Reef Conservation UK 2015 Abstracts

Saturday 28th November

ZSL London Zoo

Session I: Coral reefs and people

Reef conservation in Sabah, Borneo: a continuing challenge

<u>Plenary speaker</u>: Dr Elizabeth Wood, Marine Conservation Society

In the run-up to the 2015 UN climate change conference beginning on Nov 30th and in the midst of an El-Nino event that is bleaching and killing corals around the world, dire predictions for the future of coral reefs are rife. Warm water events and ocean acidification are not the only threats. Over-exploitation of reef resources, destructive fishing methods, coastal development and pollution have for decades been affecting the health and productivity of reefs right around the world.

The worst case scenario for the world's reefs is 'a post-apocalyptic future of algal-dominated, rubble-strewn, slowly-eroding limestone benches' (Sale, 2015). Even if this is unduly pessimistic, it is a widely accepted that, whilst crucial to address global issues, taking action at a local level to ensure reefs are healthy and resilient has never been more important. This presentation focusses on reefs in Borneo which, as long ago as the mid-1970s, were very clearly on a downward trajectory and in need of conservation action.

Concerted efforts by the Marine Conservation Society in partnership with Sabah Parks began in 1998 and led to the formation of a 350km^2 MPA six years after the programme began. The main issues at that time were clear. In the absence of any form of governance or management of fishing and in the face of increasing demand, reef resources were in severe decline. The situation was compounded by rampant fish bombing which was not only destroying large swathes of reef but contributing directly to over-exploitation.

Fish bombing is endemic in Sabah, as elsewhere in SE Asia, and eradicating it less easy than expected. Outreach and education programmes have increased awareness of the long-term implications of fish bombing but the 'soft' approach does not work with all communities. Surveillance over large areas is almost impossible, especially against fishers who are expert at evading detection. We have recently turned to more innovative solutions and are deploying acoustic detection systems that monitor fish bombs and also record them in real time, pinpoint their location and alert rangers so that they can take immediate action.

The long-term prognosis for reefs damaged by fish bombing and other activities and events, is uncertain. At some sites we have witnessed a phase shift to soft corals following death and collapse of hard corals after years of sporadic fish bombing and an episode of coral bleaching. Fish diversity and biomass on these reefs is exceptionally low and natural reversal to hard coral looks highly unlikely. We have shown that hard coral rehabilitation at fish-bombed rubble sites can be successful, but this type of intervention has limits of scale and would not solve the 'soft coral invasion issue'.

Over-exploitation in the area is driven by social, cultural and economic factors which need addressing in order to find a balance between fishing and sustainable use. Closing areas to fishing will usually lead to recovery of stocks but does not meet the immediate needs of local fishing communities. Another issue is the strongly-held belief that the sea will always provide and that poor returns from fishing are simply due to bad luck rather than over-exploitation. Awareness programmes are vitally important in these situations.

Trialling smartphones for improved fisheries data collection and management

Victoria Jeffers, Blue Ventures

Authors: Jeffers, Victoria & Humber, Frances
Blue Ventures Conservation, Level 2 Annex, Omnibus Business Centre, 39-41 North Road, London, N7 9DP, UK.

Fisheries and aquaculture support the livelihoods of at least 10 percent of the world's population, yet 75 percent of fish stocks are either fully exploited or overexploited, with severe population declines reported for many elasmobranch species. Reversing this collapsed fisheries trend requires improved management, which depends on

accurate stock status data. Yet, the majority of fisheries, in particular small-scale fisheries in the developing world, are unmonitored.

Recent advances in technology, coupled with the rapid extension of mobile technology in Africa have seen new data collection systems being utilised via open access software.

In Madagascar *Vezo* fishers depend heavily on small-scale fisheries for their livelihoods. This study reports on the first trial (2013-2014) using mobile phones as data collection tools, in the data deficient, traditional elasmobranch fishery in SW Madagascar. A network of 13 community data collectors, along 40 km of remote coastline, were trained to record shark landings via mobile phones.

At the end of the trial period, data were being successfully collected by community members and sent directly to an online database. The main challenges encountered were the lack of infrastructure and network connectivity, and low levels of technology use within the community. The project has worked closely with community members to modify and develop suitable mobile data collection and training tools.

The project demonstrates that mobile technology can empower fishers and other stakeholders to collect robust data to support adaptive fisheries management and conservation, and the potential for this approach to be adapted to broader-scale multi-species fisheries.

Biophysical decoupling and the loss of coral reef ecosystem predictability.

