#RCUK2023

Reef Conservation UK

Saturday 9rd December 2023

Newcastle University

Book of abstracts

Reef Conservation UK
Saturday 9th December 2023
Newcastle University

08:30 Registration opens
09:20 Welcome address

09:30	John Bythell	Coral Reef Science at Newcastle University	Newcastle University

09:40 Plenary speaker I

09:40	Tries Razak	Rehabilitating reef rehabilitation: Applying scientific knowledge to improve reef restoration practice in Indonesia	BRIN Indonesia

10:10 Session I: Reactive reef management

	Speaker	Presentation title	Institution
10:10	Tim Lamont	Functional performance of restored coral reefs	Lancaster University
10:30	Eveline van der Steeg	The Coralassist Plug: a novel device for rapidly outplanting sexually produced corals	Newcastle University
10:45 Speed	Zach Boakes	Nutrient dynamics, carbon storage and community composition on artificial and natural reefs in Bali, Indonesia	Bournemouth University
10:50 Speed	Morven Rae-Seaman	Quantifying habitat heterogeneity to predict biodiversity on coral reefs	University of Leeds
10:55 Speed	Alice Rogers	Introducing MizerReef - a tool to predict the future of coral reef fisheries	Victoria University of Wellington

11:00 Morning break & poster session (45 min)

11:45 Session II: Advances in monitoring and fish behaviour

	Speaker	Presentation title	Institution
11:45	Edward Sibley	The Capacity of Imaging Sonar for Quantifying the Abundance, Diversity and Size of Reef Fishes	University of Aberdeen
12:00	Katie Lee	Integrating numerical and ecological modelling to piece together the past and future of the Great Barrier Reef	University of York
12:15	Nora van Xylander	Fatty Acid Lipid Variations in Corals: Implications for Bleaching Susceptibility and Resilience	University of St Andrews
12:30 Speed	Jonathan Teague	A Demonstration of the Capability of Low-Cost Hyperspectral Imaging for the Characterisation of Coral Reefs	University of Bristol
12:35 Speed	James Boon	The influence of shelter availability and structural degradation on antipredator responses in coral reef fishes	University of Nottingham
12:40 Speed	Kirstin Gaffney	Pay-to-stay in anemonefish societies	Newcastle University
12:45 Speed	Charlotte Clay	Variation in functional composition of reef fishes along a tropical-to-temperate gradient	University of Leeds

12:50 Lunch break & poster session (70 min)

14:00 Plenary speaker II

14:00	Jane Hawkridge	Taking science to policy: insights into the workings of a public body supporting the UK Overseas Territories	Joint Nature Conservation Committee

14:30 Session III: Reef ecology & conservation

	Speaker	Presentation title	Institution
14:30	Joerg Wiedenmann	Digesting their photosynthetic symbionts helps reef corals thrive in nutrient poor environments	Coral Reef Lab, Southampton
14:45	Gordon Watson	Can the global Marine Aquarium Trade (MAT) be a model for sustainable coral reef fisheries?	University of Portsmouth
15:00	Cynthia Riginos	Hidden dimensions of coral biodiversity: cryptic taxa, hybridisation, and why it matters for conservation	University of Gothenburg
15:15 Speed	Lisa Goberdhan	Drivers of cryptic fauna bioavailability in degraded coral reef habitats	Bangor University

15:20 Afternoon break & poster session (45 min)

16:05 Session IV: Reefs in a changing world

	Speaker	Presentation title	Institution
16:05	Nick Graham	Increased resilience and regime shift reversal through repeat mass coral bleaching	Lancaster University
16:20	Kristina Beck	Physiological response and skeletal dissolution of the cold-water coral *Desmophyllum pertusum* to multiple environmental stressors	University of Edinburgh
16:35 Speed	Amanda Ford	Comparing impacts and recovery of locally managed reefs in Fiji after exposure to extreme waves from Cyclone Winston	The University of the South Pacific
16:40 Speed	Sivajyodee Sannassy Pilly	Depth variation in benthic community response to climate change	Bangor University
16:45 Speed	Javier Gonzalez	Long-term changes of coral reef diversity patterns across a latitudinal gradient in the Great Barrier Reef	Lancaster University
16:50 Speed	Liam Lachs	Emergent increase in coral thermal tolerance reduces mass bleaching under climate change	Newcastle University
16:55 Speed	Kerri Dobson	Ocean acidification does not prolong recovery of coral holobionts from thermal stress in two consecutive years	University of Southampton

17:00 Student prizes & closing remarks
17:30 Conference closes
17:45 Drinks reception at the Great North Museum - Living Planet Gallery until 19:45

Plenary I – Dr. Tries Razak

Research Fellow, Faculty of Fisheries and Marine Science, IPB University, Indonesia

Dr Tries Razak is a global expert on coral reef conservation and restoration. She has worked for decades on coral reef research programmes across Indonesia, generating a prolific record of impactful research. She received her PhD from the University of Queensland, Australia; MSc from Leiden University, the Netherlands; and BSc in Marine Science from IPB University, Indonesia. Tries co-founded the Indonesian Coral Reef Foundation in the 1990s to raise awareness about coral reef conservation and management in Indonesia. In 2021, she received the prestigious Pew Fellowship in Marine Conservation for her research on improving coral reef restoration practice in Indonesia. Recently, she received the ASEAN Research Fellowship in 2023 for her work on the effects of urbanization on coral reef ecosystems in Jakarta Bay.

Rehabilitating reef rehabilitation: Applying scientific knowledge to improve reef restoration practice in Indonesia

Many of Indonesia's coral reefs have been severely damaged by global and local stressors, and a range of active restoration techniques are now being used in attempts to rebuild degraded reefs. While Indonesia stands out for its high number of reef restoration initiatives, many lack proven effectiveness due to the absence of a solid scientific foundation for optimal site selection. Between 1990 and 2020, a total of 533 reef restoration projects were initiated across Indonesia, comprising over 170,000 units of artificial reefs, coral nurseries, and nearly 1 million out-planted fragments of hard coral. Despite Indonesia's policy encouraging diverse practitioners, there is a notable lack of coordination with wider restoration networks or scientists. Only 16% of projects incorporated a post-installation monitoring program to understand how marine organism populations respond to restoration; the remaining 84% have become one-off installations of artificial reefs with unknown long-term outcomes. Indonesian reef restoration shares many of the growing pains experienced globally in coral reef restoration, where poorly-designed projects in sub-optimal locations and a lack of appropriate methods for out-planting, monitoring, and maintenance have failed to deliver genuine conservation benefits. Incorporating clear objectives and long-term monitoring programs in project planning stages, while prioritizing knowledge exchange and engagement with the international scientific community, will significantly enhance restoration outcomes in Indonesia. This will allow the country to fulfill its considerable potential as a global leader in rebuilding damaged coral reefs.

Plenary II – Dr. Jane Hawkridge

International Implementation Co-Team Leader

Jane is a Team Leader at the Joint Nature Conservation Committee (JNCC). An alumnus of Newcastle University, Jane has a PhD in coral biology. Her interests include use of applied research to support policy, regulatory and management authorities to make informed and effective decisions that support the environment and communities. Jane leads JNCC's UK Overseas Territories (UKOTs) work programme, including coral reef conservation projects. Jane represents the UKOTs on the Global Coral Reef Monitoring Network Steering Committee, NOAA's Stony Coral Tissue Loss Disease Caribbean Cooperation Committee and Disturbance Advisory Committee, and UK Focal Point for the International Coral Reef Initiative.

Taking science to policy: insights into the workings of a public body supporting the UK Overseas Territories with nature conservation and coral reef management

Have you ever wondered what role a UK advisory body plays in coral conservation? The Joint Nature Conservation Committee has had a role providing advice on coral reefs for many years, cold water and tropical, nationally, and internationally. Our advice covers national policies for cold water corals, international policies and Conventions such as the Convention on Biological Diversity and CITES, and of course our Overseas Territories (OTs) and Crown Dependencies. Recently, we have been working with the OTs to support their coral reef conservation efforts, especially in the Caribbean, where they are battling the dual threats of coral disease and bleaching alongside increased development and tourism pressures and threats from climate change. Advising governments on the development and implementation of policies for, or affecting, nature conservation requires the latest science and collaboration. Using examples, I will discuss how JNCC works with its partners to develop coral reef advice for UK Governments and the Overseas Territories and identify some ways you may be able to support their priorities. I will also illustrate how we support the OTs to manage their wider environment for better reef resilience, enhanced economic security and disaster resilience, drawing on the role of coral reefs and associated ecosystems.

Session I:

Reactive reef management

Functional performance of restored coral reefs

Timothy Lamont[1]; Gita Alisa[2]; Rindah Vida[2]; Ines Lange[3]; Ben Williams[4]; Jason Lynch[4]; Permas Maulana[5]; Cudo Prasetya[5]; Tries Razak[6]; Nick Graham[1]

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[2]*IPB University, Indonesia*
[3]*University of Exeter, UK*
[4]*University College London, UK*
[5]*Mars Sustainable Solutions, Indonesia*
[6]*BRIN, Indonesia*

In response to extensive degradation of tropical coral reefs, hundreds of organisations worldwide are pumping billions of dollars into coral restoration. Some programmes have successfully re-established coral cover over large areas, and the scale of global restoration efforts is rapidly increasing. However, restoration progress is still almost always evaluated by changes in coral cover, with limited understanding of the recovery of ecosystem-level functions and services. For example, we don't yet know if restored reefs can support the same biodiversity, coastal protection, fisheries provision, economic opportunities and cultural value as natural coral ecosystems.

In this joint presentation by a team of early-career Indonesian and European researchers, we share quantified evidence of restored coral reefs' functional performance, at one of the world's largest reef restoration programmes. The Mars 'Reef Star' project has restored thousands of square metres of coral over the last 5 years, around an island in central Indonesia where there are also extensive patches of comparable healthy and degraded habitat. Working at this unique study system, we quantified a range of ecosystem functions that are directly related to service provision, comparing functional performance between healthy, degraded and restored areas. We demonstrate that restored reefs have fully recovered some – but not all – of the functions associated with healthy reefs. For example, when compared to healthy reefs, restored areas exhibit good recovery of carbonate budgets, colour diversity and human-perceived aesthetic value, but altered structural complexity, community structure and behaviour of key fish species.

We discuss how restored reefs are acting as novel ecosystems that provide a distinct suite of ecosystem functions and services. Restoration practitioners must now use function-specific metrics to set meaningful targets and optimise pathways to restore desirable outcomes for both reefs and people. In short, we must learn to restore not just coral, but functioning reef ecosystems.

