Reef Conservation UK 2016 Abstract booklet

Oral presentations

Plenary presentation:

Reflections on coral studies and introducing a big website

John 'Charlie' Veron

I have been working on corals for nearly fifty years, undertaking expeditions to most major reef regions of the world. The first decade was mostly spent on the Great Barrier Reef, changing the focus of coral taxonomy from the museum to the reality of the reef. Biogeographic studies further afield led to the discovery and delineation of the Coral Triangle and thence to the concept of reticulate evolution, a frontier theory for both disciplines.

Over the past two decades I have become increasingly alarmed about the projected demise of corals, currently as a result of mass bleaching and, in decades to come, ocean acidification. Attempts to raise public and political awareness of these looming catastrophes have prompted extensive mass media presentations and relevant publications.

During the past decade my colleagues and I have built the open access website www.coralsoftheworld.org now publicly available in draft form. With its all-dominating focus on the real world, this website is designed to provide a platform for current and future research and to use the best science to answer questions urgently needed for coral conservation.

Session I

Evidence of coral resilience during the recent ENSO-induced warming on the turbid-zone reefs of the central Great Barrier Reef, Australia

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During the 2015/16 ENSO-induced warming event, widespread coral bleaching was reported on Australia's Great Barrier Reef (GBR). Aerial-based surveys conducted along the entire 2,300 km length of the reef indicated that >90% of reefs exhibited signs of bleaching. Coral bleaching was especially pronounced on the reefs of the northern and central sectors of the GBR. However, despite the large number and spatial extent of the GBR's bleaching assessment, many reefs remained unsurveyed. Of particular note was the absence of data from those reefs located within turbid nearshore environments, and which are of particular interest as such reefs have recently been identified as potential climate change refugia – a hypothesis that remains to be tested. Despite the influence of terrigenous sediments, average live coral cover on the nearshore reefs of the central GBR, prior to the ENSO event, was high (mean ~40%) and coral assemblages diverse (21 genera). In August 2016, and building on previous detailed assessments of these reefs in 2013 and 2014, we undertook a further ecological assessment to quantify the extent of bleaching-induced mortality across five individual nearshore, turbid reef systems on the central GBR. Here we present the initial findings of this work. Significantly, we report no evidence of bleaching-induced mortality on any of the surveyed reefs. Interestingly, we also note no bleaching of typically susceptible taxa such as *Acropora* and *Montipora*. These results thus point to high a level of resilience within nearshore coral communities on the central GBR, and provide evidence to support the emerging turbid-zone reef climate change refugia hypothesis.

Disentangling the effects of global and local stressors on Pacific Island coral reefs

Amanda Ford
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To effectively address coral reef degradation, managers require a holistic knowledge on the relative effects of global and local stressors on the ecosystem. Human populations on Pacific Islands rely heavily on services derived from reef ecosystems, making this area an urgent research priority. Using a spatially extensive data-set covering 185 Pacific Island reefs spanning 63 locations, we investigated the main drivers of benthic community structure and differences in predominant coral growth forms within both inner and outer reef habitats. Data were collected between 2003 and 2008 using consistent methodologies which included surveys into benthic community composition, fish biomass and local socioeconomics (i.e. local human density and reliance on fishing). Additional drivers for thermal stress exposure (i.e. degree heating weeks over the previous 12 years), storm occurrence and inorganic nutrient levels were extracted from available global data-sets. Based on benthic community composition, a principal components analysis differentiated reefs with 'undesirable' characteristics such as high dead coral and fleshy algal cover from 'desirable' reefs displaying high live coral and crustose coralline algal cover across the first principal component. Percent cover of algal turfs was separately explained by the second principal component. Preliminary results from model selection indicate that timing of the survey was the most important predictor of community structure in both reef habitats, with later sites displaying more 'desirable' characteristics associated with different morphological compositions. Global factors (thermal stress exposure and storm occurrence) were generally ranked as stronger drivers compared to local factors (inorganic nutrients and local human density). Different functional groups of herbivorous fish played roles of varying importance in each reef habitat. We anticipate that our results will inform managers on how different drivers affect key benthic groups in inner and outer reef environments on Pacific Islands, allowing for more targeted management decisions in this region in the future.

