, based on 36 years of sea surface temperature data. Given historic mass bleaching patterns and thermal conditions, we find that the risk of assemblage-wide bleaching is higher in the north, suggesting a naivety of refuge corals to heat stress. However, does this pattern stand true within a single coral species? To test this, we subjected 1020 fragments of *Acropora digitifera* (collected from 200 colonies across replicate thermal refuge and hotspot outer reef sites) to a long-term marine heatwave emulation experiment. The accumulated heat stress in this experiment reached 16ºC-weeks over 5 weeks and resulted in bleaching and mortality in all fragments. Contrary to our expectations, we found that heat tolerance variability is 50% higher at thermal refugia than at hotspots, alongside higher median heat tolerance at thermal refugia, indicating a nuanced relationship between thermal regimes, other environmental factors and coral heat tolerance. Collectively, our results suggest that the apparent susceptibility of coral assemblages to marine heatwaves is dependent on the resolution of the taxonomic lens used in the study. These local-scale thermal refugia in Palau may not be safe-havens for the entire coral assemblage faced with marine heatwave stress, yet do also show signs of higher within-population median and variability of heat tolerance.

Investigating the impact of a major hurricane on larval exchanges and disease propagation in Florida

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During the past decade, the intensity of major hurricanes and disease outbreaks have been increasing, posing a serious threat on Florida's Coral Reef, which is a prime landfall target for hurricanes and a coral disease hot spot. Hurricanes significantly affect ocean transport processes trough nonlinear wind-wave-current interactions and can hence alter the exchanges of larvae between reefs and the waterborne propagation of disease agents. Due to the importance of larval exchanges in promoting the resilience of the reef system and the susceptibility of coral populations to disease outbreaks in the Caribbean, better understanding the impact of hurricanes on coral connectivity in Florida becomes critical. In this study, we combined a high-resolution coupled wave-current model with a biophysical transport model to follow the dispersion of *Montastrea cavernosa* coral larvae and stony coral tissue loss disease agents during hurricane Irma, which made landfall in the Florida Keys in September 2017. For both larvae and pathogens, we conducted a connectivity study, comparing a simulation with the hurricane to a reference simulation without the hurricane. Our results show that, while being a brief event, hurricane Irma still had a significant impact on larval and pathogens dispersal. Indeed, for larval dispersal, even though the hurricane promoted long distance connections, it also fragmented the community structure and created an imbalance in the source-sink dynamics, benefiting few areas to the detriment of the rest of the reef system. Our work also highlights that isolated reefs, low-density areas and upstream reefs are the most vulnerable to hurricanes, which provides insights towards conservation purposes. Finally, considering our results on pathogens dispersal, the study shows that hurricane Irma acted as a super-spreader event for the stony coral tissue loss disease, helping the successful settlement of the disease, dispersing the pathogens further away and reducing local retention.

Marine heatwaves as drivers of coral adaptation

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Scleractinian coral populations are being exposed to conditions above their upper thermal limits due to increasing marine heatwaves, contributing to global declines of coral reef ecosystem health. However, historic mass bleaching events indicate there is considerable inter- and intra- specific variation in thermal tolerance whereby species, individual coral colonies and populations show differential susceptibility to exposure to elevated temperatures. Despite this, we lack a clear understanding of how heat tolerance varies across large contemporary and historical environmental gradients, or the selective pressures that underpin this variation. Here we conducted standardised acute heat stress experiments to identify variation in heat tolerance among species and isolated reefs spanning a large environmental gradient across the Coral Sea Marine Park. We quantified the photochemical yield (Fv/Fm) of coral samples in three coral species, *Acropora cf humilis*, *Pocillopora meandrina* and *Pocillopora verrucosa*, following exposure to four temperature treatments (local ambient temperatures, and +3ºC, +6ºC and +9ºC above local maximum monthly mean). We quantified the temperature at which Fv/Fm decreased by 50% (termed ED50), and used derived values to directly compare acute heat tolerance across reefs and species. The ED50 for *Acropora* was 0.4-0.7ºC lower than for the two *Pocillopora* species, with a 0.3ºC difference between the two *Pocillopora* species. We also recorded 0.9ºC to 1.9ºC phenotypic variation in heat tolerance among reefs within species, indicating spatial heterogeneity in heat tolerance across broad environmental gradients. Acute heat tolerance had a strong positive relationship to mild heatwave exposure over the past 35 years (since 1986), but was negatively related to recent severe heatwaves (2016-2020). Phenotypic variation associated with mild thermal history in local environments provides supportive evidence that marine heatwaves are selecting for tolerant individuals and populations, however, this adaptation potential may be compromised by exposure to recent severe heatwaves.