The Coralassist Plug: a novel device for rapidly outplanting sexually produced corals

Eveline van der Steeg[1]; Adriana Humanes[1]; John Bythell[1]; Alasdair Edwards[1]; Liam Lachs[1]; Margaret Miller[2]; Yimnang Golbuu[3]; James Guest[1]

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[2] SECORE International, Miami, USA
[3] Palau International Coral Reef Center, Koror, Palau

Sexual coral propagation is an emerging technique designed to produce large numbers of genetically diverse corals for the purpose of reef restoration. In contrast to coral fragmentation, sexual reproduction maintains the genetic diversity of outplants and can be used for selective breeding to enhance coral heat tolerance. However, early post-settlement and outplant mortality, nursery rearing time, labour-intensive outplantation and associated costs remain severe bottlenecks hindering implementation at meaningful ecological scales. Here, we develop and field test a device for settling, rearing and outplanting corals to overcome these issues. The CoralAssistPlug (CAP) is a ceramic device designed for the rapid and cost-effective outplanting of sexually propagated corals in large numbers that maximises post-outplant survivorship. It has three main innovations: 1) built-in micro-refugia to protect young corals from grazing, 2) a relatively small size (3 by 1 cm) that is easy to handle and stacked efficiently without compromising the survivorship of corals, and 3) a hole in the middle allowing quick and efficient attachment to the reef with a masonry plug, nail or Coralclip®. This allows a three-person dive team to outplant ~120 CAPs in one 90-minute shallow dive. CAPs were settled with Acropora digitifera and outplanted to a reef crest from one to six months later. A high yield was achieved, with up to 60% of retained CAPs containing at least one live coral after three years, depending on treatment. Corals reached a mean area of 14.7 ± 0.7 cm2 and the retention rate was 75.5 ± 2.3 %. By upscaling this method to using 10,000 CAPs, the cost of a 3-year-old live coral on the reef was estimated at $11.8. CAPs can play a meaningful role in reef restoration by efficiently introducing sexually reared corals with high genotypic diversity into natural populations with application to assisted evolution techniques.

Nutrient dynamics, carbon storage and community composition on artificial and natural reefs in Bali, Indonesia

Zach Boakes[1]; Daniel J Franklin[1]; Richard Stafford[1]; I Gusti Ngurah A Suryaputra[2]; Alice E Hall[3]

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[2] Universitas Pendidikan Ganesha, Applied Chemistry Study Program, Department of Chemistry, Faculty of Mathematics and Natural Sciences, Bali, Indonesia
[3] University of Plymouth, School of Biological and Marine Sciences, Faculty of Science and Engineering, Plymouth, UK

Artificial reefs are now commonly used as a tool to restore degraded coral reefs and have a proven potential to enhance biodiversity. Despite this, there is currently a limited understanding of ecosystem functioning on artificial reefs, and how this compares to natural reefs. We used water sampling (bottom water sampling and pore water sampling), as well as surface sediment sampling and sediment traps, to examine the storage of total organic matter (as a measure of total organic carbon) and dynamics of dissolved inorganic nitrate, nitrite, phosphate and ammonium. These biogeochemical parameters were used as measures of ecosystem functioning, which were compared between an artificial reef and natural coral reef, as well as a degraded sand flat (as a control habitat), in Bali, Indonesia. We also linked the differences in these parameters to observable changes in the community structure of mobile, cryptobenthic and benthic organisms between habitat types. Our key findings showed: 1) There were no significant differences in inorganic nutrients between habitat types for bottom water samples, 2) Pore water phosphate concentrations were significantly higher on the artificial reef than on both other habitats, 3) Total organic matter content in sediments was significantly higher on the coral reef than both other habitat types, and 4) Total organic matter in sediment traps in May and September were higher on coral reefs than other habitats, but no differences were found in November. Overall, in terms of ecosystem functioning (specifically nutrient storage and dynamics), the artificial reef showed differences from the nearby degraded sand flat, and appeared to have some similarities with the coral reef. However, it was shown to not yet be fully functioning as the coral reef, which we hypothesise is due its relatively less complex benthic community and different fish community. We highlight the need for longer-term studies on artificial reef functioning, to assess if these habitats can replace the ecological function of coral reefs at a local level.

Quantifying habitat heterogeneity to predict biodiversity on coral reefs

Morven Rae-Seaman[1]; Rebecca Green[2]; Scott Bachman[3]; Steven Sait[1]; Maria Beger[1]

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[2]ARC Centre of Excellence for Coral Reef Studies, Crawley, Australia
[3]Climate and Global Dynamics Laboratory, National Center for Atmospheric Research, USA

The habitat heterogeneity hypothesis is a well-understood concept in ecology, whereby a more heterogeneous habitat supports higher biodiversity. Further, habitat heterogeneity may also predict community structure, physical complexity and adaptive ability of species and communities. Adaptive ability will be key for survival under increasingly severe anthropogenic climate change. Here, we aim to develop and test a remotely sensed metric of adaptive ability, based on key adaptive properties of species, communities, and reef systems, with an overall aim of supporting reef management and conservation.

Coral reefs are naturally heterogeneous environments, composed of various habitat types including live taxa such as coral, sponges, and algae, alongside areas dominated by sand or rubble. We build on the recently published Allen Coral Atlas, which has mapped key habitat classes on reefs worldwide using satellite imagery. Using these maps, we have developed a novel metric of habitat heterogeneity, based on beta-diversity of the habitat classes represented across a reef landscape. We test the metric's predictive ability by focusing on reefs in Ambon, Indonesia, and using linear mixed models, we modelled heterogeneity with observed species records, investigating if habitat diversity can link to measures of biodiversity that inform conservation, including species richness and functional richness.

We built a framework to measure and conceptualise adaptive ability at different levels of ecological organisation, from individuals to ecosystems. Using key traits and processes identified from this framework, we found a positive relationship between habitat heterogeneity and adaptive characteristics, suggesting more heterogeneous reefs may experience faster adaptation to the ongoing climate crisis, supporting longer-term survival. Results were not consistent across all sites in the region, highlighting that habitat heterogeneity is simply one aspect of adaptive reefs. Looking forward, results from this study should be integrated into spatial planning activities, to select sites of high adaptive ability for future conservation focus.

Introducing MizerReef - a tool to predict the future of coral reef fisheries

Chelsey Beese[1]; Peter J. Mumby[2]; Alice Rogers[1*]

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Habitat degradation on coral reefs alters community composition and energy flows, and will affect the productivity and sustainability of reef fisheries. However, our ability to predict change in future reef fisheries is limited by a scarcity of long-term catch data, a history of over-exploitation, and a lack of understanding about time lags between habitat loss and fish population responses. Here we present MizerReef, an extension of a multi-species, size-spectrum modelling framework used widely to understand and predict the impacts of fishing and climate change on multi-species fisheries. Our example model includes nine size-structured fish functional groups supported by two size-structured resources, pelagic plankton and benthic invertebrates, as well as algae and detritus. Coral reef habitat complexity is modelled through the provision of predation refuges, which protect some proportion of fish from being consumed by predators according to their body size. The model provides a tool with which to explore the consequences of habitat degradation on meaningful time scales, capturing variability in fish life histories, benthic associations, predation strategies and vulnerability to fishing. The R package we have developed has flexible options for capturing reef conditions, and the capacity to explore realistic fishing scenarios with multiple gear types. We will wrap up with a brief overview of potential applications of this new tool.

Session II:

Advances in monitoring and fish behaviour

The Capacity of Imaging Sonar for Quantifying the Abundance, Diversity, and Size of Reef Fishes

Edward C. P. Sibley[1,2]; Alethea S. Madgett[2,3]; Travis S. Elsdon[4,5]; Michael J. Marnane[4]; Euan S. Harvey[5]; Joshua M. Lawrence[8]; Thomas Cornulier[1]; Damon Driessen[5]; Se Songploy[6,7]; Jes Kettradad[6,7]; Paul G. Fernandes[8]

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Accurate and efficient survey methods are essential for quantifying reef fish assemblages to inform management and conservation. Imaging Sonars (ISs) are high frequency acoustic devices that produce camera-like images of objects. Unlike optical instruments, ISs function effectively in turbid and dark water and have proven valuable in detecting fishes in poor visibility and at night in habitats of varying complexity. We present four applications of IS to quantify fishes on tropical and sub-tropical natural and artificial reefs, contextualised in a systematic review of the topic (Sibley et al. 2023a). Firstly, we demonstrate IS to detect up to three-times as many fishes as an optical camera at an artificial reef in Western Australia, attributed to the ability of IS to detect camouflaged, site-attached fishes that cameras often fail to discriminate (Sibley et al. 2023b). Secondly, at the same habitat, we report highly variable success in identifying discrete fish species using IS alone, based on a novel clustering approach using traits that can be consistently defined using IS (Sibley et al. in press). Thirdly, we report IS to detect comparable densities of fishes at a several toppled oil and gas platform jackets and a local coral reef in the nearshore Gulf of Thailand (Sibley et al. in review). However, IS revealed fishes at the jackets to be significantly larger, a finding reinforced by concurrent stereo-video footage. Finally, we introduce a new IS-based approach to surveying fishes: the Baited Imaging Sonar (BISON), remarking on its application to enumerate fishes around a small shallow artificial reef in southeastern Florida in comparison with an unbaited IS (Sibley et al. in prep). Ultimately, we provide extensive evidence of the capacity of IS to enumerate reef fish assemblages, both in conjunction with and as an alternative to conventional optical instruments.

Integrating numerical and ecological modelling to piece together the past and future of the Great Barrier Reef

Katie Lee[1]; Jon Pitchford[2]; Jody Webster[3]; Jon Hill[1]

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[2] *Departments of Biology and Mathematics, University of York, UK*
[3] *School of Geosciences, University of Sydney, Australia*

We can learn about the future of the Great Barrier Reef (GBR) by using the past. Tidal models of the last 16,000 years up to the present day have been built to simulate how 75 metres of rising sea level from the Last Glacial Maximum have affected coral larvae transportation and coral growth, allowing us to watch the GBR develop virtually.

Pairing these tidal models with Lagrangian particle tracking software have shown that the 'sticky water phenomenon', vital for coral larvae retention and building the high density reef system, only developed 10,000 years ago and is likely to disappear in the future with rising sea levels. Understanding ecological effects of this physical change will be paramount to future conservation efforts. From these models, the resulting connectivity matrices of larval exchange are integrated with reef ecology models to simulate changes in ecological dynamics of coral and algae through time. The ecological models lead into the next step of the project, where I will be applying coral growth models to the future and the past, gradually adding external forcing, such as changes of temperature and salinity to build better predictions of the GBR's future for conservation management.