Dr Gareth Williams, Bangor University

Authors: Gareth J. Williams, Jamison M. Gove, Yoan Eynaud, Brian Zgliczynski, Stuart A. Sandin

Human impacts homogenize and simplify ecosystems, favoring communities that are no longer naturally coupled with the background environmental regimes in which they are found. Such a process of biophysical decoupling has been explored little in the marine environment due to a lack of replication across the intact-to-degraded ecosystem spectrum. Using 39 Pacific islands, 24 unpopulated (relatively free from local human impacts) and 15 populated (local human impacts present), spanning 45° of latitude and 65° of longitude, we ask, what are 'natural' biophysical relationships on coral reefs and do we see evidence for their human-induced decoupling? The percent cover of benthic groups were related to multiple physical environmental drivers using mixed-effects models and island mean condition as the unit of replication. Models across unpopulated islands had high explanatory power, identifying key physical environmental drivers of variations in benthic cover in the absence of local human impacts. These same models lost explanatory power when fitted anew to populated islands. Furthermore, key biophysical relationships at populated islands bore little resemblance to the baseline scenarios identified from unpopulated islands. Our results highlight the ability of local human impacts to decouple biophysical relationships in the marine environment and fundamentally restructure the natural rules of nature.

Marine Management? Making an oxymoron more meaningful.

Prof Charles Sheppard, University of Warwick

This focusses on the joint issue of human numbers and failure of food supply, and on the fact that coral reefs, if fished less intensively and destructively, can support much more biomass (food) than they do now, for more people. It explains some reasons why reefs cannot do what they are being asked to do. It also tries to show that failing to admit to some clear points is leading to a worsening situation. Areas of shallow sea and reef — where biological production is greatest — actually increase in value (in monetary terms) when turned into land, i.e. when landfill has made it real estate. Of our tropical shallow marine habitats, we are losing 1% to 2% per year and to date we have lost about half of all the main habitats. The issue is driven principally by politics and economics, not science. Some say we can 'manage' the marine environment, but this is simply hubris, or conceit: we rarely successfully manage any one species let alone the 'sea' or its major systems. The best we can manage might be human impacts on the sea's potentially rich coastal habitats. Although that does not sound very appealing (stopping things is rarely popular) it is time to recognize that in many cases it is the only sort of management that has a chance of working. There is a major movement now for creating very large properly protected areas, to serve as refuges and reservoirs for the ultimate benefit of people and the natural world.

Speed talk: Finding the coral reefs of the British Virgin Islands to allow effective management.

Simeon Archer, CEFAS

The British Virgin Islands (BVI) have a large marine area, which presents challenges in protecting biodiversity and sustainable management. There has been a strong commitment by Government towards marine conservation including the development of a Protected Areas System Plan, which aims to protect 33% of the near-shore marine environment.

Whereas shallow marine areas are relatively well studied, knowledge of the coral reef communities and reef distribution in deeper waters is limited. Cefas, in partnership with the National Parks Trust of the BVI and United Kingdom Hydrographic Office, undertook the first high resolution multi beam echosounder survey within the BVI, revealing the shape and characteristics of the seabed and coral reefs within the Rhone Marine Park and surrounding areas.

The acoustic seabed survey was complemented with an extensive video observation survey, collecting video and stills imagery to describe the physical characteristics and biological communities.

The survey revealed the distribution of coral reefs across the survey area in unprecedented detail for the first time. Different types of coral reef formations could also be observed, and the types and quality of coral reef communities were described and found to vary across the area.

The surveys revealed several areas where coral reefs were potentially impacted by anthropogenic activities. The surveys suggested that coral reefs were affected by sedimentation within the inner harbour, whereas in the outer harbour anchor damage could have impacted the coral reef formations and communities. In this latter example, knowledge on the presence of coral reef structures could have avoided the unintended damage to the seabed.

This new knowledge on the distribution of coral reefs provides essential data for the effective and sustainable management. The detailed distribution data allows for effective spatial restrictions or management solutions to be introduced, but also creates opportunities to improve local fisheries management.

Session II: Adaptations to global stressors

Predicting climate driven regime shifts versus rebound potential in coral reefs.

Prof Nick Graham, Lancaster University

Authors: Nicholas AJ Graham, Simon Jennings, M Aaron MacNeil, David Mouillot, Shaun K Wilson

Climate-induced coral bleaching is among the greatest current threats to coral reefs, causing widespread loss of live coral cover. Conditions under which reefs bounce back from bleaching events or shift from coral to algal dominance are unknown, making it difficult to predict and plan for differing reef responses under climate change. We document and predict long-term reef responses to a major climate-induced coral bleaching event that caused unprecedented region-wide mortality of Indo-Pacific corals. Following loss of >90% live coral cover, 12 of 21 reefs across Seychelles recovered towards pre-disturbance live coral states, while nine reefs underwent regime shifts to fleshy macroalgae. Functional diversity of associated reef fish communities shifted substantially following bleaching, returning towards pre-disturbance structure on recovering reefs, while becoming progressively altered on regime shifting reefs. We identified threshold values for a range of factors that accurately predicted ecosystem response to the bleaching event. Recovery was favoured when reefs were structurally complex and in deeper water, when density of juvenile corals and herbivorous fishes was relatively high and when nutrient loads were low. Whether reefs were inside no-take marine reserves had no bearing on ecosystem trajectory. While conditions governing regime shift or recovery dynamics were diverse, pre-disturbance quantification of simple factors such as structural complexity and water depth accurately predicted ecosystem trajectories. These findings foreshadow the likely divergent but predictable outcomes for reef ecosystems in response to climate change, thus guiding improved management and adaptation.