Breaking Waves: Using Live Coral and Crustose Coralline Algae to Protect Critical Coastal Infrastructure

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It is known that for many coastal areas with coral reefs, up to 97% of the incoming wave energy is attenuated by the living reef structure itself, primarily the reef crest and the fore reef buttress. As climate change intensifies heat into the world‚Äôs oceans, increased and more frequent wave energy events are expected to impact such coastlines. The island of Oahu, within the State of Hawaii, was recently identified as having the greatest amount of coastal infrastructure in the United States at risk from accelerated coral reef loss due to climate change (including increased wave energy events). Hawaiian corals are documented to have extremely slow natural growth rates, averaging only 1-2 cm per year; increased wave energy events are expected to accelerate reef crest loss, resulting in even greater frequency and intensity of wave energy events over-topping the existing protective reef structure and impacting the shorelines. The Hawaii Coral Restoration Nursery (HCRN), along with its University of Hawaii (UH) and Hawaii Department of Transportation partners, is undertaking a pilot project to fast grow both coral and crustose coralline algae (CCA) in innovative ways to maintain and enhance both reef crest and reef flat structures specifically to attenuate wave energy effects in areas threatening identified critical coastal infrastructure such as highways, power plants, sewage treatment plants, industrial areas, military bases, airports, harbors, and tourism hubs. The HCRN is a government-run land-based coral nursery with a 95% survival rate for outplanted corals; and is known for a strong focus on biosecurity and ecological integrity. This effort will involve the use of new concrete three-dimensional printing technology combined with amongst the largest nursery-grown corals to date, along with development of an innovative CCA paint-like application in partnership with both the UH Engineering departments and a number of marine environmental engineering companies.

Depth-dependent vulnerability to catastrophic thermal disturbance at a highly productive, uninhabited reef system

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Coral reefs are exposed to increasing frequency and severity of marine heatwaves under global warming. Widespread coral mortality is commonly reported following extreme and prolonged heat-stress, with often concomitant declines in reef fish abundance, biomass, and diversity as critical live coral habitat is lost. However, it is unclear what role depth gradients on coral reefs play in determining variable reef fish community responses to extreme thermal disturbance and whether natural zonation patterns of high-diversity reef fish assemblages are disrupted. This limits our understanding of the natural ecological organisation of coral reefs and how changes in biophysical gradients under climate change are likely to impact reef community structure and fisheries carrying capacity. Reef bathymetry and local hydrodynamics govern the upslope delivery of cool nutrient-rich pelagic waters to the shallows, a forcing known to affect standing reef fish biomass, and which may also provide shelter for these highly productive nearshore ecosystems during intense heat stress. Here, we quantify depth zonation patterns in reef fish assemblages at Jarvis Island, a highly productive uninhabited coral reef ecosystem in the central equatorial Pacific. This remote reef system has been exposed to repeat bleaching over the past six decades but most recently the 2015-16 El Niño that resulted in 95% coral mortality across depths of 0–25 m. We use standardised coral reef monitoring data from in-water fish surveys between 0–30 m depth around Jarvis across six years (2010–2018) spanning the 2015-16 event. Specifically, we investigate how the standing biomass and trait-structure of reef fish assemblages varied across depths before, during, and after the catastrophic coral loss of the 2015-16 El Niño event to assess depth-dependency in the vulnerability or resilience of this historically resilient ecosystem. Results will offer nuanced insight into the potential survival trajectories for reefs in this era of ocean change.