During this project, the models developed will be packaged into usable and tested open source code that can be used by researchers or coral reef managers with little coding experience. Modelling is now advancing to a point where it may be possible to predict where the last reefs could survive on the GBR, and pinpoint potential locations where reefs it may migrate to in the future.

A Demonstration of the Capability of Low-Cost Hyperspectral Imaging for the Characterisation of Coral Reefs

Jonathan Peter Teague[1]; John C C Day[1]; Michael Allen[2]; Eric Hochberg[3]; David Megson-Smith[1]

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The use of hyperspectral imaging in marine applications is limited, largely due to the cost-prohibitive nature of the technology and the risk of submerging such expensive electronics. Here, we examine the use of low-cost (<5000 GBP) hyperspectral imaging as a potential addition to the marine monitoring toolbox. Using coral reefs in Bermuda as a case study and a trial for the technology, data was collected across two reef morphologies, representing fringing reefs and patch reefs. Hyperspectral data of various coral species, *Montastraea cavernosa*, *Diploria labyrinthiformis*, *Pseudodiploria strigosa*, and *Plexaurella* sp., were successfully captured and analyzed, indicating the practicality and suitability of underwater hyperspectral imaging for use in coral reef assessment. The spectral data was also used to demonstrate simple spectral classification to provide values of the percentage coverage of benthic habitat types. Finally, the raw image data was used to generate digital elevation models to measure the physical structure of corals, providing another data type able to be used in reef assessments. Future improvements were also suggested regarding how to improve the spectral data captured by the technique to account for the accurate application of correction algorithms.

The influence of shelter availability and structural degradation on antipredator responses in coral reef fishes

James Boon[1,2]; Sally Keith[2]; Dan Exton[3]; John Stratford[4]; Jason Lynch[4]; Richard Field[1]

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[3]*Operation Wallacae, Wallace House, UK*
[4]*Department of Geography, University College London, UK*

The loss of reef-building corals and continual erosion of dead coral colonies has led to the well-documented decline of structural complexity on Caribbean coral reefs. This regional-wide degradation could have significant consequences for species that use the reef architecture as a refuge from biotic and abiotic stressors. Notably, shelters play a key role in the anti-predator responses of organisms, as predation risk is often lower in areas with more available shelters due to the reduced foraging efficiency of predators. This begs the question – how will the antipredator responses of coral reef fish change as shelter availability reduces across the Caribbean? Past studies have assessed anti-predator responses of single taxa against simple metrics of structural complexity. Yet none have explicitly measured refuge availability, explored more than two metrics of escape response, or considered the work in the scope of Caribbean-wide coral reef degradation. Here, we explore the anti-predator responses of a broad range of fish species between sites with different levels of structural complexity around the island of Utila, Honduras. We use structure-from-motion photogrammetry to construct 3D models of reefs and extrapolate shelter availability and complexity metrics. We combine this with in-situ anti-predator experiments using a 3D printed model predator, where we record a suite of behavioural responses, including escape response, flight initiation distance, distance fled, and distance to nearest refuge. We then consider these results within the optimal escape theory framework. From anecdotal observations during data collection and initial analysis, we anticipate that our findings will indicate the importance of considering behavioural shifts in response to coral reef degradation.

Pay-to-stay in anemonefish societies

Kirstin Gaffney[1]; Megan Bartlett[1]; Theresa Rueger[1]

[1]*Newcastle University*

In cooperative societies of unrelated individuals, helping effort by non-breeders is an evolutionary mystery as it is unclear why they invest in unrelated offspring. One explanation is that subordinates are appeasing the dominant breeders in order to avoid group eviction - the 'pay-to-stay hypothesis'. This has been observed in mammals, birds and freshwater cichlids, however, in marine fishes within-group behaviours are still largely unknown. Here, we aimed to test this hypothesis in anemonefishes (Amphiprion sp.) which form groups consisting of one dominant breeding pair and non-breeding subordinates. We hypothesised that subordinate anemonefish 'pay to stay' through maintaining and defending the anemone host. Using three anemonefish species (A. percula, A. perideraion and A. clarkii) in a comparative approach, we experimentally prevented 'helping' by placing a focal subordinate in a clear box near the anemone to assess two key predictions of the pay-to-stay hypothesis: (1) helpers will be punished after insufficient helping and (2) they will increase helping behaviour thereafter. Our findings will expand our understanding of the evolution of sociality in the marine realm and provide insight into the role of relationships between fish and their cnidarian hosts in the evolution of complex social groups.

Variation in functional composition of reef fishes along a tropical-to-temperate gradient

Charlotte G. Clay[1]; James D. Reimer[2,3]; Brigitte Sommer[4]; Katie M. Cook[1,5]; Masaru Mizuyama[2,6]; Masami Obuchi[2,3,7]; Iori Kawamura[2]; Hiroki Kise[2,6]; Maria Beger[1,8]

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Aim – We explore the variation in trait composition of coral-associated fish assemblages along a tropical to warm temperate gradient in Japan between 24o and 35o N. We ask the following questions: (i) Do trait combinations vary along the latitudinal gradient? and (ii) Does trait space reduce with increasing latitude, indicating a simplified community trait assembly and lower functional diversity with decreasing temperature?
Methods – Based on reef fish abundance/ biomass surveys at 31 sites, we applied linear models to assess the relationship between latitude and community-weighted trait means (CWM) and thus whether the prevalence of traits varied along the latitudinal gradient. We utilised ordination techniques to test the hypothesis that trait space would be reduced towards the northern poleward latitudes. We visualised changes in trait space with convex hulls and examined latitudinal patterns in beta diversity.
Results – We found significant functional turnover in all metrics along the environmental gradient. We found a reduction in specialist habitat traits (coral substrate preference, nesters, herbivores) and an increase in generalist traits (predators) with increasing latitude, along with a contraction in trait space from tropical to temperate reefs.
Conclusions – Increasing simplification of community trait assembly and trait space contraction with increasing margionality is closely linked with with latitudinal gradients in temperature, suggesting some species' range expansion might be ongoing in response to climate change.

Session III:
Reef ecology & conservation

Digesting their photosynthetic symbionts helps reef corals thrive in nutrient poor environments

Jörg Wiedenmann [1]; Cecilia D'Angelo [1]; M. Loreto Mardones [1]; Shona Moore [1]; Cassandra E. Benkwitt [2]; Nicholas A. J. Graham [2]; Bastian Hambach [3]; Paul A. Wilson [3]; James Vanstone [1]; Gal Eyal [4]; Or Ben-Zvi [5]; Yossi Loya [6] & Amatzia Genin [7,8]

Contributed equally: Jörg Wiedenmann, Cecilia D'Angelo, M. Loreto Mardones.

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Coral reefs are highly diverse ecosystems that thrive in nutrient-poor seas, a phenomenon frequently referred to as the "Darwin paradox". Nonetheless, even in nutrient-poor ocean basins, reefs can be replenished regularly with dissolved inorganic N and P from deeper, nutrient-rich water through upwelling, internal waves and vertical mixing. Substantial amounts of nutrients in their inorganic form are also released by filter feeders in the intimate vicinity of the corals or enter the reef from land-based sources. These inorganic forms of N and P constitute a key nutrient pool, which is, however, primarily accessible to the photosynthetic symbionts and not to the coral host. Accordingly, it is unclear to which extent dissolved inorganic nutrients contribute directly to the success of symbiotic corals.

We demonstrate that symbiotic coral animals can satisfy a substantial amount of their N and P demand through 'farming' and digestion of excess symbiont cells. Thus, we show that both the symbionts and the host gain growth-related benefits through the efficient, reciprocal exchange of the essential cellular nutrients. Since both organic and inorganic sources of N and P are overall scarce in oligotrophic tropical waters, the symbiotic lifestyle offers corals a truly competitive edge over exclusively heterotrophic animals that rely solely on N and P in organic forms, or exclusively autotrophic plants such as macroalgae that are restricted to N and P in dissolved inorganic form.

The fully closed cycle of reciprocal N and P exchange between the symbiotic partners can explain the evolutionary and ecological success of symbiotic corals in well-lit, nutrient-limited warm water habitats. It also underpins the vulnerability of symbiotic corals to disturbances of their nutrient environment.

Can the global Marine Aquarium Trade (MAT) be a model for sustainable coral reef fisheries?

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Globally, six million coral reef fishers provide ~25% of emergent countries' catch, but species have low value. The Marine Aquarium Trade (MAT) targets high value biodiversity, but missing data amplifies draconian governance and demands for international prohibition. To stimulate sustainability and reef conservation investment, we generate a fiscal baseline using the first global analysis of numbers, diversity and biomass of MAT-traded organisms. Each year ~55 million organisms worth US$ 2.15 billion at retail are traded comparable with major fisheries e.g. tuna. A sustainable MAT also requires over-exploitation assessments. We identify 25 species/genera with 'Extremely High' risk-ratios and place the Indonesian and Sulu-Celebes Seas in the highest exploitation category. Despite predicted hobbyist number increases, unabated reef degradation and low governance will transform the MAT into an aquaculture-dominated industry decoupled from communities (i.e. culture located in importing countries). A 'MAT-positive' future requires evidence-based management/governance, consumer education and sustainable practice incentivisation, but can address the biodiversity, social and economic inequality crises.

Talk

Hidden dimensions of coral biodiversity: cryptic taxa, hybridisation, and why it matters for conservation

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It has long been recognised that morphological variation in corals does not align well to genetic variation. Multilocus population genetic surveys often uncover distinct genetic taxa within morphologically defined taxonomic species, so called cryptic species. Additionally, hybridisation among corals has often been suspected, with genetic studies confirming some examples. The emerging consensus, then, is that genetically distinct groups may commonly coexist within dispersal range and that these groups may be linked by low levels of gene flow. Inferential power was limited for earlier genetic studies that used relatively few markers, whereas modern genomic studies that use thousands of DNA markers are much more sensitive to subtle genetic subdivisions. To investigate the prevalence cryptic taxa and hybridisation among corals, we focus on population genomic data. We undertook a structured literature review and re-evaluated published studies for evidence of cryptic taxa and hybridisation using stringent and reproducible criteria. We find that signatures of cryptic taxa are common across corals and hybridisation is frequent. The pervasiveness of these phenomena should influence how we approach coral conservation and restoration, and these implications will be discussed. We will also present best practice guidelines for population genomic studies such that their results can more readily guide conservation and restoration practice.