Decadal trends in community structure of the coral reefs of the Chagos Archipelago

Professor John R Turner, Bangor University

The remote reefs of the mostly uninhabited Chagos Archipelago serve as an important reference site, providing a benchmark for reversing damaged ecosystems elsewhere. *Most importantly, they allow impact of climate change to be assessed in the absence of local anthropogenic impacts.* Coral and fish communities are largely intact and functional, but have been subjected to more frequent extreme warming events in 1997, 2010, 2015 and 2016, and occasional COT outbreaks (eg. 2013). Since 2006, video surveys to 25m depth at 25 permanent monitoring sites across the atolls of the archipelago have been undertaken to establish an archive of community structure. The northern atolls exhibit higher coral cover (~40-50%) than the southern atolls (~30%) with increasing algal and soft coral cover with depth, and atoll lagoons exhibit greater hard coral cover than seaward reefs at all depths. Coral mortality was detected in atolls with enclosed lagoons following warming events in 2010 and 2013 but was absent from well-flushed atolls. North western seaward coral reefs are dominated by 2-3m diameter colonies of *Acropora* tables, most having re-established since the 1997 ENSO event. By 2013, senescence was apparent in the largest of these (~10%) and by 2015 many had collapsed and been removed from the reef. *Acropora* White Syndrome (AWS) was identified in 2014 (~5% prevalence) and AWS increased at some northern atolls in 2015 (to 22% prevalence). Reassessment of archived video from 2006 confirmed *that AWS was a new threat to the reefs of Chagos despite their relative isolation*. Assessments of coral recruits (~40% being tabular *Acropora* species) indicate that *the capacity for recovery is good*, although many are lost when dead coral substrate is removed from the reefs. The longer term resilience of the Chagos Archipelago reefs will have been severely tested by the 2016 warming event and awaits further study.

The role of microbiome in thermal tolerance of the Red Sea corals

Eslam O. Osman[1, 2]; David J. Suggett[1, 3]; Christian R. Voolstra[4]; D. Tye Pettay[5]; Mark E. Warner[5]; David J. Smith[1]

Coral reefs are immensely vulnerable to climate change and the effects of ocean warming, acidification and deoxygenation; in efforts to understand whether and how reef systems will survive into the future, research is increasingly focusing on present day populations acclimatized to thrive under relatively extreme conditions. Whilst corals thrive along a range of environmental conditions, including relative extremes, within the Red Sea, these coral populations are still considered somewhat of a "black box" of the genetic and physiological signatures throughout this system. Coral microbial communities (the "microbiome") are recognized as a major component as to how corals

"acclimatize" to different environmental conditions; therefore, this work aimed to investigate the historical thermal variability along the Red Sea and subsequently identify the relative role of coral endosymbiont identity versus bacterial community associated with differences in coral thermal tolerance. Remotely sensed data (1982-2012) intriguingly demonstrated a migration of Sea Surface Temperature anomalies (i.e DHW) from the south to the north during this time frame. Analysis of historical leaching records indicated that coral populations were more tolerant to bleaching compared to the southern Red Sea. *Symbiodinium* clade type (ITS2) and microbial community (16S metagenomics) associated with six key coral species persisting across five sites of the northern Red Sea (29˚-20˚N) were then examined. *Symbiodinium* clade identity associated with each coral species generally remained highly conserved throughout the sites sampled. In contrast, microbial communities were variable within and between species across Red Sea sites, and putative functional roles of this changing microbiome across different thermal regimes is currently being explored. Corals from two sites (central-Jeddah and northern-Hurghada) were exposed to a thermal stress experiment which confirmed that corals were more heat resistant at Hurghada (annual SST mean is 3.3 ˚C less) than Jeddah; however symbiont types were identical at both sites. Our findings suggest that higher latitudes of the Red Sea will broadly serve as a potential coral refugia as sea surface temperatures continue to rise.

Pan-ocean photophysiological plasticity in coral reefs

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The oligotrophic nature of tropical coral reefs means that light is vital to reefal productivity, supporting the development of reef frameworks and multi-trophic communities. Photosynthesis also plays a major biogeochemical role and significantly contributes to the natural environmental variability observed in reef environments. Photophysiological processes therefore hold the key to understanding reef functioning, from the individual to ecosystem levels. We have investigated the photophysiological plasticity of coral reef primary producers (corals, fleshy macroalgae, and crustose and free-living coralline algae) in the Red Sea, Indian Ocean and Caribbean, in response to spatiotemporal changes in environmental conditions. We find that strategies such as dynamic photo-inhibition allow typically low-light adapted organisms to survive high-light conditions via pigment modification and secondary metabolite production. Depth gradients highlight specific strategies for maximising photosynthetic efficiency despite reductions in light availability in deeper waters. Photophysiological plasticity may help to explain why some studies have found that calcifying organisms are not as sensitive to projected environmental change as might have been predicted. Importantly, non-calcifying photosynthesisers such as fleshy macroalgae and seagrasses also harbour significant photophysiological plasticity in response to varying environmental conditions. This supports the suggestion that non-calcifying organisms will benefit from elevated CO_2 conditions, fuelling concerns over future shifts towards macroalgal-dominated reefs.