Acknowledging differences: Latitudinal variation in population transient dynamics of morpho-functional coral groups

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Coastal marine habitats, specifically coral reefs, are often seen as sentinels for marine ecosystem collapse brought on by climate change. Taxonomic and functional differences characterize biogeographical differences in ecological communities along environmental gradients, presenting variations in spatial and temporal dynamics. Population dynamics are often assessed through long-term asymptotic rates that represent a stable state population, while transient (short-term) dynamics provide additional information on a population's resilience to disturbance in stochastic environments. Latitudinal variation in transient dynamics highlights the demographic plasticity of coral populations and the need to expand our knowledge across different morpho-functional coral groups. Here, we assess morpho-functional coral groups from marginal and reef-accreting environments along the Kuroshio current in Japan and Taiwan to explore the demographic factors causing differences between different environmental settings. At eight locations along the Kuroshio current, coral individuals were tagged and followed from 2021-2022 to quantify their vital rates. Significant differences in vital rates are hypothesized to be linked to temperature stability, where larger resistance and compensation from disturbances reflects temperature variability and extremes in marginal environments. Among different morpho-functional groups, populations of bushy weedy corals (i.e., *Pocillopora* spp) in reef-accreting environments are hypothesized to respond quickly to disturbances with their fast life history strategies, whereas massive stress-tolerant corals (i.e., *Dipsastraea* spp) with slow life history strategies are likely to have more stable populations but present longer recovery times Assessing the transient dynamics of different morpho-functional groups and understanding the extent of their tolerance to environmental variation is crucial as it unveils their possible responses to perturbations and their future population trajectories under climate change.

Developing a methodology for the global assessment of increased coastal flooding risk due to coral reef degradation under climate change

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Waves reaching the coast can carry a lot of energy that is mostly dissipated by bottom friction. The presence of healthy coral reef ecosystems forming a complex habitat is hence critical to reduce onshore wave energy and potentially prevent wave-induced coastal flooding, particularly in tropical regions exposed to cyclonic events. Reef erosion and climate-induced coral degradation will reduce the coastal protection offered by reef ecosystems; however, there is no method available to quantify or predict this loss, particularly at the global scale. This work presents such a methodology, building on the work from Scott et al. (2020) quantifying the wave energy dissipated by coral reefs with a hydrodynamic model. In Scott et al. (2020), coral reefs are assumed to be healthy, with a high diversity and habitat complexity, which is transposed in the model with a high friction coefficient. In this work, coral reefs' friction coefficients are updated with predictions of coral species diversity under future climate conditions (SSP1-2.6 and SSP5-8.5) from Couce et al. (submitted). We present preliminary results of the hydrodynamic model focusing on two different beach transects, showing evidence that projected future losses of coral diversity leads to an increase in onshore wave energy and hereby increase risk of coastal flooding. We further propose steps to generalize the method to enable a global risk assessment of coastal flooding driven by on-going coral reef degradation, which could inform on where to prioritize future reef restoration efforts.

Using diel resolved pH and dissolved O2 measurements as indicators of reef health