Drivers of cryptic fauna bioavailability in degraded coral reef habitats

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Coral rubble is a naturally occurring habitat on tropical coral reefs, formed by the physical destruction of hard corals through hydrodynamic action or bioerosion. Despite its seemingly barren and featureless appearance, coral rubble form complex microhabitats that can host a great density and diversity of life including microbes and biofilms, sessile and encrusting taxa, and motile cryptobenthic fauna and fishes. Motile cryptic fauna, including crustaceans, annelids, and molluscs, comprise the highest density and diversity of animals directly associated with coral reef substrates. Their diversity and abundance enable them to perform a wide range of functional roles including scavenging, predation, bioturbation, and parasitism. However, one of their more influential roles is arguably as a significant basal energetic resource to higher level consumers.

Ongoing coral reef degradation caused by local and climatic factors have resulted in coral rubble becoming an increasingly prevalent bottom habitat on reefs globally. As such, there is critical need to determine whether increasing degraded habitats, like coral rubble, may support reef trophodynamics through enhanced biodiversity and resource availability from the bottom-up. In this study, we aim to understand what factors, from microhabitat to seascape scales, influence cryptic fauna bioavailability in coral rubble habitats. We examine naturally derived coral rubble habitats across Palmyra Atoll, an uninhabited remote atoll in the Central Pacific, and use multivariate analyses to determine the effects of habitat type, rubble morphology, and sessile organism cover on cryptic fauna community structure, density and size spectra.

Session IV:
Reefs in a changing world

Increased resilience and regime shift reversal through repeat mass coral bleaching

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Coral reef ecosystems are expected to decline in coral dominance, and more reefs undergo regime-shifts to non-coral states, due to increasingly frequent and severe marine heatwaves. However, long-term detailed ecological datasets spanning multiple heat stress events are rare, making ecosystem predictions less certain. We assessed coral reefs across the inner islands of the Seychelles using a 28-year dataset, spanning severe marine heatwave events in both 1998 and 2016, which both caused severe coral bleaching and mortality. Following the 1998 bleaching event half the reefs underwent regime shifts to macroalgae, while half recovered their coral cover. We anticipated subsequent severe bleaching events would mean more reefs undergo regime shifts, and overall condition declines. However, we document faster coral recovery from the more recent 2016 mass bleaching event, than the earlier 1998 event, with recovery trajectories about 4 years ahead. Further, compositions of benthic and fish communities were more resistant to change following the more recent heat stress, having stabilized in a persistent altered state following the initial climate disturbance. Surprisingly, one reef that had regime-shifted to macroalgal dominance following the 1998 bleaching event, is recovering to a coral-dominated regime following the second bleaching event. This is a rare example of a regime-shift reversal in a natural system. Collectively, these patterns indicate that the system may be more resilient to repeat heatwave events than anticipated, perhaps due to adaptation of coral populations and increased herbivory. This is not to say severe and frequent coral bleaching events will not keep reefs in a degraded low coral cover state if climate change increases unabated, but it does give some reason to be optimistic that meeting ambitious climate targets could result in coral reefs persisting.

Physiological response and skeletal dissolution of the cold-water coral *Desmophyllum pertusum* to multiple environmental stressors

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The cold-water coral (CWC) *Desmophyllum pertusum* is an important ecosystem engineer, forming complex three-dimensional reefs in the deep sea. These reefs consist of both live corals and dead skeletal parts and are associated with high biodiversity. However, CWCs are threatened by various environmental stressors due to climate change. Previous laboratory studies mainly focused on the effects of individual environmental factors, especially elevated temperatures and reduced pH. So far, little is known about the effects of reduced oxygen concentration and food availability on CWCs and the combined effect of all these stressors. Therefore, we are conducting a long-term aquarium experiment with *D. pertusum* under end-of-century conditions. We are investigating the combined effect of increasing pCO2 (400 and 1000 ppm), elevated temperature (9 and 12 °C), reduced oxygen concentration (80 % and 100 %) and reduced food supply (25 and 50 mg C m-2 d-1) on coral mortality, calcification, respiration, and energy reserves over one year. In a parallel experiment, we are also examining dissolution rates of live and dead skeletons at different pCO2 levels (750, 1000 and 1250 ppm) using buoyant weighing and computed tomography (CT) scans to better predict how ocean acidification will affect the structural integrity of CWC reefs in the future. Here we will present preliminary data collected after six months of the experiment. After three months, calcification rates were lowest in the multiple stressor treatment with reduced food availability. The dissolution rate of dead coral skeletons was highest at lowest seawater pH. We hypothesise that live corals are able to cope with projected environmental changes over short time periods, but not over one year. In the long-term, we predict the combination of all four factors will negatively impact the physiology of *D. pertusum*, mainly driven by warming and reduced food availability.

Comparing impacts and recovery of locally managed reefs in Fiji after exposure to extreme waves from Cyclone Winston

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As the climate warms, coral reefs face an increasing frequency and severity of damage from thermal stress at the same time that a greater proportion of tropical cyclones are expected to reach the strongest categories. This may increase the potential for cyclone waves to damage coral reefs. Understanding the dynamics of coral reef recovery from severe cyclone wave impacts is essential to support projections of reef community trajectories under future climate scenarios. We present an evaluation of two large barrier reef systems in Fiji under varying forms of local management using data collected prior, directly after, and four years following Tropical Cyclone Winston which made landfall in February 2016 and generated extreme waves 11 standard deviations above the long term average. Our study aimed to: (1) quantify the impact and recovery of benthic communities on reefs with different management interventions; (2) determine how storm wave energy can be linked to changes in hard coral cover and composition; (3) measure to what extent the hard coral communities were able to reassemble within four years; (4) assess trajectories of reef fish communities and whether they can be linked to observed differences in benthic communities and management. The cyclone's impact on hard coral communities was severe, with an average relative loss of 63% coral cover and corresponding increases in rubble and turf algae across most reefs. However, the recovery and reassembly of the hard coral community to pre-cyclone composition by 2020 was remarkable, indicating high resilience. Fish biomass was high across all sites with a marginal positive effect of no-take areas, and most functional groups (aside from corallivores) were little impacted by the cyclone. No-take areas did not promote faster recovery, but all sites were removed from local impacts, known to be highly productive and exposed to strong currents; factors expected to facilitate high resilience.

Depth variation in benthic community response to climate change

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Coral reefs are increasingly impacted by climate-induced warming events. However, little is known about how the response of shallow coral reef communities to thermal stress varies with depth. Here we assess depth-dependent changes in coral reef benthic communities following successive marine heatwaves in 2015 to 2017 by examining the effects of initial and repeated thermal stress across a 5–25 m depth gradient. Our analyses show an overall decline in hard and soft coral cover and an increase in crustose coralline algae, sponge and reef pavement following successive marine heatwaves in a remote reef system. Greater changes in benthic group cover were found at shallow (5–15 m) than at deeper (15–25 m) reef zones. Our findings also indicate variable benthic community response to elevated seawater temperatures across depth. The loss of hard coral cover was better predicted by initial thermal stress, whilst the loss of soft coral was associated with repeated thermal stress following successive warming events. By surveying multiple depth gradients, our study shows that benthic communities across a depth range extending to 25 m did not escape the impacts of successive marine heatwaves, raising concerns about the resilience of shallow coral reef communities to increasingly severe climate-driven warming events.

Long-term changes of coral reef diversity patterns across a latitudinal gradient in the Great Barrier Reef

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Quantification of biological diversity across large spatial scales has revealed patterns that appear to reflect general principles governing the organization of life on Earth. However, in recent decades climatic and anthropogenic pressures have driven changes in diversity patterns, creating uncertainty around whether these general patterns and principles hold in the current era of rapid environmental change. Coral reef ecosystems have experienced some of the most severe changes worldwide of any ecosystem; a product of interacting local and global drivers. We use the Long-Term Monitoring Program (LTMP) of the Australian Institute of Marine Science; one of the most comprehensive monitoring programs of coral reef ecosystems worldwide. This monitoring dataset provides the opportunity to evaluate not only how the Great Barrier Reef (GBR) has changed over long temporal scales (1995 to 2022) but also how these changes vary across a large latitudinal gradient (14°S to 24°S). We analyse how and why patterns of reef fish diversity have changed over the past three decades by examining local diversity (α) and species turnover (β). We explore possible drivers of these patterns by focusing on the latitudinal gradient, fluctuations in coral cover and changes in coral composition. We found a systematic increase in reef fish turnover and a high fluctuation in the species richness across the latitudinal gradient in the GBR and time. Particularly, we found declines in species richness of fish at lower latitudes and increases at higher latitudes, which are consistent with disturbance-driven fluctuation in coral cover and coral composition. More broadly, our work provides fundamental insight into whether classic macroecological patterns are fit for coral reef ecosystems in the Anthropocene. These analyses and insights are only possible due to this standardised large-scale and long-term monitoring effort.

Emergent increase in coral thermal tolerance reduces mass bleaching under climate change

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Recurrent mass bleaching events threaten the future of coral reefs. To persist under climate change, corals will need to endure progressively more intense and frequent marine heatwaves. Yet, it remains unknown whether coral thermal tolerance (i.e., the overall temperature stress threshold of the coral community) can keep pace with ocean warming. Here, we reveal an emergent increase in the thermal tolerance of coral assemblages at a rate of 0.1 °C/decade for a remote Pacific coral reef system. This led to less severe bleaching impacts than would have been predicted otherwise, indicating adaptation, acclimatisation or shifts in community structure in either the corals or symbionts. Using future climate projections, we show that if thermal tolerance continues to rise over the coming century at the most-likely historic rate, substantial reductions in bleaching trajectories are possible. High-frequency bleaching can be fully mitigated at some reefs under low-to-middle emissions scenarios, yet can only be delayed under high emissions scenarios. Collectively, our results indicate a potential ecological resilience to climate change, but still highlight the need for reducing carbon emissions in line with Paris Agreement commitments to preserve coral reefs.