Ocean acidification and the future of cold-water coral reefs.

Dr Sebastian Hennige, Heriot Watt University

Authors: S.J. Hennige[1]; N.A. Kamenos[2]; J.M. Roberts[1]
[1]Centre for Marine Biodiversity and Biotechnology, Heriot-Watt University, Edinburgh, EH14 4AS, UK
[2]School of Geographical and Earth Sciences, University of Glasgow, Glasgow, G12 8QQ, UK

Cold-water corals, such as *Lophelia pertusa,* are key habitat-forming organisms found throughout the world's oceans to 3000 m deep. The complex framework of these vulnerable marine ecosystems supports high biodiversity and commercially important species. Due to the proximity of cold-water coral reefs to the aragonite saturation horizon, they are arguably more at risk to ocean acidification than tropical corals. Currently, over 95% of cold-water corals live in aragonite-saturated water, but by the end of the century this is projected to decrease to less than 40%. Given the importance of cold-water coral reefs, a key question is how both the living and the dead framework will fare under projected climate change. From long-term multi-stressor experiments, we demonstrate that *L. pertusa* can physiologically acclimate to increased CO_2, showing sustained net growth. However, this is at a cost to its skeletal structure of newly grown polyps, and decreased crystallographic and molecular organisation of skeletal calcium carbonate. Although physiological acclimation to projected conditions is evident, we also demonstrate that there is a negative correlation between increasing CO_2 levels and breaking strength of exposed framework (~20-30% weaker after 12 months), which forms the foundation of cold-water coral reefs. The question remains as to whether *L. pertusa* can continue to grow at a rate that supports net reef growth in a rapidly changing ocean, or whether energetic reallocation combined with weakening and dissolution of foundation framework will result in ecosystem and associated biodiversity loss. Effective management of cold-water reefs is a key priority, and management options within the context of North Atlantic coral-reef connectivity will be discussed.

Gene expression underlying the heat stress tolerance of *Porites lobata* from the Persian/Arabian Gulf.

Dr Cecilia D' Angelo, Ocean and Earth Science, National Oceanography Centre, University of Southampton

Authors: Cecilia D'Angelo[1]; Sebastian Baumgarten[2], Christian R. Voolstra[2], John Burt[3] & Joerg Wiedenmann[1]
[1] Coral Reef Laboratory, University of Southampton, Waterfront Campus, National Oceanography Centre, Southampton, SO14 3ZH, UK [2] Red Sea Research Center (RSRC), King Abdullah University of Science and Technology, Thuwal 23955-6900, Kingdom of Saudi Arabia [3] Marine Biology Laboratory, Centre for Genomics and Systems Biology, New York University – Abu Dhabi, PO Box 129 188, Abu Dhabi, United Arab Emirates

Coral communities from the Persian / Arabian Gulf ("The Gulf") survive summer temperatures of up to 36ºC on a regular basis. Most corals elsewhere on the planet, including conspecifics of Gulf corals, are already killed at water temperatures above 32ºC. Therefore, corals from the Gulf represent ideal models to study the limits of thermal tolerance in reef corals. Gene expression forms an integral part of the organismal response to challenging environmental conditions, the altered expression patterns can result from changes in both, the constitutional expression and the short-term regulation of stress-response genes. We have selected *Porites lobata* as a model to study gene expression of Gulf corals as this species 1) has a cosmopolitan distribution, 2) represents a habitat-forming species in the Gulf and 3) is suitable for long-term culture in experimental aquarium systems. Here, we present the results of our analysis of the transcriptome of *Porites lobata* from Sadiyaat reef and the changes in gene expression associated with the exposure to different environmental stressors.

Uncovering the volatile nature of coral reefs.