Ancestral symbiont diversity has enabled rapid adaptation of reef corals to climate change

Prof. Dr. Jörg Wiedenmann
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Corals communities in the Persian / Arabian Gulf (PAG) withstand regular summer maxima of up to ~35^{o}C, temperatures that kill conspecifics elsewhere. Due to the recent formation of the PAG and its subsequent shift to a hot climate, these corals have had only <6k years to adapt to these extreme conditions and can therefore inform on how coral reefs may respond to global warming. Key to coral survival in the world's warmest reefs are symbioses with a newly discovered alga, *Symbiodinium thermophilum*. Currently, it is unknown whether this symbiont originated elsewhere or emerged from unexpectedly fast evolution catalysed by the extreme environment. Here we show that the rapid temperature adaptation of PAG corals was facilitated by the positive selection of preadapted symbionts. Analysing genetic diversity of symbiotic algae across > 5,000 km of the PAG, the Gulf of Oman and the Red Sea coastline, we established that *S. thermophilum* is a member of a highly diverse, ancient group of symbionts cryptically distributed outside the PAG. We conclude that maintaining the largest possible pool of potentially stress tolerant genotypes by protecting existing biodiversity is crucial to promote rapid adaptation to present-day climate change, not only for coral reefs but for ecosystems in general.

Coral bleaching affects the Maldives Archipelago again in 2016: How does this event compare to 1998 and has the previous event shaped the patterns we see today?

Benjamin Cowburn, IUCN Maldives

April 2016 was the most significant mass bleaching event in the Maldives archipelago since 1998. The reefs around 12 islands in North Ari atoll, Maldives were assessed for bleaching impact. The mean coral cover bleached from the 12 islands surveyed was 54% (SE±3.9). The island with the highest proportion of bleached corals was Velidhu with 75%, and lowest in Maalhos with 30%. Reefs were assessed between 3 depth layers, shallow (2-5m), mid (8-12m) and deep (30-20m) and it was found that deeper reefs bleached less severely both in the amount of coral bleached and the intensity of bleaching. Pete Mumby's spatial ecology lab modelled the vulnerability of all reefs in the Maldives at a 4 x 4km resolution, based on their past experience of chronic and acute thermal stress in 1998. The predictive power of this model for explaining the bleaching experienced in 2016 is investigated, along with novel climate indicators. The ecological and climatic variation between islands is used to explore whether any 'climate refuges' exist, to try and identify where corals may stand the best chance of surviving a future in of ever rising sea temperatures.

Coral Histology: An Investigation into the Cellular Mechanisms of Coral Bleaching in The Andaman Sea, Phuket, Thailand

Lorna Wilkinson (MSc), Newcastle University

Coral bleaching is a major contributor to coral mortality, having the potential to cause reef degradation and trigger ecosystem collapse. Since the first regional bleaching events, which were documented in 1979, coral bleaching has increased in both intensity and frequency over large spatial scales. Episodic coral bleaching events have been documented in the Andaman Sea, Phuket, Thailand, in 1991, 1995, 1998, 2003 and 2010 since regular coral reef monitoring began in the early1980's.
This study presents histological examination of the reef building coral *Acropora hyacinthus*, during a natural bleaching event in Phuket. Monthly sampling carried out before-during-after bleaching exhibited progressive histopathological abnormalities in the host tissues resulting in a complete loss of zooxanthellae population densities. The results reported here highlight 2010 as the most severe bleaching event to be documented so far for a region that has previously been considered as particularly resilient. The clear temporal disparity between visible and physiological bleaching response at the cellular level provide evidence for local thermal thresholds to be established using histopathology as an early indicator of organism response.

Session II

Seabirds enhance reef productivity in the absence of rats

Nicholas A J Graham[1,2,*], Shaun K Wilson[3,4], Pete Carr[5], M. Aaron MacNeil[6,7], Simon Jennings[8,9]

Islands in the Chagos Archipelago differ markedly depending on whether rats are present or absent. In the presence of rats there are few seabirds, whereas in the absence of rats dense breeding seabird colonies exist, with the identification of 10 Important Bird Areas (IBAs). This study investigates the spatial nutrient subsidy that seabirds bring from the open ocean to the adjacent coral reef environment. We studied 12 islands in Chagos in 2015, six with rats and six with no rats. As predicted, there were huge differences in seabird colonies, with an estimated total nutrient input per reef area two orders of magnitude greater for islands with no rats. Using stable isotopes of nitrogen ($\delta^{15}N$), we demonstrate that soil and leaves from a coastal plant had substantially elevated nitrogen loads on islands with seabirds. On the reef flat ~100m from shore, filter feeding sponges and *Halimeda* algae had smaller, but still substantially enhanced nitrogen loads on islands with seabirds. On the reef crest ~200m from shore, turf algae and muscle tissue from a herbivorous damselfish had greater nitrogen loads on the islands with seabirds. Using otoliths from the herbivorous damselfish, we demonstrate that the fish are growing more rapidly on the islands with seabird nutrient subsidies. Underwater visual census along the reef crest confirms this pattern at a community scale, with greater biomass of all fish functional groups on the islands with seabirds, with the greatest effect for herbivorous fish. This study highlights the critical role seabirds play in enhancing the productivity of coral reefs adjacent to oceanic islands. De-ratting of islands in places like Chagos will not only be beneficial to terrestrial biodiversity, it will also have a substantial positive impact on adjacent marine ecosystems.