Ocean acidification does not prolong recovery of coral holobionts from thermal stress in two consecutive years

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Corals are experiencing more frequent and intense thermal stress events, with some locations now experiencing thermal stress in two or more consecutive years. However, under predicted future ocean conditions, corals will simultaneously be exposed to chronic ocean acidification (OA). Some corals will likely be more resistant and/or resilient to these predicted conditions than others and may be critical to reef persistence in the future. Following natural thermal stress events in two consecutive years (2014 and 2015), we evaluated the effects of simulated OA and feeding on the physiological recovery of *Montipora capitata* and *Porites compressa* sourced from Kāne'ohe Bay and Waimānalo Bay, Hawai'i. We hypothesized that OA would prolong bleaching recovery and increase susceptibility to repeated bleaching, while heterotrophic feeding on zooplankton would mitigate the negative effects of OA on bleaching recovery and OA-induced bleaching susceptibility. Following the 2014 thermal stress event, simulated OA did not slow recovery of the holobiont and feeding enhanced recovery. However, neither feeding nor simulated OA affected coral susceptibility to the 2015 thermal stress event. Recovery strategies employed between species and between sites differed, highlighting that coral reef restoration and management should consider species-level and site-specific vulnerabilities. While bleaching resistant phenotypes of *M. capitata* and *P. compressa* can be found in Kāne'ohe Bay and Waimānalo Bay, our results suggest that *M. capitata* is more likely to persist on Hawaiian reefs than *P. compressa* under predicted future ocean conditions. Overall, our findings highlight the immediate threat that thermal stress presents, the lack of additional stress to the holobiont from OA, the importance of heterotrophy in resilience, and the potential significance of local biotic stressors (i.e., predator outbreaks) for resiliency under annual thermal stress.

Poster Session

The functional ecology and restoration potential of artificial reefs

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The marine environment is facing increasing pressures and today, 60% of the world's major marine ecosystems that underpin livelihoods have been degraded or are being used unsustainably. Governments, organisations, scientists, and communities are trying to find alternatives that can mitigate the environmental, economic, and social challenges caused by industrialisation by seeking to restore and balance nature. Traditional conservation measures, such as no take-zones, reserves, and marine protected areas have been used for decades, but attention has progressively shifted toward active restoration methods in response to accelerating coral decline. Artificial habitats (including purpose built reefs and unintentionally established reefs on industrial infrastructure) provide several ecological benefits such as reef restoration of degrading communities, increasing prey availability and shelter for fish, and also promoting an increase of biomass of benthic invertebrates.

An aspect that has received little attention is how fish assemblages associated with artificial reefs function compared to natural communities. Although community composition may differ between natural and artificial habitats resulting in novel ecosystems, those ecosystems may function in a similar way, which must be investigated to determine habitat value and restoration capability. This will improve our understanding of the resilience to stressors, allow for the potential conservation of species that might have been reduced in natural habitats due to multiple stressors, and to ensure that a harmful novel ecosystem does not evolve and begin to negatively impact natural habitats. Fish communities are key to ecosystem functioning, and fisheries management requires a better knowledge of fish community responses, particularly in terms of how species traits respond to anthropogenic pressures and environmental changes.

This presentation will discuss the functional ecology of fish assemblages associated with tropical artificial reefs and their restoration potential, with a focus on reefs at industrial infrastructure (platforms and pipelines) in comparison to natural reefs and soft sediment habitats.

Poster

Spatial heterogeneity in coral reef communities

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Modern coral reefs are experiencing multiple anthropogenic pressures, resulting in changes that are affecting ecosystem services and the appropriate science needed to understand these transitions. Species richness is a traditional measure used to estimate biodiversity trends and monitor ecosystem health, however even if these measures appear constant, underlying changes in species composition and associated degradation may be overlooked. Recently, more complementary measures such as Beta diversity have been used to estimate the variability in species composition among sampling units for a given area at a given spatial scale. In this study the associated statistical test for homogeneity of multivariate dispersion is used to characterise the variability in the spatial consistency of coral reef benthic communities. Analysis was conducted on data that were collected at 30 sites around the island of Tutuila in the U.S. Territory of American Samoa. SCUBA surveys were conducted at 10 meters depth along six 25 meter transects. Sites were selected within each major watershed, representing a gradient of nutrient pollution, human population, and wave exposure. Multivariate dispersion was tested at different spatial scales at the transect and site levels, in addition to different species taxonomic resolution. These results will used to inform local monitoring efforts with regard to appropriate scales and locations at which to conduct surveys.

Numerical Investigation on Flow field and Potential of Scouring Around reef cubes®

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Reef cubes®, artificial reef units designed to enhance the marine habitat for ocean-dwelling organisms within coastal infrastructure designed by ARC Marine, are deployed and tested in Torbay, United Kingdom to investigate their effect on adjacent flow field structures in marine environments. Findings gathered from the above will assist in determining how current designs influence flow hydrodynamics that facilitates habitat growth, provide shelter for marine organisms, and are optimised for future deployments; this includes potential formation of local scour holes around cube configurations which may either affect long-term stability and position of structures or encourage the development of habitat feature to enrich marine life. This study numerically explored changes in the flow field hydrodynamics around the cubes with different arrangements and analysed their effect on shear stress both on the structure and its surrounding seabed. The model utilised the incompressible unsteady Reynolds-averaged Navier Stokes (URANS), coupled with the k-ω SST turbulence closure. Accuracy, and reliability of the model is ensured by validating against relevant experimental data from literature, and qualitatively from physically observed evidence. Calculations of bed shear stress which served as a primary parameter in assessing the development of local scour around these cubes were used. Deployment configuration and orientation are analysed to identify structures that provide the best environment in terms of flow velocities suitable for marine organisms, as well as the positional stability of these cubes.

The Influence of Marine protected areas and latitude on the functional diversity of temperate macroinvertebrate assemblages

Bethany Woodhead[1]; Maria Beger[1]; Josie South[1]

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Climate change and human exploitation are altering marine ecosystems via poleward range shifts and species losses, but management in marine protected areas (MPAs) can mitigate the threat via reduced anthropogenic disturbance. Macroinvertebrates play important functional roles in marine ecosystems including nutrient cycling, and water purification, meaning their loss could drastically alter marine habitats. Functional traits are characteristics of species that relate to the roles they perform in ecosystems. By assessing functional diversity (FD), the question of whether MPAs offer adequate protection of FD can be addressed.
Using four different trait categories, fuzzy coded traits and alpha FD indices alongside the Jaccard dissimilarity index (beta-diversity), we test the hypothesis that macroinvertebrate FD will be greater in protected areas than non-protected areas over temperate regions of the globe. To highlight what differences in traits may be causing variations in FD, I use generalised linear models to assess the influence of protection and latitude on the abundance of genera with specific traits.
Most FD indicators were similar for both assemblages and beta-diversity was low suggesting the assemblages were not dissimilar from each other. However, functional dispersion was lower for the protected assemblage suggesting the diversity of traits supported by MPAs is lower than that of unprotected areas. The abundance of highly mobile, free-living macroinvertebrate genera was greater in MPAs than unprotected areas, and the distribution of different feeding strategies and of small macroinvertebrates was determined by latitude but not protection.

Here, we show that certain functional traits are over-represented in MPAs, potentially at the demise of others. Furthermore, environmental conditions also determine macroinvertebrate distribution directly and indirectly. MPA managers should aim to conserve complete functional assemblages so that the provisioning of ecosystem services from the marine environment can be sustained for the future, particularly when managing commercially important but often neglected invertebrate fisheries.

The potential role of amino acids in the physical resilience of coral skeletons under ocean acidification: insights from synthetic aragonite precipitations

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Tropical coral skeletons are composed of aragonite (CaCO3) and organic macromolecules. The concentration of biomolecules, e.g., aspartic acid (Asx), the most abundant amino acid in coral skeletons, has a positive relationship with seawater pCO2 and a negative relationship with seawater pH, known as ocean acidification (OA). OA typically reduce the degree of calcification in the coral skeleton. However, the effect of the increase in the concentration of biomolecules on the hardness of the coral skeleton is poorly understood.

Here, we precipitated synthetic aragonites without (control) and in the presence of key coral skeleton amino acids (aspartic acid, glutamic acid, and glycine). Aragonite crystals were precipitated from 1 µM, 100 µM, and 5 mM of each amino acid from a control solution. The control solution was seawater manipulated to have a pH and DIC, representing the coral calcification site. The synthetic aragonites were embedded in epoxy resin and polished to produce cross-sections suitable for micro-indentor analysis of Vickers hardness. This metric represents the skeleton's resilience to breakage and erosion. A Leco Vickers LM 243AT micro indentation hardness tester equipped with a pyramid diamond indenter impressed each sample using a mass of 25 g for 10s. Scanning electron microscopy (SEM) was used to measure and compare each sample to the indent dimensions of pyramid diamonds.

Aragonite precipitated with 5 mM Aspartic acids had Vickers hardness values approximately double compared with the control. The concentration of skeleton aspartic acid has a positive relationship with pCO2. Previous observations showed that the porosity and skeleton structure may change under OA. We concluded that an increase in skeletal aspartic acid in corals under ocean acidification may increase the hardness of the skeleton.

A collaborative approach to coral disease in the UK Overseas Territories

Bryony Meakins[1]; Abbie Dosell[1]; Jane Hawkridge[1]

[1]*JNCC*

Coral reef ecosystems in the UK Overseas Territories contribute to making the Caribbean region a biodiversity hotspot and are relied upon for the valuable services they provide to society. The health of coral reefs across the Caribbean is severely threatened by human activity, coral disease, and climate change. In addition to existing pressures, the highly contagious stony coral tissue loss disease (SCTLD) has reached the Caribbean region and is having a devastating effect on infected coral reefs.

To effectively respond to SCTLD, sharing knowledge and experiences of the disease is critical. The JNCC-led Darwin Plus (DPLUS147) project – Collaborative approach to managing coral disease in UK Overseas Territories – is supporting the response. The project fosters partnership between governments, NGOs, academic institutions, and wider stakeholders to coordinate effective coral reef management decisions through the Coral Conservation in the Overseas Territories (C-COT) working group, which the project funds. The C-COT working group was formerly known as the Collaborative Coral Reef Working Group (CCRWG) and has met nearly forty times since late 2019 and held two, in-person workshops.

Project partners have received funding to manage SCTLD through different treatment approaches, while considering the importance of managing pressures on reefs through resilience-based management approaches. The project has worked closely with other existing JNCC-led projects, namely two CSSF funded projects, ‘Implementing Coral Reef Action Plans for the UK Overseas Territories Coral Reef Initiative’ and the ‘Climate change adaptation and hurricane disaster resilience’ project.

Dear enemies of nasty neighbours?