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Coral reefs are subject to degradation by multiple environmental stressors which are predicted to intensify into the future. Stress can result in ecosystem composition changes from hard coral to macroalgae dominated reefs often with an increase in soft corals and sponges. Such changes alter net metabolism with implications for the biogeochemistry of reef systems, which can be used to provide insight into reef functioning. We investigated this using high temporal resolution pH and dissolved oxygen (DO) data at four Caribbean reefs sites with varying cover of hard and soft coral, sponges and macroalgae. The data was interrogated for the strength of the 'metabolic pulse', specifically, the daily oscillation in pH and DO, and their co-variation, indicative of the net balance of light -dependent and -independent metabolic processes. Lab-on-chip pH sensors were deployed alongside conductivity, temperature and DO sensors mounted on a custom-built platform to record measurements every 1-2 hours for periods of 9 – 47 days. Light-driven process likely controlled both pH and DO, with healthier sites exhibiting a larger diel range in both DO and pH, and a stronger relationship between the two, than heavily degraded sites. At a macroalgae dominated sites pH and DO decoupled during daylight hours. The apparent requirement for daylight could indicate that this decoupling was driven by macroalgae, potentially through carbonate dissolution or oxygen ebullition. Our data suggests that long-term pH and DO measurements may be a potential method for monitoring coral reefs.

Poster

Implications of habitat restoration for tropical seabirds and coral reef ecology

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Although historically islands were viewed as havens of biodiversity, their ecosystems are fragile to threats such as invasive species, land use alterations, and climate change. The decimation of breeding seabird populations on numerous tropical islands has caused interruptions to natural nutrient flows, whereby seabirds transfer nutrients from their pelagic foraging areas to their terrestrial breeding colonies and adjacent coral reef habitats. Here, we investigate what the implications of reversing habitat degradation could be for tropical seabird populations and coral reef ecology. We demonstrate that when successful, rat eradications and the management of vegetation could lead to tropical atoll islands supporting healthy seabird populations. We also reveal the potential for atolls throughout the Indian and Pacific Oceans to support breeding seabird populations and increased seabird nutrient fluxes under different habitat restoration scenarios. Our results illustrate that the restoration of tropical seabird communities could also boost reef fish biomass, coral growth, and coral reef functioning (both bioerosion and grazing). Given the potential benefits for both biodiversity and coral reef ecosystem functioning, the restoration of tropical island ecosystems for seabirds should be a conservation priority.

Poster

Investigating biotic homogenization of herbivorous reef fishes across a spatiotemporal disturbance-recovery gradient

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Herbivorous reef fishes perform critical processes and functions that maintain healthy, resilient, coral reef ecosystems. To better understand the response of herbivorous fishes to acute disturbance and their role in reef recovery processes, this study aims to investigate biotic homogenization (taxonomic and functional) of herbivorous fish across a spatiotemporal reef disturbance-recovery gradient. Using conventional coral reef Underwater Visual Surveys (UVS) and long-term data from Zanzibar, before and shortly after the 2015-16 coral bleaching event, and recovery data (Sep/Oct 2022), the proposed study investigates the consequences of biotic homogenisation for recovery processes. Multidimensional tait-space and functional entity analyses, and Generalised Linear Models (GLMs) are applied to: 1) Investigate temporal variation in herbivorous fish communities and key benthic indicators of reef health, and; 2) Assess biotic homogenization of herbivores within and among reef sites and its relationship to recovery outcomes. Preliminary results are presented.

Contemporary disturbances and ecological memory modulate dynamics in the world's coral reefs

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Drivers of coral reef degradation are multiple and vary inherently in intensity, spatial extension, and frequency. However, rapidly changing conditions alter disturbance patterns, highlighting the need for a better understanding of how the transition from pulse events into more persistent stress will impact reef dynamics. Here, we conduct a global analysis of the impact of eleven acute disturbances on the reef integrity by using the rate of change of coral cover as a measure of damage. Then we tested how the magnitude of the damage of thermal stress, cyclones, and diseases vary among the Tropical-Atlantic and Indo-Pacific reefs, and, whether the cumulative impact of thermal stress and cyclones modulate the response of reefs to future events. We found that, independently of the risk type, the damage largely depends on the condition of reefs before the impact, the intensity of disturbance and the biogeographic region (probably reflecting differences in coral composition). Moreover, changes in coral cover after bleaching events were largely influenced by the cumulative stress of past impacts regardless of the intensity and initial coral cover, suggesting an ecological memory of coral communities. Contrary, the effect of cyclones (and likely other physical impacts) was primarily modulated by the reef's initial condition and seemed not to be influenced by previous impacts. Our findings also underscore that coral reefs are still capable to recover if stressful conditions are reduced, yet, the lack of action to reduce anthropogenic impacts and greenhouse gas emissions will trigger reef degradation. We uphold that the implementation of strategies based-evidence can help managers to take better decisions to face future impacts.