Dr Dan Exton, *Operation Wallacea*

Authors: Dan A Exton[1], Terry J McGenity[2], Michael Steinke[2], David J Smith[2], David J Suggett[3]
[1] Operation Wallacea, United Kingdom [2] School of Biological Sciences, University of Essex, United Kingdom [3] Functional Plant Biology and Climate Change Cluster, University of Technology, Sydney, Australia

Biogenic volatile organic compounds (BVOCs), in particular dimethyl sulphide (DMS) and isoprene, have fundamental ecological, physiological and climatic roles. Our current understanding of these roles is almost exclusively established from terrestrial or oceanic environments but signifies a potentially major, but largely unknown, component of coral reef ecosystem function. The tropical coast is a transition zone between the land and ocean, characterized by highly productive and biodiverse coral reefs, seagrass beds and mangroves, which house primary producers that are amongst the greatest emitters of BVOCs on the planet. Here, we synthesize our existing understanding of BVOC emissions to produce a novel conceptual framework of the tropical coast as a continuum from DMS-dominated reef producers to isoprene-dominated mangroves. We use existing and previously unpublished data to consider how current environmental conditions shape BVOC production across the tropical coastal continuum, and in turn how BVOCs can regulate environmental stress tolerance and species interactions via infochemical networks. We use this as a framework to discuss how changing tropical coastal BVOC emissions could not only play an important role in regulating local climate and thus mitigating future temperature rises, but directly influence the ability of corals to withstand anomalous environmental stress episodes. We highlight the complete lack of current knowledge required to understand the future ecological functioning of these important systems, and to predict whether feedback mechanisms are likely to regulate or exacerbate current climate change scenarios through environmentally and ecologically mediated changes to BVOC budgets at the ecosystem level. Without answering these important questions, coral reef managers are unable to truly understand what the future holds for coral reefs and their associated habitats, and to design conservation strategies appropriately.

Speed talk: Significant increases in Great Barrier Reef coral bleaching over the last three centuries.

Dr Nicholas Kamenos, University of Glasgow

Authors: Nicholas A. Kamenos[1,] & Sebastian Hennige[2]
[1]*School of Geographical & Earth Sciences, University of Glasgow* [2]*Centre for Marine Biodiversity and Biotechnology, Heriot-Watt University*

Mass coral bleaching events during the last 20 years have caused major concern over the future of coral reefs worldwide. Despite such losses to key ecosystem service providers, little is known about bleaching frequency prior to 1979 when regular modern systematic scientific observations on the Great Barrier Reef (GBR) began showing increases in bleaching prevalence. To understand the relevance of current bleaching trajectories, the likelihood of future coral adaptation, and thus coral survival, records of natural pre-industrial bleaching frequency and prevalence are needed. Here we use GBR coral cores, to extend the observational bleaching record by 405 years to begin in 1575. *Porites* sp. corals exhibited natural bleaching patterns prior to industrialisation, but bleaching frequency has increased over the last three centuries. While corals will have acclimatized and adapted in response to past changing conditions, the recent mass bleachings may herald that corals have reached an upper bleaching threshold, a 'tipping point' beyond which reef ecosystem survival is uncertain.

Speed talk: Physiological response of Symbiodinium populations adapted to different thermal regimes in the Red Sea.

Eslam Osman, University of Essex

Authors: Eslam Osman; D. Tye Pettay; Christian Voolstra; Mark E. Warner; David J. Smith; David J. Suggett

Climatic change is causing dramatic changes to the stability of coral reefs worldwide. Studies have particularly focused on the distribution and physiological flexibility of coral-algal symbioses over latitudinal gradients in an attempt to understand how coral reefs will potentially respond to the continued stress caused by climate change. It is clear that corals can flexibly associate with stress tolerant symbionts (genus *Symbiodinium*) when persistently living in high temperature environments or during times of anomalous thermal stress; however, the physiological response of coral-algal symbioses over latitudinal gradients and the very different thermal regimes throughout the largely understudied region of the Red Sea is still unknown. We therefore contrasted the thermal tolerances of coral-algal symbiosis in Thuwal, Saudi Arabia versus Hurghada, Egypt where the seasonal thermal maximum thresholds are very different (32^{o}C and 29^{o}C, respectively). The abundant coral species *Pocillopora damicornis* was particularly interesting because thermal stability was different between populations inhabiting the two locations despite associating with the same clade C ITS2 symbiont: specifically, heat-stress induced declines of photochemical operation was only observed form the naturally warmer more southerly red sea site (Saudi). These physiological differences reveal the importance of adaptation to local environmental conditions yet contradict previous studies that show populations of the same symbiont type living at high temperatures are better adapted to thermal stress. As such, this symbiosis may be living near its thermal maximum on the reefs near KAUST and/or there may be further genetic differentiation for the host and symbiont. Further field surveys at five sites along Egyptian coast from the northern Gulf of Aqaba to southern Egypt (1000 km) are discussed and reveal species-specific differences in coral/symbiont specificity over this latitudinal range.

Speed talk: Genetic structure of the thermos tolerant coral-symbiotic alga, *Symbiodinium thermophilum*, across extreme environmental gradients.