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Aggressive territoriality is a costly behaviour yet can have significant benefits for resource acquisition. Mechanisms that allow an individual to recognise whether another individual is a competitive threat before they initiate aggression can allow them in some cases to avoid that individual, rather than fight, conserving vital energy. Studies of competitor recognition most commonly compare responses of an individual to conspecifics versus heterospecifics. However, we have little knowledge of how responses to different individuals of the same species vary. The 'dear enemy' effect suggests that territorial individuals able to recognise their neighbours will exhibit less aggression than would be directed towards a stranger. This effect reduces the costs of competition between neighbouring individuals, which will come into contact more frequently than with strangers. Conversely, the 'nasty neighbour' effect hypothesises that neighbours are associated with greater perceived threat, eliciting heightened aggression. We tested these opposing hypotheses in territorial farming damselfish using a common bottle presentation experiment design to initiate aggressive interactions between neighbouring and stranger damselfish. Individual farming damselfish were significantly more aggressive towards their neighbour than a stranger, offering support for the nasty neighbour hypothesis. Aggression also varied substantially between individuals. Nasty neighbours may become more common with increased conspecific density, leading to greater energy loss through aggressive interactions and diminished condition. Moreover, time and energy spent fighting neighbours may make territory holders more vulnerable to intrusion by transient competitors. Identifying the patterns and mechanisms behind conspecific competitor recognition is vital to understanding the ecological consequences of territorial aggressive behaviour.

Climate REEFS: Integrating evolution, ecology, and socio-economics for sustainable coral reefs and fisheries in a changing climate

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The livelihoods and food security of ~1 billion people who depend directly on coral reef ecosystems are at risk from climate change. As more frequent marine heat waves cause widespread coral death and associated declines of ecosystem services, adaptation strategies are paramount for biodiversity conservation and sustainable fisheries. Currently, management strategies mostly target reefs less exposed to thermal stress, and ignore biological and socio-economic adaptation. Working across the Philippines and Indonesia, Climate REEFS engages expert scientists and NGO implementers to translate ecological, social, and gender implications of adaptive reefs into improving people's lives now and into the future, implementing early action to mitigate climate vulnerability of both people and reefs.

Climate REEFS aims to identify adaptive reefs and reduce climate vulnerability of reef-reliant communities. It will resolve knowledge and sustainability gaps by providing proof-of-concept that 'adaptive' reefs are identifiable from space, and advancing understanding of how reef-dependent women, men, and marginal groups are vulnerable to climate-driven reef degradation.

We are quantifying and testing how reef geomorphology and thermal regime predict biodiversity and adaptive capacity (i.e., genomic diversity). Further, Climate REEFS characterizes how demographic factors shape socio-economic vulnerabilities and adaptability. Adaptation here encompasses genetically imbued thermal resistance of organisms, variability in thermal regimes, and socio-economic resilience of communities, institutions, and systems.

Deciphering the effects of nitrate enrichment and heat stress on the physiology of the coral Acropora tenuis and the composition of its associated symbiotic and microbial communities.

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Coral reefs are unarguably under increasing pressures arising from various environmental stressors. Coral survival in the face of environmental change relies heavily on nutrient exchanges between the host and the photosynthetic endosymbionts. While the functional contribution of the coral microbiome remains poorly understood, increasing evidence suggests that associated microorganisms are essential for coral resilience as they are intricately linked to nutrient cycling and energy flows in the ecosystem. Nitrogen underpins many aspects of coral holobiont functioning but the effect of its availability in its most abundant environmental form, nitrate, on the coral response to stress is equivocal: while nitrate sustains symbiont communities, it has also been reported to have adverse effects on the response to oxidative stress and to accentuate bleaching. In this study, using a crossed treatment experimental design in a mesocosm setup, we investigated the responses of the coral Acropora tenuis to a nitrate enrichment of 5 µM in combination with a heat stress of 4 DHW over a period of 3 weeks. Corals' health was monitored throughout the experiment and corals' physiological response to the different treatments was assessed at the start of the stress and at the end of the experiment by measuring respiration rates, photosynthetic capacity, growth rates, symbiont densities, pigment and protein contents. In addition, corals were sampled to identify the composition of the associated symbiont and microbial communities using high-throughput sequencing of the genes ITS2 and 16S respectively. The heat stress treatment induced moderate to severe bleaching that was not alleviated by the increased nitrate supply. Nuances in the physiological data and the integration with the sequencing data give valuable inputs into the holobiont's functioning by disentangling the effect of nitrate availability and heat stress on the resilience of the coral and the stability of its associated symbiotic and microbial communities.

Spatial and Temporal Variations in Size-Frequency Distributions and Coral Colony Growth Rate of Coral Communities in Jangamo, Mozambique

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Effective monitoring of coral community changes relies substantially on the choice of relevant metrics used for assessment. Relying solely on coral cover overlooks the complexity of reef ecosystems. Instead, size-frequency distributions enable valuable insights into coral community demographics. Yet, this approach has not previously been used to assess the health of coral communities in Jangamo, Mozambique, that is influenced by diverse disturbances at small spatial scale. To address insights into the dynamics of coral communities within different ecological setting, we examined small-scale variability in the size-frequency distributions and colony growth of corals across depths, locations, and time (2022-23) in Jangamo, Mozambique. We calculated the size-frequency distribution parameters to study population dynamics and compared size distributions using two-sample Kolmogorov-Smirnov test. We used ANOVA and Linear Mixed Model to identify differences among locations, depths, and time. We found that the size structure of corals exhibits significant variations across different depths and locations. The coral communities found in all study locations were comprised by small colonies. Among locations, Paindane Bay had higher mean colony size, while Coconut Bay exhibited the highest coefficient of variations (CV). Among depths, we observed that shallow sites had higher mean colony size than deep sites. But the deep sites displayed a greater CV, indicating more variability in colony size. Our findings indicated annual growth transitions in coral communities, as evidenced by a reduction in skewness in the size distributions across depths and locations. However, some large colonies experienced partial mortality. These variations in size-frequency distributions underscore the potential impacts of fluctuations in coral vital rates (e.g., growth rate, recruitment, and mortality), possibly influenced by disturbances in Jangamo. Therefore, our research contributed to a better understanding of coral community dynamics in different reef environments and highlights the need for a comprehensive approach to coral reefs monitoring and conservation.

Poster

Reef shark abundance trends inside one of the world's principal shark sanctuaries: evidence of population stability

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Marine protected areas (MPAs), and more recently shark sanctuaries, are key tools in addressing the global decline of reef sharks. However, assessing their efficacy is challenging due to the lack of long-term data sets for shark abundance, particularly throughout the Indian Ocean. Most studies evaluate MPA efficacy spatially, comparing species abundance inside and outside of protective boundaries. However, snapshots of species abundance are less robust than long-term monitoring and can prevent detection of slow population declines. Here we use baited remote underwater video stations (110 sites, 464 hours of footage) collected over a 5-year period (2016-2020) to assess reef shark abundance trends within the Maldives shark sanctuary. No significant trend in relative shark abundance was found at either the species or community level, suggesting that the population is temporarily stable. Findings represent an important baseline post-sanctuary implementation and provide empirical evidence that shark sanctuaries can be an effective conservation tool for reef sharks.

Poster

Investigating upwelling dynamics in the Chagos Archipelago and associated impacts on coral reef benthic communities

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The Chagos Archipelago in the Central Indian Ocean is largely void of direct local human pressures, and therefore serves as a prime location to study fluctuations in natural environmental processes and associated impacts on reef communities. In this study, we are interested in using temperature data and nitrogen stable isotope signatures to quantifying the upwelling regime across three atolls in the archipelago and explore impacts on the benthic reef community. Using high resolution depth-stratified temperature data from loggers recording over a 1.5-year period, we characterise the upwelling regime around the archipelago. Tissue samples of calcifying algae (Halimeda sp) were collected from logger locations upon deployment and retrieval of instruments. Using stable isotope analysis, variation in the δ15N signatures of these algal samples will be investigated to establish whether variability in upwelling is meaningfully impacting reef organisms. At sites with greater upwelling, measured in degree cooling hours (DCH), we expect to see changes in δ15N signatures and altered depth zonation, compared to sites less impacted by upwelling. This work forms the basis of the first chapter of a PhD thesis and is ongoing.

Ecological resilience metrics are robust across data qualities but sensitive to community size

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Abundance indicators, such as the Living Planet Index (LPI), are critical to coral reef monitoring and governing biodiversity change. However, the LPI's biases has been criticised, with resilience suggested to represent a superior representation of ecosystem decline. Resilience is of particular concern for coral reefs due to their capacity to transition between alternative stable states, with resilience loss the primary indicator of an oncoming shift from coral dominance to algal. The ability to generically quantify ecosystem resilience from a timeseries is therefore desirable but has been challenging using empirical data. Novel resilience indicators rooted in dynamical system theory have fortunately emerged to fulfil this need. Here, we collate the cutting edge of resilience indicators and assess their behaviour across data corruptions mimicking the data qualities present in routine reef monitoring using simulated multi-species communities. We demonstrate that their efficacy is robust to both timeseries length and search effort error but are sensitive to the choice of species contributing to the indicator's calculation. Reef managers resultantly have a reliable real-time monitoring tool for ecosystem resilience loss, to whom we provide practical advice and good practice to maximise generic resilience monitoring.

Acropora digitifera bred from parents of known heat tolerance show proteomic differences during a sub-lethal bleaching event

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Assisted evolution using selective breeding has been proposed to enhance the heat tolerance of coral populations faced with marine heatwaves and climate change by exploiting breeding between the most heat-tolerant individuals within a population. Genetic variability in heat tolerance is known to exist within healthy populations (providing material for artificial selection). However, little is known about the mechanisms driving different individual responses to marine heatwave stress. Here, we examine the proteomic response to a natural bleaching event in corals selectively bred for 'low' and 'high' heat tolerance.

Parental Acropora digitifera colonies with known heat tolerance were selected from Mascherchur reef, Palau, and used for selective breeding in April 2018. Offspring from ‘high’ and ‘low’ heat-tolerant parents were kept in a common ocean nursery after an initial rearing phase in aquaria. The offspring experienced a 2-month in-situ marine heatwave in 2020 reaching 6 DHWs. Visual surveys were taken throughout the heat stress to record bleaching and mortality, and 78 colonies were sampled at the peak of the event for photosynthetic pigments, symbiont ITS2 type profiles, and host proteome. There was no coral mortality but paling and bleaching which occurred in 53% of the offspring. The onset of visual responses was more rapid and severe in offspring from high-rather than low-tolerant parents. However, no differences were found in photosynthetic pigments between the two lineages. We found the C40 ITS2 profile dominated the population, although, with a higher proportion of Durusdinium spp. in the offspring from high heat-tolerant parents. The proteomes were distinctly separated between the two groups of offspring, with over 200 differentially abundant proteins identified. Through functional analysis of the proteome, we explore the hypothesis that corals from the ‘high’ heat-tolerant lineage can prevent further damage by bleaching as a controlled protective action against heat stress.