Investigating the transmission of the stony coral tissue loss disease among coral reefs in the US Virgin Islands

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Over the last eight years, the Stony Coral Tissue Loss Disease (SCTLD) has spread in the Caribbean and the Gulf of Mexico, leading to significant losses in coral cover and diversity. In the United States Virgin Islands (USVI), it has now become the greatest threat for shallow coral reefs (0 - 30m), even beyond climate change. In addition, the disease has recently been observed at low mesophotic depths (30 - 60m), thereby threatening the refuge potential of upper mesophotic coral ecosystems (UMCEs) for shallow species. However, the causative agent for this outbreak is currently unknown. Here we show how a three-dimensional high-resolution biophysical model coupled with a SIR epidemic model can characterize the potential causative agent(s) of the disease and its vector(s). Based on these findings, we assess the extent to which UMCEs are threatened by the spread of the SCTLD. We assume the disease agents to be transported within different materials (coral mucus, dead tissues, and/or suspended sediments) presenting specific buoyancy behaviors. The results of our simulations emphasize the importance of the disease vectors buoyancy on its propagation pattern. In particular, we find that the SCTLD may be transported by negatively buoyant materials referring to fine silts, and we conclude that the UMCEs are likely to be affected by the spread of the disease. Calibration of our epidemiological model with species-specific parameters gives a mean transmission time of 6.0 days, with a basic reproduction number above 1.1. This study follows a new connectivity-based approach to understand the spread of the SCTLD in the USVI, particularly between shallow coral reefs and UMCEs. More generally, this method could bring some insights into the characterization of other marine disease vectors and could provide a valuable complement to field experiments to support the management of coral disease outbreaks.

Using time-series analysis of reef orthomosaics to explore the population demography of a shallow reef-building coral

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In a world where coral reefs are under threat, there is an urgent need for in-depth assessments of coral populations that go beyond the traditional metric of live cover. Here, we use a time series of orthomosaics to explore how a population of the reef-building coral *Acropora digitifera* changed over five years at two neighbouring sites on a shallow reef in Palau. Size-frequency distributions revealed that while *A. digitifera* cover increased during the initial study period, this was contrasted by low recruitment and a shift towards populations dominated by larger colonies. Following this period, Typhoon Surigae passed over Palau, which corresponded with a sharp decline in *A. digitifera* colony density at the more exposed site. However, the less exposed site appeared to continue with similar population trends as observed before the typhoon. This emphasises the value of having demographic data under background conditions to provide context to the impacts of acute disturbances. Pre-disturbance fate-tracking of individuals revealed an unexpected size-survival relationship under background conditions at this reef, whereby the probability of mortality significantly increased with size. This relationship appears to be related to the growth patterns of *A. digitifera*. The smallest colonies are densely branched, a morphology that appears to protect them from intense wave action. At ~10cm diameter, colonies then experienced a dramatic decline in survival, as they grew upwards and became more exposed to injury and dislodgement in this shallow environment. This pattern of growth also resulted in a positive relationship between radial extension and colony size, as the uncaptured vertical growth only occurs during the earlier life stages of *A. digitifera*. These results further demonstrate the importance of conducting a variety of demographic analyses to build a bigger picture of a coral population's health, structure, and dynamics, and highlight key areas for future work.