Dr Ben Hume, Ocean and Earth Science, National Oceanography Centre, University of Southampton

Authors: Hume, B. C. C.1, D'Angelo, C.1, Burt, J.2 & Wiedenmann, J.1
1 Coral Reef Laboratory, Ocean and Earth Science, University of Southampton, Waterfront Campus, National Oceanography Centre, Southampton, UK. 2 Marine Biology Laboratory, Centre for Genomics and Systems Biology, New York University Abu Dhabi, Abu Dhabi, UAE

Increasing frequency and severity of coral bleaching events triggered by our warming oceans continue to degrade coral reef ecosystems on a global scale. Accordingly, coral ecosystems surviving in extreme thermal environments such as those found in the Persian/Arabian Gulf (the PAG) are being developed as model systems to elucidate the mechanisms underlying coral holobiont thermotolerance. Given that these ecosystems are surviving in thermal environments not expected before the end of the next century in tropical and sub-tropical waters elsewhere, they can inform on how/if coral ecosystems may adapt to survive in waters of the future.

In the PAG coral communities experience temperatures ≥35oC every summer, temperatures that prove fatal to conspecifics elsewhere. Apparently integral to their survival is their association with a recently discovered alga, Symbiodinium thermophilum, with which they form a year-round association. This association has been demonstrated as stable across the considerable salinity and temperature gradient that exists from the southern PAG to the Gulf's entrance. However, within the narrow channel of water (~70km) that connects the PAG with the adjacent Gulf of Oman, the Strait of Hormuz, the predominance of these associations begins to diminish being replaced by more traditional thermotolerant associations such as S. trenchii and C15-group until S. thermophilum associations are rare in waters off Muscat.

Here I will present an analysis of >100 S. thermophilum associations over >1000km of coastline across 9 reefs that assesses the genetic structure within this group. The results demonstrate a clear genetic disparity between coral populations found within the PAG and those immediately external. I will discuss these findings in the context of the

extreme conditions these corals endure, and the implications this genetic structure has for contemporary conservation strategies of assisted migration and evolution.

Session III: Diversity and distribution

The ecology of coral reefs in the North Atlantic and principles for conservation.

Plenary speaker: Dr Jan Helge Fosså, Institute of Marine Research (IMR), Norway

There are a number of coral species in the deep and cold world ocean and in my talk I will concentrate on a reef building species most common in the North Atlantic: Lophelia pertusa (Linnaeus, 1758). It has a wide distribution, but so far it seems like it is particularly abundant along the continental shelf, coast and fjords of Norway. Other important areas of occurrence are off the west coasts of Ireland and Scotland, around the Faroese and the south coast of Iceland.

Lophelia was first described by Linné in 1758, and further described and accompanied by exquisite drawings by Gunnerus in 1768. Hundred years later, the Norwegian marine biologist Michaels Sars noted that the species could build reefs.

But it was not until recently, thanks to modern technology, that we realized how common these reefs are and the extent of their size, the largest detected being 45 km long and the highest individual mounds up to 50 m high.

The first colour video films of deep coral reefs in the Norwegian continental shelf were provided during seabed mapping carried out by the oil industry in the early 90´s. Concomitant to this, local fishermen organisations claimed that bottom trawling was damaging coral grounds and that the fish had disappeared. The concerns of the fishermen initiated investigations by the IMR and so a mapping program was launched in close cooperation with them. The close collaboration between scientists and the fishermen was a success and decisive in implementing an effective mapping strategy. Documentation of the severe damages that bottom trawling was inflicting on the sea floor became available: videos showed smashed corals and extensive barren areas along the continental shelf.

Coral reefs are threatened by a number of industries. Foremost, bottom trawling is still the largest hazard to deep coral reefs, although longline and gillnet fishing are also a concern. Offshore oil related activities often conflict with reef occurrences, while in the coastal zone, salmon farming is a growing problem. Lastly, ocean acidification may pose the most serious threat in the near future.

In my talk I will present you with the biology and ecology of Lophelia, and their ecological importance as a habitat for fish and invertebrates as well as their role in the carbon cycle. I will show examples of growth forms in major coral areas on the continental shelf and examples of severe impacts from fishing. I also touch upon mapping methods.

Norway was the first country to protect cold-water corals in European waters. The documentation of damages to Lophelia reefs on trawl grounds provided by the IMR prompted the Norwegian fisheries authorities to implement a regulation for the protection of deep-water coral reefs against damage from fisheries in 1999 . This protective regulation acts on three levels: (i) total ban on bottom trawling for selected areas, (ii) prohibition of the intentional destruction of reefs and precaution when fishing in the vicinity of known reefs and (iii) precaution regarding unknown reefs, i.e. if coral bycatch from bottom trawling exceeds a certain level, the vessel shall move on at least two nautical miles away before fishing may continue; the incident should also be reported to the fisheries authorities. This last principle refers to FAO´s move-on rules developed to protect vulnerable habitats in the deep-sea.

Today there are 9 reefs (or reef areas) with the highest level of protection. In addition, the environmental authorities through the Norwegian Nature Conservation Act have conserved one reef in the Trondheimsfjord. In 2015, IMR proposed 9 new candidates for protection. We are optimistic that the Government will declare these 9 new reefs as Marine Protected Areas (MPAs) involving the highest protection before Christmas.