Integrating 3D Printing and Ecosystem-Level Strategies for Self-Sustaining Coral Reef Restoration

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Coral reef ecosystems are facing unprecedented challenges necessitating urgent and innovative restoration strategies. Coral reef restoration has emerged as a pivotal avenue of research, focusing on the development and implementation of strategies to rehabilitate and sustain these intricate ecosystems. However, current approaches are often small in scale, extremely time consuming and one dimensional in focus. The Rapid Resilient Reefs for Coastal Defense (R3D) project will be the first of its kind by taking an integrated, ecosystem-level approach to design and build a living coastal-protection system. The overarching goal of this research is to develop self-sustaining coral reefs that possess the inherent capacity to regenerate and adapt in response to environmental changes. We aim to do this by integrating multidisciplinary techniques and harnessing technological advances such as 3D printing. 3D printing technology allows us to enhance scalability and the creation of custom-designed structures with intricate geometries that optimize coral settlement and survival, provide important habitat for non-reef building organisms, and increase wave attenuation. This project underscores the critical importance of multidisciplinary collaboration in coral reef restoration efforts, emphasizing the role of 3D printing technology in catalyzing innovation. By merging expertise from various fields, this research seeks to contribute significantly to the development of resilient coral reefs capable of withstanding environmental pressures and safeguarding coastal communities.

Re-Imagining Coral Reefs

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Coral reefs play a pivotal role in sustaining the livelihoods of approximately one billion people worldwide, offering both direct and indirect benefits. Regrettably, only a small fraction of the worldwide populace have the privilege to appreciate the enchanting beauty of these habitats firsthand, or to witness the ramifications of their degradation and the efforts undertaken to restore them.

Traditionally, the multifaceted data sourced from these vibrant ecosystems are presented through conventional media and academic publications, somewhat diluting the urgent and hopeful undertakings in coral conservation amidst a prevailing narrative of environmental despair. Simultaneously, the realms of virtual reality (VR) and the metaverse, which are primed to facilitate multi-sensory experiences, remain largely untapped, engulfed by the worlds of gaming and social networking.

To bridge this gap, our multi-disciplinary team—comprising students, architects, and marine biologists—leveraged digital tools commonly employed in spatial design to transform field data from Indonesian coral reefs into an immersive VR environment. This innovation allows users to virtually traverse healthy, degraded, and reimagined coral landscapes, fostering a deeper connection and understanding of these critical ecosystems.

During the poster presentation, in addition to written content, we will present VR and AR models that are complemented by explorations into 3D printed prototyping, with the entire developmental trajectory captured on film. This enterprise, which laid the foundation for a summer school in 2023 and was exhibited in central London, aspires to evolve into a robust educational instrument for practitioners of coral reef restoration, as well as enthusiasts keen to immerse themselves in the wonders of coral habitats.

By harmonising technology and conservation, we aspire to engender a new wave of environmental stewardship, fostering a more profound connection between individuals and the irreplaceable coral ecosystems that grace our planet.

What's on the menu? Effects of seabird-mediated nutrients on parrotfish nutritional resources, substrate preferences and feeding behaviour.

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From the arctic tundra to mangrove islands and coral reefs, seabirds mediate nutrient availability enhancing primary productivity and shaping entire food webs. Nutrients deposited as guano at seabird rookeries leach to adjacent waters supporting coral reef health and important ecological functions. Around islands with seabird colonies, primary producers (e.g., algae and corals) and consumers (e.g., herbivorous fish) assimilate these allochthonous nutrients which can lead to a higher overall biomass of coral reef fishes and faster growth rates of parrotfish as compared to islands without seabirds. However, the pathways by which seabird nutrient subsidies alter parrotfish demographic rates and the wider implications for key geo-ecological functions (e.g., bioerosion) performed by parrotfish are not well understood. Parrotfish target epilithic and endolithic phototrophs which colonise carbonate substrates, predominantly protein-rich cyanobacteria. Therefore, we hypothesise that seabird-mediated nutrients may increase the availability and quality of microscopic phototrophs targeted by parrotfish, and consequently, affect feeding substrate selection, feeding rates and the behaviour of parrotfish. Using an inter-island seabird gradient in the Seychelles and Chagos archipelagos, we focus on this unexplored link by combining in situ quantification of feeding rates and behavioural observations with microscopy of feeding substrate cores, substrate imagery analysis and nutrient content investigation. Preliminary results from the microscopy of substrate cores show distinct patterns in the abundance and diversity of epi- and endolithic assemblages at seabird-rich versus seabird-free islands. For example, cores of the parrotfish Scarus rubroviolaceus at a seabird-rich site showed higher densities of some cyanobacteria genera, such as Calothrix, Phormidium, Spirulina and Leptolyngbya, as well as pennate diatoms. Although data processing and analysis is still in progress, these early results may suggest a bottom-up regulation of parrotfish nutritional resources by seabird-mediated nutrients.

Factors limiting range edge populations of the pink sea fan (*Eunicella verrucosa*)

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The Pink Sea Fan (Eunicella verrucosa), a Gorgonian cold-water octocoral, inhabits a range extending from the north of Ireland to the Mediterranean Sea. Recognized as a priority species within the UK Post-2010 Biodiversity Framework and a Species of Principal Importance under the UK Wildlife and Countryside Act 1981, many marine protected areas (MPAs) in the UK are designed to safeguard priority species like the Pink Sea Fan. However, to effectively design MPAs and protect our enigmatic marine fauna, a comprehensive understanding of population connectivity and limiting factors at range edges is imperative.

Our multidisciplinary research approach integrates molecular ecology, histology, and ocean dynamic modelling to unravel the Pink Sea fans' life history and connectivity. The molecular ecology approach employs whole genome sequencing (WGS) to capture genetic variations across the species' range and at its edges. This enables us to explore fine-scale connectivity patterns and evidence of genetic adaptation to environmental extremes at range edges.

Histological analysis aims to determine the timing of gonadal development, elucidating reproductive processes, and determining growth rates and temperature-related pelagic larval duration (PLD).

Additionally, we are developing partial tracking models (PTM), to simulate connectivity throughout the species' range. PTMs help identify key populations that uphold gene flow to edge populations, adding a contemporary component to support our genetic research. Furthermore, these models facilitate the assessment of particle dispersal within suitable habitats, offering insights into potential settlement regions and the potential for range expansion or contraction.

In summary, our research aims to evaluate the current effectiveness of the MPA network in preserving connectivity within the Pink Sea Fan populations. By integrating genetic insights, biological data, and modelling techniques, we strive to contribute valuable information for the conservation of this remarkable species and the preservation of marine biodiversity in the UK and beyond.

Progress, Pitfalls and Successes of community led Coral Restoration in the Pacific

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Pacific Island Communities (PICs) have been resilient in the face of natural disasters, with coral reefs and mangroves, acting as natural barriers to storms and hurricanes. Climate change has increased the frequency and severity of such events. Other climate change consequences such as sea level rise, ocean warming, ocean acidification and reduced biodiversity on reefs is testing the resilience of these remote communities.

The Climate Resilience by Nature (CRxN) project is a partnership between Kyeema Dawn Foundation, Corals for Conservation and Just World Partnerships. With the majority of funding provided by the World Wildlife Fund. The project supports and empowers young indigenous scientists and community leaders in their fight against climate change through education and facilitation of locally managed affordable nature-based solutions.

This has included holding a workshop where 19 Pacific island marine scientists attended. Building on their current knowledge they were taught how to select potential coral nursery sites and the various methodologies to construct coral nurseries. Attendees were invited to write and submit a budgeted proposal to set up nurseries within their villages. Six proposals were submitted covering eight potential sites across Papua New Guinea (PNG), Samoa and Fiji. All of these projects have since received funding.

Further community training in additional livelihoods was held on Yule Island in PNG and Montorki in Fiji. This training included learning how to set up coral nurseries, rearing free range chickens (an alternate protein source to fish), seaweed farming and discussion about implementing local marine protected areas as well as other sustainable farming practices.

We aim to explore the progress, pitfall and successes of this pan Pacific project. Looking specifically at how engaging with communities through empowerment can lead to productive and sustainable coral reef conservation and management through restoration and monitoring programmes, along with other sustainable reef and livelihood practices.

Seabird nutrient enrichment effects on cryptobenthic fishes

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The world's smallest vertebrates, cryptobenthic reef fishes, play a critical role in coral-reef ecosystem functioning. Their high abundance, rapid growth, larval dynamics, and extreme mortality underpins reef productivity, by converting hard-to-access food sources to readily accessible nutrients for larger reef consumers. These fishes' life-history traits make them highly vulnerable to environmental disturbances: in particular, their limited dispersal and rapid turnover expose them to risks of rapid genetic isolation and local extinction. Here, we study how variation in nearshore nutrient subsidies affect these fish communities. We compared two sites located in Fregate Island, Seychelles, that differ in seabird-related nutrient inputs, and used stable isotope analyses both on end-members (turf algae, macroalgae, sponge) and select species of cryptobenthic fish to explore how nutrient loads affect these fish communities. We show that while fish communities remain similar across both sites, they exhibit higher reliance on benthic nutrient sources as opposed to pelagic sources when located close to seabird colonies. Overall, higher δ15N close to shore near seabird colonies suggests that cryptobenthic fish rely directly on seabird-derived nutrients close to shore, and mixing models highlight that benthic nutrients can reach farther into reefs when coupled with seabird inputs. This study underlines the important role of seabirds for oligotrophic reef ecosystems, and evidences how cryptobenthic fish can transfer these nutrient subsidies to larger predators. With increasing anthropogenic pressure on reefs, including the threat of invasive species to seabirds, evaluating the response of cryptobenthic fish to localized environmental variations is a critical step in elucidating how these chronically understudied fish may influence coral reefs' future.

The use of acoustic cues in clown anemonefish social hierarchies

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The development of sensory systems to detect and respond to stimuli has been key in evolution by allowing the exchange of information between individual and its surroundings. Fish represent 35% of the total chordate biomass and half of vertebrate species but knowledge about acoustic communication in fishes is limited compared to other groups. One group of fish that is ideal to study fish acoustic cues is anemonefishes of the genus Amphiprion. Anemonefishes can hear sounds between 75 and 1800 Hz, with the most sensibility to frequencies below 200 Hz and produce a wide variety of sounds using their jaw teeth and vibrations from their rib cage, which generates variation in their vocalizations related to their body size. Sounds seem to be used for territorial defence, but it is unclear whether sounds are used in a social context such as communication within the group, establishing dominance and assessing competitors within the group, reproductive activities, or individual recognition. Thus, sound may be key to maintain their strict hierarchical structure. The aim of this PhD project is to fill this knowledge gap and understand the role of acoustic signalling in clownfish groups. The study will involve field experiments in Papua New Guinea. The methods include the setup of GoPros to record group behaviour and Audiomoths to record audio data in the field using both breeding and non-breeding clown anemonefish groups.