The role of lipids in the resilience of corals to bleaching

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Coral bleaching occurs with increasing frequency and threatens the future of reefs. Bleaching occurs when corals expel their photosynthetic symbionts (zooxanthellae) in response to stressors such as temperature, light and nutrients. The resilience of corals to bleaching varies between coral species and along water depth gradients and is influenced by the composition of lipids in the coral tissues. Lipids fulfill a range of functions in corals, acting as energy reserves, forming cell membranes, and providing signaling between cells. At present it is unclear how lipids influence susceptibility to bleaching. The presented research will investigate variations in the tissue lipids of corals of *Pocillopora meandrina* and *Acropora retusa* coral along a depth gradient (5m to 25m) at the outer reef adjacent to the CRIOBE research lab in Moorea (17°30'S, 149°50'W), French Polynesia. Previous research indicates that shallow waters corals are more susceptible to bleaching than their deeper water counterparts, where *Acropora* species are more susceptible to bleaching than *Pocillopora* species at this site. Gas-Chromatography Mass Spectroscopy (GC-MS) will be used to identify how lipid compositions vary between these coral species with different bleaching susceptibility and along a depth gradient for each coral species. This data will indicate which lipid compounds are reduced in corals that are most susceptible to bleaching.

Session V:
Other

Coral Growth Measurements in a Restoration Context: A Review of Methods

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Coral Reef restoration has become more prominent in the past 40 years as the decline in coral reefs has become more severe. Restoration projects measure the success of their aims in relation to growth and survival rates of coral. With a large diversity of methodologies and coral morphologies, this review hypothesised that these would be selected based on the aim of the publications. A total of 58 publications were reviewed for (1) aims, measurement method and coral morphologies, (2) to quantify experimental design and highlight variables that may be underreported and (3) provide a solution, adjusting areal and volumetric growth, allowing for coral start size comparisons. Firstly, it was found that branching morphology and linear extension were the primary morphologies and measurements regardless of aims, and that depth and temperature were only reported in 69% and 36% (respectively) of publications. Secondly, study length duration was highly variable, with the majority being 1 year long, which highlights the need for long-term studies to account for variations in growth rates throughout a corals life cycle. Finally, areal and volumetric growth rates were reported which accentuated a need for a solution to rescale these growth rates allowing for comparison between starting sizes. This review focuses on summarising the currents trends in restoration methodologies and morphologies in relation to project aims, highlighting any biases and underreporting in the literature. Addressing these issues could allow for more accurate cross study comparisons of coral growth rates through providing more comprehensive experimental designs and correcting for any misleading reporting of coral growth rates.

Poster

Inverse modelling for coral population vital rates

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Understanding structured population dynamics of corals is central to their conservation. This process usually requires growth, mortality and reproduction (vital rates) information gathered at the individual level, capturing the entire life-cycle. However, following coral individuals though time is difficult and sometimes unfeasible, due to the many challenges associated with working in the marine environment. For example, if tagged corals cannot be found again then data points are lost. In addition, other processes such as partial mortality (shrinkage) or asexual reproduction (fission) can be difficult to ascertain. Population size structure data, however, can be more easily obtained through photo-transects, as it does not require the tagging and revisiting of specific individuals. Recent developments in integral projection models (IPMs) allow the estimation of population vital rates using time series data, which overcomes the challenge of having to follow individual corals through time. With a time-series of population size structure of the subtropical endemic *Pocillopora aliciae* in the Solitary Islands Marine Park, Australia, we reconstruct unobserved vital rates using inverse IPMs. We then evaluate these estimations against known vital rates from tagged corals. We show that by incorporating independent estimates on vital rates where known, better results can be reconstructed from the inverse estimation. With many coral reef scientists sampling reefs using photo transects, we advocate for the uptake of more inverse modelling in coral demography.