Selection drives apparent population structure in a widely distributed temperate octocoral.

Tom Jenkins, University of Exeter

Authors: Jenkins TL, Holland LP, Stevens JR

Population connectivity is an important component of meta-population dynamics in marine systems, which can influence population persistence, migration rates, and conservation decisions associated with protected areas. To this end, a number of studies over the last decade have reported levels of population structure in a variety of temperate marine organisms in the northeast Atlantic. Here, we used microsatellite markers to assess the population structure and connectivity of two octocoral species, *Eunicella verrucosa* and *Alcyonium digitatum*. Our

results suggest that there is regional structure in *E. verrucosa* which is organised into Marseille, southern Portugal, western Ireland, and the remaining populations from the southwest UK and northwest France. However, much of the observed structure, particularly the Irish populations, is driven by two loci that are likely under selection. Removal of these loci result in the Irish populations being grouped with the UK and France populations and evidence for the isolation of Portugal becomes weaker. In comparison, there is very little observed structure in *A. digitatum* with little genetic differentiation in the Irish populations, which suggests high gene flow and connectivity in this octocoral. Therefore, despite similarities in the habitat preferences and life history of these two species, they exhibit quite different population structure at a regional level. The results have conservation implications as *E. verrucosa* is protected in the UK and so the population structure observed here will be useful for relevant stakeholders involved in the designation and management of networks of protected areas.

Modelling larval dispersal on the global scale: Implications for the response of corals to climate change.

Dr Sally Wood, University of Bristol

Authors: S. Wood[1], I.B. Baums[2], C. B. Paris[3], A. Ridgwell[4,5], W.S. Kessler[6] and E. J. Hendy[1]

[1] School of Earth Sciences, University of Bristol, UK. [2] Department of Biology, Pennsylvania State University, USA. [3] Rosenstiel School of Marine and Atmospheric Science, University of Miami, USA. [4] Department of Earth Sciences, University of California, Riverside, USA [5] School of Geographical Sciences, University of Bristol, UK. [6] Pacific Marine Environmental Laboratory/NOAA, USA.

Reef-forming corals, immobile as adults, disperse between fragmented populations via a pelagic larval life history stage. Larvae drift with the ocean currents over potentially vast distances, allowing corals to reach new habitats and spread genetic material (termed 'connectivity'). This process exerts a major influence on coral biogeography, and is also likely to play a significant role in the response of corals to climate change; influencing their ability to replenish damaged populations (roll with it), adapt to new conditions via genetic diversity (run with it) or shift distributions in response to changing environmental conditions (run away!). Determining levels of connectivity between populations is therefore important in informing management and conservation of coral reefs as well as predicting their future distributions.

However, released in their billions and less than mm's in size, larvae are impossible to track directly in the open ocean. To overcome this problem, biophysical modelling is commonly used to explore the patterns and drivers of dispersal in a synthetic environment. I present results from the first global scale model of larval dispersal in corals, which aims to investigate the link between dispersal and coral biogeography as well as provide information of relevance to studies of reef resilience and vulnerability. In particular, I focus on dispersal across the world's largest marine barrier - the 5000-7000km expanse of open-ocean separating frequently disturbed eastern pacific reefs from western sources of population replenishment. Finally, I discuss work to incorporate the influence of abiotic factors in the model in order to predict future changes in dispersal patterns.

The early history of coral triangle biodiversity.

Dr Nadia Santodomingo, Department of Earth Sciences Natural History Museum

Authors: Nadia Santodomingo and Kenneth G. Johnson

Studies on the fossil record of Miocene corals from Indonesia are helping to better explain the origins and historical trends of diversity in the Coral Triangle. In this talk, we will present examples of comprehensive taxonomic analyses of two important reef builders, the genus *Acropora* and the family Merulinidae, by using both fossil and modern material. New material of coral fossils include thousands of well-preserved specimens collected under the framework of the Throughflow Project (TF). In the first example, we examined 4729 *Acropora* specimens from the TF collections and museum specimens. Previous knowledge on the fossil record of *Acropora* in the Indo-Pacific region only accounted for two species. Our outcomes confirmed the presence of 31 species of *Acropora*, from which six are new to science. We extend the range of 23 extant species to have their first occurrence during the Neogene, including 12 that were already present in the early Miocene. This evidence supports the hypothesis of an early origin of most *Acropora* lineages and their evolutionary persistence throughout the Cenozoic.