Differential responses to heat wave scenarios reveal species-specific physiological resilience in common Red Sea corals

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The increasing frequency and severity of marine heat waves constitute a major threat to coral reefs, resulting in the global loss and degradation of coral reef ecosystems and their ecological functions. Corals' abilities to resist and recover from stress, i.e. their resilience capacity, greatly influence how strongly a reef is affected. In the Gulf of Aqaba (GoA), northern Red Sea, various marine taxa display exceptionally high thermal thresholds, making it a potential reef refugium from climate change. To better understand the physiological mechanisms involved in resilience, common reef-building coral species from the GoA were exposed to two simulated marine heat wave scenarios (+3-4°C and +7-8°C above ambient seawater temperature), followed by a recovery period. Among the three species examined, *Stylophora pistillata* was the most sensitive and showed distinct responses between treatments. While photosynthetic parameters were enhanced at +3-4°C, severe bleaching was recorded at +7-8°C, from which it recovered partially. *Pocillopora verrucosa*, in contrast, showed minimal responses overall, signifying an extraordinary thermal resistance through physiological plasticity. Massive coral *Porites lobata* appeared initially robust to thermal stress, but showed a delayed bleaching response, potentially linked to longer-term variations in photosymbiont physiology and density. These species-specific stress and recovery responses reveal bleaching resilience capacities and mechanisms varying between taxa, and how these may shape future coral reef communities.

The long-term effects of abiotic and biotic stressors on the population dynamics and reproduction of anemonefishes

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Coral reef fishes are increasingly threatened by changing environments, with research noting negative impacts on fecundity, habitat selection, metabolic performance, and predator responses when coral reef fishes are exposed to environmental stress. Given projected future increases in the intensity of multiple environmental stressors on coral reef ecosystems, researching how multiple abiotic and biotic variables interact to impact fitness and population dynamics will be crucial to determining resilience and vulnerability among coral reef fishes. Here, we use an emerging model for marine fish ecology, anemonefishes, to study responses to environmental stress among coral reef fishes with high site fidelity. We measured abiotic and biotic variables (temperature, irradiance, turbidity, and pH) at the level of individual anemonefish groups along environmental gradients, such as distance from river mouths, in Kimbe Bay, Papua New Guinea. Additionally, long-term abiotic logging stations measured abiotic factors (temperature, irradiance, salinity, and current) at regular intervals throughout the study period. Repeated measurements of anemonefish sizes and their host growth, reproductive output, recruitment, and health parameters were collected for six lunar months, representing six reproductive cycles. The resultant environmental stressor profiles allow identification of habitat-specific environmental pressures, in addition to revealing their temporal intensity and stability. Moreover, two significant environmental disturbance events occurred during the study period, allowing comparisons before, during, and after the occurrence of disturbance events, including flooding and bleaching. The study outcomes will help to determine which life stages are most vulnerable to the environmental stressors and disturbances related to climate change, and will also reveal which coral reefs will become most inhospitable to site-dependent coral reef fishes as environmental stressors continue to pressure coral reef ecosystems.

Understanding and predicting present and future coral reef distribution via multimodal machine learning

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Coral reefs are complex systems on which millions of people rely for food, protection from coastal storms, and income from tourism. Coral species – and the biodiversity they support – are threatened with functional extinction over the coming decades due to coastal pollution, mechanical damage, and the sustained ocean temperature rises and ocean acidification driven by anthropogenic greenhouse gas emissions.

Reef conservation efforts over wide areas are limited by their substantial resource demands. Robust, quantitative methods are necessary to direct these efforts to areas where future environmental conditions will be most conducive to long-term coral growth, and inform more radical conservation methods such as assisted migration. To predict future environmental suitability, it is first necessary to understand how historic environmental conditions have resulted in the present-day distribution of coral reef systems.

This work explores the ability of multimodal machine learning methods to predict the present-day distribution of coral on the Great Barrier Reef using three decades of environmental data. It builds on comparable literature by implementing more sophisticated machine learning models, and by increasing the spatial and temporal resolutions of input data to scales more relevant to ongoing conservation initiatives. This also results in greater predictive performance than previous methods.

Future work will apply these machine learning methods to the output of global climate models to determine forecasted environmental suitability, emphasising interpretability and explainability. The project aims to assist in the optimisation of current coral conservation initiatives, offering a vital contribution to the preservation of the biodiversity and ecosystem services of coral reefs.

Ecological Significance and Multifaceted Challenges of Arabian Gulf Coral Reefs

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Arabian Gulf coral reefs stand out as vital ecological assets due to their exceptional resilience to harsh environmental conditions. This region has garnered significant scientific attention, serving as a focal point for understanding coral reef persistence in a changing world. Summer temperatures in the Gulf routinely surpass 35°C, while winter brings lows of 13°C, rendering it a natural laboratory for coral adaptation studies. Despite their tenacity, these reefs have witnessed extensive bleaching episodes over the past decade, attributed to rising sea temperatures and various stressors. Population-related pressures are among these stressors, resulting in noticeable shifts in coral physiological responses. Although corals display adaptability, the escalating stressors have led to a surge in coral bleaching, threatening this delicate ecosystem. Numerous studies have probed the link between rising temperatures and coral bleaching in the Arabian Gulf, yet critical knowledge gaps persist, necessitating ongoing research to address emerging inquiries. Secondary stressors, notably elevated nutrient levels such as phosphate and nitrogen pollution, exacerbate the frequency and severity of bleaching events. Scientific interest in comprehending the influence of physical extremes on Gulf coral reef communities has spurred the development of research programs, with the United Arab Emirates taking a lead role. The resilience and adaptability of Arabian Gulf coral reefs offer optimism and valuable insights for global coral preservation efforts. To safeguard the survival of these reefs in the face of complex environmental challenges, collaborative efforts between developers, research institutions, and cross-border initiatives are essential. Given their vulnerability to climate change in this intricate landscape, ongoing monitoring, research, and cooperative strategies are critical for preserving their ecological significance and resilience. As the effects of climate change unfold, the Gulf's coral resilience and adaptability offer valuable insights that can guide global coral preservation endeavors.

Poster

Inconsistent Coral Bleaching Risk Indicators Between Temperature Data Sources

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Coral reefs are facing severe threats and are at risk of accelerated decline due to climate change-induced changes in their environment. Ongoing efforts to understand the mechanisms of coral response to warming rely on multiple sources of temperature data. Yet, it remains uncertain whether the Sea Surface Temperature (SST) data used for coral reef studies are consistent among different data products, despite potential implications for conservation. A better understanding of the consistency among the different SST data applied to coral reefs may facilitate the fusion of data into a standard product. This will improve monitoring and understanding of the impact of global warming on coral reefs. Four types of SST data across North-Western and South-Western Australia are compared to assess their differences and ability to observe high thermal stress during historical coral bleaching events. The four SST data sources included those derived from Global Circulation Models, NOAA CoralTemp SST product, ESA CCI SST product, and coral core derived SST. Coral bleaching risk indicators, Degree Heating Week (DHW), and Degree Heating Month (DHM) were calculated using these sources and compared for consistency. DHW and DHM were inconsistent among data sets and did not accurately reflect high thermal stress metrics during moderate and severe bleaching events. Some reefs did not experience bleaching in spite of high DHWs and DHMs, suggesting a mismatch in data scales, or perhaps other oceanographic factors and coral adaptation. By exploring the differences and similarities among these four data sources, this study highlights the need to compare existing indicators of thermal stress from different data sets.

Trophic ecology of corals under high turbidity regimes in Singapore

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Scleractinian corals are the dominant reef-building taxa on coral reefs and typically thrive in shallow and nutrient-poor tropical oceans. Yet, recent studies have highlighted that corals are not solely confined to clear-water regions, with extensive coral growth occurring in marginal coastal areas characterised by high terrestrial sedimentation and nutrient inputs (i.e., turbid coral reefs). Corals are sustained by a combination of autotrophy (via symbiosis with photosynthetic dinoflagellates) and heterotrophy (via particle capture and assimilation of dissolved compounds). As light availability is significantly reduced within turbid environments, it is hypothesised that turbid corals may exhibit a greater degree of heterotrophy in order to meet their nutrient requirements. This suggests a difference in the relative importance of the algal endosymbionts in coral nutrient acquisition under turbid versus clear water settings, which may underpin bleaching resilience and reef development. However, trophic strategies of turbid corals, and the relative importance of their algal endosymbionts, is poorly understood. This is due to the lack of studies quantifying nutrient acquisition strategies for turbid coral genera. Here, we gain a comprehensive understanding of the trophic dynamics for thirteen coral genera covering five different growth morphologies from highly turbid reef sites in southern Singapore. Trophic dynamics were quantified using bulk stable isotope measurements (δ13C and δ15N) and isotopic niche analysis of coral tissue and symbionts, further supplemented by local water quality data. Our results define the extent of heterotrophy in largely unstudied coral species, revealing a range of mixotrophic strategies employed by the different coral genera in Singapore, and suggests that turbid corals might not be as heterotrophic as previously assumed.

Same but different: Intraspecies variation in demographic performance among cryptic Pocillopora species

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Anthropocene jeopardizes a sustainable future for coral reef ecosystems, urging the identification of functional and genetic diversity changes that may relate to a populations' capacity to avoid regime shifts. Assessing the response diversity of scleractinian corals is sometimes hindered by the indistinguishable morphology of cryptic species that live in sympatry. The Pocillopora genus is famous for hosting cryptic species and is widely distributed across environmentally varied ecoregions throughout the Indo-Pacific. However, morphologically similar cryptic species may possess different, yet unknown strategies and demographic performances. Here, we tackle this issue to evaluate how genetic variation underpins response diversity and divergent population resilience.

Our research examined 1) the richness of Pocillopora haplotypes in Taiwan; 2) the composition of haplotypes across environments; and 3) their link to demographic performances by combining information from genetic sequences and their vital rates. The mitochondrial Open Reading Frame (mtORF) showed a diversity of Pocillopora haplotypes among regions and across environments. The diversity of Pocillopora haplotypes was associated with the contrasted growth rates between marginal to reef accreting environmental settings. Our results provide a unique lens of the diversity in Pocillopora, identifying contrasting demographic responses between cryptic species, and improving our understanding of how it could affect community resilience in response to future climatic change.