Nutrition from reef fish in Pacific fishing communities following reef disturbances

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Healthy coral reef ecosystems underpin the supply of fish available for human diets in tropical regions. As the diversity of fish supported by reefs is altered following disturbances, the micronutrients available to people is also impacted. Using time series data from reefs and household interviews on dietary habits in French Polynesia, we investigated the effects of changes in reef condition and fish communities on the diets and nutrition of people on two islands, Moorea and Raiatea. Coral cover increased from 2010 to 2020 on both islands, with no clear effect on the biomass of functional fish groups relevant to fisheries. We found that the nutrient density people obtained from fish was greater in Moorea compared to Raiatea, owing to a higher frequency of fish consumption, however the diversity of fish eaten was higher on Raiatea. Although people in Moorea received greater nutrient densities per food category in their diets, fish was the fourth greatest contributor to nutrient density on both islands with dairy foods contributing the most. Females and older respondents had higher nutrient densities in their diets, with a similar but weaker effect observed for nutrient density obtained from fish alone. People from fishing households had higher dietary nutrient densities and people who ate traditional Polynesian fish-based meals more frequently, as well as those who spoke Polynesian and had a lower level of academic education, received higher nutrient densities from fish. Our results suggest that the nutrition people receive from fish is determined largely by socioeconomics and desire to eat certain foods, rather than the local availability of fish present on reefs or diversity of fish eaten. Nutritious reef fish appear to be a healthy option for people where less healthy western-introduced foods are common, even when coral reefs are in a degraded state.

Coral reef reflectance for remote-sensing applications: a case study from French Polynesia

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Coral reef environments are threatened by multiple anthropogenic stressors. To inform more efficient local management strategies that support coral reef resilience, high-resolution spatial data of key environmental parameters is critically needed. High-resolution maps of, for example, coral species distribution, reef structural complexity, bleaching, and water quality would be highly useful in the selection of priority sites for coral reef protection and restoration action. Excitingly, new remote-sensing technologies are increasingly enabling such maps to be produced at low cost and over large spatial scales. Importantly, understanding the optical properties of different species of corals is a key condition for the development of advanced remote-sensing applications: in clear and shallow coral reef environments, benthic reflectance makes a major contribution to the total optical signal retrieved by a remote-sensing instrument. Therefore, to successfully map, for example, water quality parameters, it is essential to first accurately understand and remove the effect of coral reflectance. Here, we present initial results from a fieldwork campaign in summer 2022 at Tetiaroa, a low-lying atoll in French Polynesia. Coral reef reflectance was measured at 21 sites using TriOS RAMSES hyperspectral sensors (optical resolution: 3.3 nm). The coral reflectance data indicates differences between coral species and corroborates previous findings in the literature. The next step of this research project is to complement these initial findings with the analysis of the inherent optical properties of water constituents. This will allow for forming a comprehensive understanding of the different factors contributing to the total optical signal detected by remote-sensing instruments. Ultimately, better understanding the optical properties of coral reef environments will enable the production of high-resolution spatial-temporal data using remote-sensing. Future work will build on these results to map and monitor the flows and hotspots of nutrients across the coral reef seascape using multispectral/ hyperspectral drone and satellite imagery.

Nitrate in the coral symbiosis: from the regulation of its assimilation to its impact on the physiology of the holobiont