Contrasting effects of benthic algae on microenvironment of coral-algal interactions

Hendrikje Jorissen, Christina Skinner, Ronald Osinga, Dirk de Beer, Maggy M. Nugues
Ecole Pratique des Hautes Etudes

The spatial competition between reef-building corals and other benthic, sessile organisms and the outcome of these interactions, is one of the main drivers in structuring reef communities. Recently many of the worlds coral reefs have shifted from coral to algal dominance. The consequences however, of such a transition, for coral-algal competitive interactions and their underlying mechanisms remains poorly understood. At the microscale specifically, it is unclear how diffusive boundary layers (DBLs) and surface oxygen concentrations at the coral-algal interface vary with algal competitors and competitiveness. In this study, we used field observations and microsensor measurements in a flow chamber, to show that coral (massive *Porites*) interfaces with thick turf algae, macroalgae and cyanobacteria, which are successful competitors against the coral in the field, are characterised by a thick DBL and hypoxia at night. While in contrast, coral interfaces with poorer competitors, such as crustose coralline algae, conspecifics and thin turf algae, were found to have a thin DBL and low hypoxia at night. Furthermore, we found that increasing water flow speeds reduced DBL thickness and hypoxia at the interface, but not when thick turf was upstream. Our results support the importance of water-mediated transport mechanisms in coral-algal interactions. Increasing algal dominance, particularly denser assemblages, will be associated with thicker DBLs, higher hypoxia and higher concentrations of harmful metabolites and pathogens along coral borders. This in turn will facilitate algal overgrowth of live corals. These effects will also be influenced by abiotic factors, such as flow speed and position of the algae relative to the coral.

Species interactions through space and time

Sally A. Keith, PhD, Assistant Professor, Center for Macroecology, Evolution & Climate, University of Copenhagen

As a high diversity system, the interplay of multiple species is an essential component of coral reefs. Our understanding of how and why species interactions vary through space and time, and the subsequent influence on species distributions over biogeographic scales, is extremely limited. To begin to reveal the role for biotic interactions in biogeography, I am using Indo-Pacific butterflyfishes as a model system. My team has so far observed >3000 interactions amongst 34 species of butterflyfishes across four countries, three of which are regions of overlap between different biogeographic provinces. We focus on aggression and feeding behavior to tease apart the potential for species interactions to set biogeographic borders, maintain high diversity systems, and mediate the response to severe disturbance events. Here, I will share some preliminary results that show aggression networks and feeding behaviour are strongly context-dependent. These results highlight the need to understand the link between species interactions and biogeographic patterns more clearly so we can improve forecasts of species' responses to environmental change into the future.

Productivity-driven shifts in coral reef benthic communities: when is there too much of a good thing?

Dr Gareth J. Williams, School of Ocean Sciences, Bangor University

Changes in primary productivity have pronounced effects on coral reefs. In some instances, evidence suggests a positive effect of increased pelagic productivity and associated particulate food availability on the cover of calcifying benthic organisms (e.g. hard corals, crustose coralline algae). In contrast, extreme levels of primary productivity can often lead to undesirable regime shifts where fleshy macroalgae dominate. Identifying the conditions under which increases in primary productivity switches from being beneficial to reef-calcifiers versus leading to their demise is a research priority. Using a series of unpopulated Pacific reefs and by combining high-resolution in situ oceanographic measurements, oceanographic models, benthic community surveys, and statistical modelling, we explore the effects of changing levels of primary productivity on benthic community structure. We show increases in particulate food supply driven by local oceanographic processes, such as internal waves and downwelling, can correlate with higher heterotrophy in hard corals and their overall dominance as benthic competitors. The relationship between nutrients and coral dominance has a limit; at the extreme, these same oceanographic processes of nutrient delivery operating at similar intra-island spatial scales can elevate primary productivity to such a degree that corals lose the battle for space on the reef floor, resulting in stable regime shifts to fleshy macroalgae. Here we discuss at what point along the primary productivity axis these dramatic shifts in benthic organisation occur.