In the second example, we integrated fossils into the phylogeny of Merulinidae (former Favidae). For the first time, coral fossils are explicitly incorporated as non-contemporaneous terminal taxa into a coral phylogeny. The combined analysis of fossils with modern taxa resulted in older estimates of divergence times than using solely the calibration of nodes in a molecular tree (with modern specimens only). Our results provide unique insights into the times of origin and diversification within the family showing that its origins date from the Early Cretaceous, with the main clades diverging around the Paleocene/Eocene boundary, and during mid Eocene, and mid Miocene age. This result also supports the hypothesis of early diversification of Indo-Pacific lineages as high levels of cladogenesis are observed since the early Oligocene, reaching its maximum in the Middle Miocene.

The main palaeoenvironments interpreted from our Indonesian localities are mostly associated with shallow turbid habitats. The role of these challenging habitats during the early diversification of the Coral Triangle demands further study as they might play similar functions in today's reefs. Finally, our outcomes emphasize the high potential of incorporating the fossil record into the construction of robust phylogenetic hypotheses that better explains when, how, and where coral evolution had happened.

Speed talk: Using light sheet fluorescence microscopy to measure the metamorphic rate in *Favia fragum* larvae.

Sophie Stephenson, University of Essex

The environment in which coral reefs have persisted in for centuries is in a state of transition that under current predicted rates could end in their demise by the end of 2100. The past 50 years has already seen a 20% loss of reefs globally, illuminating an inability to acclimate or adapt at a rate synonymous with climate change. Studies predict that scleractinian corals will be obligated to shift to higher latitudes in an attempt to escape conditions that exceed their thermal threshold. Consequently, the planktonic larval life stage is projected to adhere to the biggest evolutionary adaptations. However, knowledge gaps in larval physiology and development currently limit our understanding of the adaptive potential of this life stage.

Microscopic studies have been pivotal in unravelling the organisation of tissue and symbiotic zooxanthellae at a cellular level, however the phototoxic effects of imaging live corals has previously limited long- term studies. Light sheet fluorescence microscopy (LSFM) has been developed to combine high optical resolution and sensitivity with minimal illumination that diminishes phototoxic effects to a point that has no immediate or lasting impacts on the physiological state of coral. In this study LSFM was used as a novel technique to develop a baseline rate of metamorphic development in *Favia fragum* larvae under conditions synonymous to their natural environment. A time frame of the development of anatomical features, including mouth, tentacles and mesentery dissepiments, was used in the criteria to define the baseline. Changes in the distribution and density of zooxanthellae and areas of increased green fluorescent protein intensity were measured throughout metamorphosis. This baseline will enable future studies to investigate the impacts of ocean warming and acidification on the rate of metamorphic development at a cellular level.

Speed talk: A multidimensional approach to habitat complexity.

Charlie Dryden, Newcastle University

Coral reef habitat structural complexity is positively related to both abundance and diversity of the reef fish community, and the loss of this complexity through coral reef degradation is an important concern, especially in the Caribbean. Studies examining habitat flattening effects have often attempted to devise novel methods of measuring complexity without appreciation of the underlying theory. Multiple measures, each assessing different aspects of complexity, are evidently required to further understanding and this study provides one approach to achieving this. A novel pathway analysis allowed us to examine interacting effects of different metrics and influences of these on fish diversity. We used structural equation modelling (SEM) to derive a hypothetical construct of both "refuge" on reefs and overall "complexity" as essentially unmeasurable entities. The approach means we could for the first time examine the relationships among the variables and also their contribution to overall complexity. Additionally when examining the relationship between complexity and the fish community we were able to better understand both the effects of the individual variables and of overall

reef complexity on fish diversity. Then in order to understand in greater detail the efficacy of this approach we examined the relationship between fish functional diversity and the SEM derived "refuge" variable. Through this approach we were able to identify a specific habitat characteristic which relates to the functional diversity on coral reefs. In addition to this we also found relationships between a number of key functional groups and refuge on Caribbean reefs. This work not only furthers our understanding about processes influencing the functioning of reefs but also how future changes to the reef habitat may affect the fish community.

Speed talk: Comparing manual and computer-assisted benthic cover estimations from underwater imagery at a Norwegian rocky reef.

Marie-Lise Schläppy, University of the Highlands & Islands

Authors: Aleksej Šaškov[1], Thomas G. Dahlgren[2], , Yuri Rzhanov[4] , Marie-Lise Schläppy[3]
[1] Coastal Research and Planning Institute, Klaipėda University; Lithuania; [2] UNI Research, Norway; [3] Environmental Research Center; [4] Center for Coastal and Ocean Mapping/Joint Hydrographic Center, University of New Hampshire, USA

Studying the environmental impacts of anthropogenic impacts requires the ability to detect alterations in benthic assemblages over time to assess changes potentially due to human activity. In this study, a rocky reef near Aalesund in Norway was surveyed using a remotely operated vehicle (ROV) to collect video transects. The analysis of percentage benthic cover was carried out in two ways and compared: one analysis of benthic cover was carried out manually and one analysis was carried out by automatically extracting data from video mosaics of the video transects. Eighty mosaics were analysed and benthic cover was estimated by using a computer algorithm that was optimized manually using a training set of colours representing various types of benthic cover. The two methods were compared and contrasted. The computer estimation was equally or more consistent than the human analysis, more effective in terms of manpower required, has a decrease of analysis error and a higher reproducibility. Taxonomic resolution was better in the manual analyses but came at a higher cost in specialist time. In conclusion, computerized image analyses of video mosaics are therefore a more rapid, reproducible and cheaper way to measure changes in benthic assemblages on rocky reefs than manual analyses.