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In oligotrophic reef systems, coral holobionts are remarkably efficient at assimilating nitrogen through heterotrophic feeding or the uptake of dissolved inorganic nitrogen. *Symbiodiniaceae* are vital partners of the symbiosis for nutrient assimilation. In addition to providing translocated photosynthates, they account for most of the uptake of dissolved inorganic nitrogen. Although NO_3^- is the most abundant source of nitrogen in the ocean, little is known about the mechanisms regulating its assimilation by the holobiont. Coral hosts are unable to reduce nitrate as they lack the necessary enzymes, whereas *Symbiodiniaceae* have been shown to express the enzyme nitrate reductase (NR). However, the evidence supporting the active reduction of nitrate by the symbiotic algae during symbiosis is scarce and equivocal. This research aimed at deciphering the pathways of NO_3^- assimilation in both free-living *Symbiodiniaceae* and in hospite symbionts while also investigating the relevance of inorganic nitrogen source in physiological responses to stress. We investigated the expression and regulation of NR both in free-living *Symbiodiniaceae* and in in hospite symbionts using a combined western blot and qRT-PCR approach. We showed that the expression and regulation of NR in free-living *Symbiodiniaceae* is a dynamic and reversible process impacted by NO_3^- and NH_4^+ concentrations. Symbionts from N-depleted corals incubated with NO_3^- enriched seawater showed an increase in NR synthesis over time. Interestingly, NR protein synthesis did not correlate with NR gene expression, hinting towards a potential post-transcriptional regulation of the enzyme. Additionally, we investigated the impacts of inorganic N source (NO_3^- vs NH_4^+ vs N depletion) in combination with stress on the physiology of *Symbiodiniaceae* (photosynthetic responses, ROS and NO production). The availability of inorganic nitrogen improved photosynthetic capacity while reducing ROS production. Moreover, preliminary experiments showed that NO_3^- and NH_4^+ had differential effects on the physiological responses of *Symbiodiniaceae* subjected to stress.

Low-Cost Hyperspectral Imagers as a Tool for Assessing Coral Reef 'health'

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A significant marine impact of anthropogenic climate change has been the increasing prevalence of bleaching events on coral reefs. There is a pressing requirement for new monitoring techniques and methodologies to monitor these invaluable ecosystems. Non-destructive techniques which can gather higher definition information are hugely advantageous over the traditional in-situ, image-based techniques currently utilised. Underwater Hyperspectral imaging (UHI) can reveal information about marine environments. Hyperspectral imaging has the ability to detect minute colour changes in marine organisms such as corals and colour change metrics can be used to assess and monitor 'health'. Due to the advances in new optical technologies, low-cost imagers can be developed at a fraction of the cost of traditional commercially available systems. The availability of low-cost imagers makes the technology more widely accessible for marine applications where previously the high financial cost as well as the inherent financial risk of submerging equipment was prohibitive. Due to the reconstruction method utilised by the LVF-DSLR, 3D information is also recovered via structure from motion (SfM) photogrammetry from the dataset enabling for additional topological measurements of the marine ecosystem to be derived. From one dataset on a coral reef, the operator would be able to ascertain, from 3D data, the reef rugosity, species zonation/distribution as well as spectral data revealing pigment concentrations of corals and even fluorescence data (under UV light). These imagers can also supplement and verify (at high spatial resolution) hyperspectral measurements made by satellite/airborne systems which are capable of imaging large areas but only at relatively low spatial resolution. Where any imaging performed above the water's surface requires correction algorithms to account for the attenuation of light through the atmosphere and the water, by deploying an imager underwater the 'true' spectrum can be directly measured and this can be used to validate the correction algorithms.

Mainstreaming coastal nature-based solutions as an approach to tackle climate change adaptation, enhance biodiversity and promote human wellbeing in the UK

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Accelerating adaptation measures globally at the scale and speed needed to meet the looming challenges of climate change is a priority. Nature-based solutions (NBS) for adaptation are grounded on the role of nature in reducing human vulnerability to the effects of climate change. In addition, NBS deliver multiple benefits for biodiversity and human wellbeing by protecting existing habitats, restoring degraded ecosystems, improving the sustainable management of landscapes, and creating novel habitats. Although NBS for climate change are gaining political attention in the UK, coastal habitats have received far less interest than terrestrial ecosystems. In this way, there is an urgent need to create awareness and demonstrate the potential of coastal habitats in supporting adaptation, enhancing biodiversity, and promoting human wellbeing. This study gathered and analysed evidence on coastal NBS in the UK by conducting a non-systematic literature review. Additionally, semi-structured interviews with national and international experts led to identifying lessons, barriers, reflections on the benefits assessment, and critical aspects for the future deployment of coastal NBS. As a result, a set of recommendations were provided to advocate for the rise of political awareness and scaling up of coastal NBS as an entwined synergetic solution to address the climate and ecological crises.