An integrated ecosystem assessment to identify biological signals of the island mass effect

Beth Francis, Bangor University

Phytoplankton production is known to drive marine ecosystem trophic-structure and impacts on global fisheries yields.
Phytoplankton biomass is particularly influential near coral reef islands and atolls that span the oligotrophic tropical oceans. The paradoxical enhancement in phytoplankton near an island-reef ecosystem — The Island Mass Effect (IME) — was first documented 60 years ago, yet much remains unknown about the knock-on biological effects of this ecologically important phenomenon.
Coral reef islands and atolls across the Hawaiian Archipelago have shown a particularly pronounced IME, with nearshore concentrations of phytoplankton on average 30-85% higher relative to open ocean conditions. This equates to a higher food delivery to primary consumers on the reef, which in turn may support increased diversity and abundance of higher trophic levels.
However, despite this seemingly critical role of productivity in driving ecosystem structure on coral reefs, little is understood about how biological communities change along these productivity gradients driven by the IME.
Using integrated ecosystem assessment data collected over a 5-year time period in West Hawai'i, we illustrate differences in biological community structure at multiple trophic levels along an offshore-onshore gradient in phytoplankton biomass, at numerous sites, and depths spanning the mid-scattering layer (~200m) and the deep-scattering layer (~500m).
Using these data, we hope to present the first quantitative assessment of the biological signals of the IME along the coastline of a coral reef island in the Hawaiian Archipelago.

Dispersal vs environmental controls on scleractinian coral species assemblages

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Assemblages of reef-building corals exhibit regional differences in species composition yet the drivers of these differences are unresolved. Environmental factors and habitat availability only poorly predict the location of large-scale biogeographic borders, where multiple species reach distributional limits. In contrast, these borders align well with geographic features. However, the role of dispersal in generating and maintaining biogeographic patterns through barriers to, or highways for, range expansion is unknown. To bridge this knowledge gap I test the extent to which coral dispersal driven by ocean currents could contribute to differences in species assemblages across the Indo-Pacific. To assess the relative importance of dispersal to other hypothesised mechanisms, I compare the role of dispersal against that of environmental conditions. Specifically, I quantify the correlation between assemblage similarity metrics amongst reef clusters against a) a network that represents potential connectivity between reef clusters, and b) similarity in environmental conditions. I apply the output of the first global model in coral connectivity together with spatial statistics and network analysis. My results show that similarity in coral assemblage composition correlates most strongly with potential connectivity between reef clusters. This suggests that dispersal is a more influential than environmental filtering in generating and maintaining coral biogeographic patterns; its importance may previously have been underestimated due to inadequate data.

Session III

Project coral – developing protocols for predictable broadcast coral spawning in captivity

Jamie Craggs, Aquarium Curator, Horniman Museum & Gardens

Project Coral is an innovative captive coral sexual reproductive research project, run by the Horniman Museum and Gardens, London, in collaboration with University of Derby, S.E.A Aquarium, Singapore and SECORE International.
Broadcast spawning correlates strongly with a number of environmental signals, (seasonal temperature, lunar and diel cycles) however few robust experimental studies have examined the role of these putative cues in triggering spawning. In the purpose built aquarium laboratories microprocessor technologies are used to investigate the influences of the lunar cycle, diurnal changes, seasonal temperature changes, solar irradiation patterns and nutritional input on broadcast coral gamete (egg and sperm) production and release.

Since 2012 gamete development has been induced in thirteen Acropora species within closed systems in London and in-vitro fertilisation capacity has been developed to produce genetically diverse coral in captivity.
Through developing a deeper understanding of broadcast spawning events in captivity Project Coral aims to support climate change research focusing on reproduction, reef restoration efforts and develop new sustainable coral aquaculture techniques.

How to make marine co-management happen in Northern Mozambique: practical solutions from the field

Ercilio Chauque, Our Sea Our Life

Locally-Managed Marine Areas (LMMAs) are a key tool to protect critical nearshore habitats, species, biodiversity and ecosystem functions as well as aid in the recovery and sustainability of fisheries, though LMMAs only work when they are well enforced and compliance is high. Globally, many marine protected areas are not managed and the real challenge is often related to the active engagement of all stakeholders and decision makers, both prior to the creation of LMMAs and afterwards. Stakeholders' interests and awareness should be aligned to guarantee management interventions are based on a common understanding which will positively influence the effectiveness of LMMAs. Our Sea Our Life is a project implemented in Northern Mozambique that is testing such a decision-making process for further replication. This presentation will address examples of actions around LMMAs that a) increase community participation and interest in conservation; b) help to overcome the opportunity costs of conservation; c) reduce dependence on marine resources, and d) help to provide a sustainable form of income to support conservation activities. Our Sea Our Life aims to develop a manual from lessons and successes in the field to help expand the approach elsewhere in Mozambique and beyond.

Fishers' knowledge of spawning aggregations and landings data inform management of the endangered Nassau grouper

Marta Calosso, DA, MRes**,** Research Associate, Department of Environment & Coastal Resources, Turks & Caicos Islands Government

As a result of high fishing pressure, particularly targeting spawning aggregations, populations of Nassau grouper (*Epinephelus striatus*) have declined dramatically throughout the Wider Caribbean Region, and the species is now regionally endangered. The Turks and Caicos Islands (TCI) have one of the healthiest remaining populations of Nassau grouper, possibly as a consequence of low fishing pressure on spawning aggregations, since local fishers predominantly target queen conch (*Strombus gigas*) and spiny lobster (*Panulirus argus*) for the export market. In 2015 a closed season for *E. striatus* (banning harvest and sale) was introduced to cover the presumed months of aggregation (December 1 to February 28). In the last year prior to the seasonal closure, we conducted semi-structured interviews with local fishers and monitored landings in order to assess the extent to which aggregations were targeted. Following its implementation, the effects of the seasonal closure on fishers and the fisheries in general was also investigated through interviews. Only 38% of fishers had either seen or fished *E. striatus* aggregations. While all trap boat fishers targeted aggregations, only 19% of free-diving fishers did. Catch per unit effort was over twice as high for trap boat fishers versus spear fishers. The effects of the seasonal closure may have resulted in other species of grouper being targeted more heavily; Nassau grouper being mislabelled; unknown species of grouper being imported; trap fishers forgoing days' fishing; and fishers targeting conch and lobster more heavily. While the seasonal ban was scientifically justified, the unexpected consequences need to be considered in a holistic approach to the management of multispecies, multi-gear small-scale fisheries of the TCI.

Small-Scale MPAs, Local Communities and Their Future in the Philippines – Experiences from Napantao, Sogod Bay

Alex Ferguson[1], Tom Dallison[2] & Tristan Brown[3] Coral Cay Conservation, UK / Philippines

Coral Cay Conservation (CCC) have been established in the Philippines since 1996. Methods post-2013 aim to provide scientific capacity to local and provincial governments. Facilitating the development of marine conservation directives and the establishment of marine protected areas (MPAs) within Sogod Bay, southern Leyte, the Philippines. Small-scale MPAs, an integral component to the livelihoods of local stakeholders and their respective

coral reef communities, are facing chronic threats to their success from lack of enforcement and compliance. Aiming to increase fishery capacity and productivity whilst protecting, preserving and promoting coral reef systems and their services for current and future generations within Sogod Bay. CCC has developed a three-tiered holistic methodology to fisheries and coral reef conservation; adapting an ecosystem approach.
CCC report, and address, the cause-effects of a small-scale MPA (5ha), Napantao, established in 1996, from 2013 to 2015, on the present coral reef system, its fishery and local communities. Initial results indicate the MPA is buffering fish species decline against local and far-field stressors with levels of diversity inside the MPA greater than those outside of the boundary (p= <0.05). The MPA has failed however, to protect commercially important fishes and benthic substrate communities. Age, size and poor levels of enforcement are concluded to be the main drivers. Therefore CCC calls for, and discusses, the establishment of a large-scale marine reserve (MR) within Sogod Bay, encompassing the established small-scale fisheries into a vast MPA network with standardised, holistic directives. CCC's efforts in community engagement and education hold a significant role in the proposed approach and therefore, directly addressing system-decline drivers with the continued development of multifaceted consortiums and promoting a bottom-up approach to coral reef management, CCC aims to facilitate the protection of essential ecosystem services for current and future generations; setting a precedent for the Philippines.

Modelling coral reef condition to support planning for the persistence of marine biodiversity: A proof-of-concept study

Ans Vercammen [1], Jennifer McGowan [2], Andrew T. Knight [1] and Maria Beger [2]
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Marine spatial conservation prioritisation is impeded by scarcity and lack of aggregation of regional-scale biophysical and ecological data. As a result, current spatial prioritisation approaches aim for representation but generally do not account for habitat condition, potentially leading to sub-optimal planning solutions that fail to ensure biodiversity persistence. This study aimed to validate a novel method of incorporating reef condition in a regional spatial prioritisation and to determine how considering spatial variability in reef condition alters conservation priorities. Using coral cover as a surrogate measure, I developed a spatially explicit model of reef condition across the Coral Triangle region, based on aggregated georeferenced survey data and a freely available dataset of macro-ecological variables. Model-based predictions were applied to generate a complete map of reef condition for the CT region. I used Marxan, a popular decision support tool, to select sets of conservation sites that meet specific objectives. A baseline scenario representing 20% of all habitat types was compared to habitat representation after adjusting for predicted coral cover. I also classified coral reef habitat by condition (low-medium- high) to allow target setting that either prioritises preservation of high-condition reefs or restoration of low-condition reefs. I found that accounting for modelled reef condition produced small-scale spatial shifts in conservation priorities compared to habitat representation without condition data. As expected, there were striking differences in the spatial arrangement of conservation sites based on target-setting for the protection of high-condition reefs compared to restoration-focused target setting aimed at low-condition reefs. The findings suggest that site selection for marine protected area (MPA) networks is less likely to ensure persistence when information about reef condition is unavailable. This proof-of- concept study provides a new tool to account for the unequal conservation value of coral reefs and consider alternative management actions in the design of MPA networks.

The Spiritual Pathway at the IUCN World Conservation Congress: implications for coral reef conservation

Robert Sluka, A Rocha International

Faith and spirituality has been a marginal conversation around the edges of conservation with the occasional paper either blaming or defending the world's major religions for their role in environmental degradation. However, the recent IUCN World Conservation Congress developed a series of pathways through the congress where participants could follow certain threads of thought found in posters, talks, exhibition booths, and high-level dialogues. A Rocha International, a faith-based biodiversity conservation NGO helped to facilitate the Spiritual Pathway at this congress which allowed substantive dialogue that moved beyond conflict models or naïve assumptions about the role of faith/spirituality in conservation.

What are the implications of outcomes and discussions on faith/spirituality at the IUCN WCC for coral reef conservation? I will report on the Spiritual Pathway activities at the congress briefly summarising main takeaways,

give a short example of how A Rocha is integrating faith into its coral reef conservation work in Kenya, and then pose several questions which could stimulate interesting discussion over coffee and particularly with wine in the evening.

Session IV

How corals apply the Goldilocks Principle to engineer habitat

Hennige, S.J. (University of Edinburgh, UK)

The occurrence and proliferation of reef-forming cold-water corals is reliant upon optimal current conditions, where provision of organic material is at a velocity suitable for prey capture by the coral. The occurrence of a significant proportion of dead skeletal framework on reefs highlights that when flow is sub-optimal, prey capture and ingestion rates are likely inadequate to facilitate survival. The reef forming coral *Lophelia pertusa* has an optimal range of flow velocities in which they can capture food efficiently. This 'Goldilocks Zone', where the flow is neither too fast nor too slow, will promote coral growth compared to zones of sub-optimal flow velocity. The disruption of flow by the coral also creates sub-optimal velocity regions behind it, potentially contributing to mortality of downstream corals. Here we demonstrate using Particle Imaging Velocimetry how corals modify their flow environment, and how coral reefs grow according to the Goldilocks Principle, by using a theoretical laminar flow system and iterative growth of a model coral.

Pink Sea Fans (*Eunicella verrucosa*) as Indicators of the Spatial Efficacy of marine Protected Areas in Southwest UK Coastal Waters

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Recent studies have demonstrated the utility of integrating 'citizen science' data into mainstream scientific analysis, particularly where broad-scale spatial patterns of distribution are required. In UK waters, the pink sea fan (*Eunicella verrucosa*) is a nationally protected slow growing, cold-water coral, and is a representative species of reef features that provide habitat for many other sessile species. However, this species is susceptible to physical impact, and vulnerable to bottom-towed fishing gears. In this study, data from a volunteer-based marine survey programme ('Seasearch') are analysed and the spatial distribution and relative abundance of pink sea fans throughout southwest UK coastal waters described. The congruence between pink sea fans and the extant southern UK MPA network is reported, and the current threat from Bottom-Towed Gear (BTG) is quantitatively assessed. This analysis reveals that protection of this and other benthic species has been increased by management of previously 'open access' MPAs. Nonetheless, areas of pink sea fan habitat and their host reef systems exist outside extant protected areas in southwest UK seas, and may be at risk from bottom-towed fisheries. This analysis demonstrates the utility of well-organised citizen science data collection and highlights how such efforts can help inform knowledge on broad-scale patterns of biodiversity.

Quantifying parrotfish carbonate cycling and predicting impacts of environmental change

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Parrotfish play a key role in a number of ecological and physical processes on coral reefs. In addition to their role in algal grazing, parrotfish are major bioeroders on reef substrates, removing and ingesting framework material which is subsequently excreted as sediment. On some reefs, parrotfish can account for up to 80% of biogenic sediment production. Through these processes, parrotfish exert a strong influence on reef growth potential, and can underpin the formation and maintenance of tropical coastal landforms such as islands and beaches. However, despite the importance of parrotfish bioerosion, quantitative data to support estimates of both rates of bioerosion, and of the

resultant sand generation remain sparse. Here, we present estimates of parrotfish bioerosion and sediment production from the Vavvaru reef system in the central Maldives, Indian Ocean. Data will be presented on 6 of the most common species which are also widespread throughout the region, representing scraper and excavator feeding modes and sizes ranging from <15cm to 60cm. *Chlorurus strongylocephalus* had the highest erosion rate, with the largest (>45cm) individuals eroding over 550kg of substrate individual^{-1} year^{-1}, approximately 8.5 times more than a 20cm individual of the same species. Understanding how parrotfish bioerosion and sediment production vary between species and sizes classes is important given that species assemblages and population size structure can be altered by environmental disturbances such as overfishing and habitat degradation. The potential impacts of these disturbances for overall parrotfish bioerosion and sediment production, and the implications of this for the reef system are discussed, and is the focus of ongoing work.

Structural complexity mediates functional structure of reef fish assemblages among coral habitats

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Coral community composition is changing on coral reefs worldwide. Direct anthropogenic stressors and climate change have differential effects among coral species, causing increased dominance of more stress-resistant and/or weedy coral species. The extent to which altered composition of coral assemblages influences reef fish assemblages remains largely unknown. We investigate how the functional structure of fish assemblages varies among six distinct coral habitats. An ecological traits-based analysis was used to compare the functional richness, functional evenness, and functional divergence of fish assemblages among these coral habitats. Our results reveal differences in the functional richness and functional divergence, but not functional evenness, of fish assemblages, with structural complexity of coral habitats being the best predictor of these differences. Fish assemblages in branching *Porites* habitat were functionally richer than those in *Pocillopora* and soft coral habitats, largely due to the presence of nocturnally active, schooling cardinalfishes in the branching *Porites* habitat. Massive and branching *Porites* habitats displayed greater functional divergence in fish assemblages than *Pocillopora* habitats because of a greater abundance of small, schooling planktivores which were rare or absent on lower complexity *Pocillopora* habitats. Our results indicate that coral composition may act as a habitat filter, affecting the distribution and abundance of associated species traits, particularly those of small-bodied schooling fishes.

How healthy were corals during the late 20th century in the pristine Chagos Archipelago?

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The Natural History Museum's collections include thousands of coral specimens collected from the Chagos Archipelago from 1880 to 1978. Prior to the 1980s monitoring of reefs was rare, so these collections provide an irreplaceable snapshot of coral growth and the endolithic boring communities. Without these historical data, it is impossible to show how these processes have shifted since then. We are applying nondestructive microcomputed tomography (microCT) on complete coral colonies to obtain species specific growth rates (Figure 1), skeletal bioerosion rates (Figure 2), and identify epi and endobionts (Figure 2). Results reveal a dichotomy between high bioerosion and no apparent relationship between growth rates and depth.

The photoprotective role of cyan fluorescent proteins in symbiotic corals

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Mass coral bleaching events are major drivers of reef decline. High levels of photosynthetically active light exacerbate bleaching induced by elevated temperatures. An understanding of photoprotective mechanisms employed by the coral host is therefore vital to the understanding of the stress physiology of reef corals. Corals produce a variety of green fluorescent protein (GFP)-like proteins, including fluorescent proteins (FPs) and non-fluorescent chromoproteins (CPs), some of which have been shown to screen coral zooxanthellae from damagingly high light intensities. I will present the results of experiments performed to assess the photoprotective role of cyan fluorescent proteins (CFP). Two different colour morphs of the coral Hydnophora grandis characterised by a high (cyan morph) or low (brown morph) CFP contents were provided with light of different quality and quantity under otherwise comparable conditions. We found that high intensities of blue light result in a higher growth rate and less photodamage in the cyan morph as compared to the brown specimens. However, the increased growth rate of the brown morph observed under low intensities of blue light suggest that there is an energetic trade-off associated with the high-level expression of fluorescent protein pigments required to enhance photoprotection.

Scleractinian coral lesions: frequency, severity and distribution on intertidal and subtidal reef flats around Phuket's Laem Panwa peninsula.

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The global decline of coral reef ecosystems is in part driven by the increasing frequency and severity of bleaching events and disease outbreaks. The reefs around Phuket's Laem Panwa peninsula have been impacted by a succession of bleaching events, and coral diseases are known to be present. Nevertheless, severe disease outbreaks observed elsewhere in the Indo-Pacific following bleaching have not been detected in this area, despite long-term monitoring by the Phuket Marine Biological Centre since the mid-1980's. This work aims to investigate the impacts of successive bleaching events on community structure, mortality and lesion prevalence on inshore subtidal and intertidal reefs. This investigation has highlighted the long-term impacts of bleaching on coral cover and community structure, the role of partial versus total colony mortality in driving these broad-scale changes, and the remarkable resilience of intertidal coral reef ecosystems to both bleaching and disease when compared with subtidal habitats. No disease outbreaks were detected on surveyed reefs in the aftermath of the 2010 or the 2015-2016 global coral bleaching events. Coral communities have some capacity for recovery in response to major stressors such as thermal bleaching, particularly those in highly variable habitats. However in the context of increasing frequency of bleaching events due to climate change, it is important to foster resilience by minimising the impact of other anthropogenic stressors.