Session IV: Variable threats faced by reefs

The need for a holistic approach to disease causation – a look back over 6 years of research.

Dr Mike Sweet, University of Derby

Authors: Sweet, MJ. Bythell, JC.

Coral diseases have been studied for over 40 years, yet the mechanisms of how a coral goes from a healthy to a diseased state remains unknown. Here, we explore the lessons learnt from 6 years of research on coral diseases, from one research institute. Our findings show coral diseases are typically polymicrobial in origin, i.e. specific disease-associated microbiota develop, which are distinct from those of healthy corals. These include several '*potential*' pathogens that are rare or absent in healthy individuals. A variety of novel techniques, are now available for us to refine these '*potentials*' into more realistic '*candidates*' and from there, traditional methods such as Henle-Koch's postulates can be attempted. However, there are several cases of notable failures with regard to such challenge experiments. Add the continued difficulty of identifying these candidate pathogens to the lesion itself and we appear to be stuck. This has led some researchers to question the fundamental paradigm of disease causation as a result of exposure to a single '*primary*' pathogen. Furthermore, if we explore the response of the host as well, the rabbit hole deepens. In our experimental studies, a strong correlation has been shown between *Symbiodinium* density and antimicrobial properties. A result which may, at least in some part, help explain the observed links between bleaching and the onset of disease. Questions remain, with regard to; what extent and exactly how the holobiont is able to 'modify' its '*normal*' microbiota, what impact stress has on specific host control mechanisms, and how the coral responds to pathogen challenge and infection. While 'omics approaches are already providing a more comprehensive understanding of host responses, a holistic approach to these key questions needs to occur in

order to fully understand disease causation and the limits to adaptation and resistance in response to environmental stress.

Use of mesophotic reefs by invasive Western Atlantic lionfish.

Dom Andradi-Brown, University of Oxford

Authors: Dominic Andradi-Brown[1,2], Alicia Hendrix[2], Rachel Grey[2,3], Alex D. Rogers[1], Dan Exton[2]
[1]Department of Zoology, University of Oxford, UK [2]Operation Wallacea Ltd, Old Bolingbroke, Spilsby, Lincolnshire, UK [3]College of Charleston, South Carolina, USA

The severe negative effects of invasive lionfish (*Pterois volitans and Pterios miles*) on western Atlantic shallow reefs are well documented, yet despite lionfish recorded on deeper reefs, the use of mesophotic reefs in invasive lionfish ecology and life history remains a significant gap in our knowledge. We combine unpublished and previously published studies of lionfish abundance and body length on shallow (0-30m) and mesophotic (30-150m) reefs from 63 sites in seven western Atlantic countries and eight sites in native-range Indo-Pacific countries. Lionfish were broadly found at similar abundances on adjacent shallow and mesophotic invaded reefs, while relative abundance distributions across the depth gradient were similar between invaded western Atlantic and native Indo-Pacific range sites. In some locations mesophotic lionfish were larger than shallow individuals, suggesting the mesophotic zone may form part of a natural ontogenetic migration, with older lionfish found at greater depths.

To further understand these patterns we conducted detailed lionfish surveys around Utila, Hondruas from 5-85m depth during June-September 2015. Preliminary analysis indicates a depth refuge around Utila, with greater densities of larger lionfish recorded on mesophotic reefs than shallow reefs. We took detailed measurements and dissection data of circa 500 lionfish across this depth range. Male lionfish were found to be more reproductively mature at mesophotic depths than shallow depths, though interestingly reproductive maturity and mean gonad weight was not found to be different between shallow and mesophotic depths for female lionfish. This study highlights the need for lionfish adaptive management to consider lionfish populations below the depth limit of recreational SCUBA diving, as the focus of most previous control (culling) measures has been shallow water.

Island evolutionary stage a stronger short-term driver of island instability than sea-level on Maldivian reef rim islands.

Dr Kyle Morgan, University of Exeter

Authors: K. Morgan[1], C. Perry[1]
[1]*Department of Geography, University of Exeter, Exeter, United Kingdom*

Coral reef islands are considered highly vulnerable landforms to global environmental change, because they are inherently low-lying (<3 m elevation) and comprised of unconsolidated bioclastic sediment generated from adjacent reef communities. Future scenarios of sea-level rise often portray islands as passive geomorphic entities that will drown on their platforms following inundation. However, this is overly-simplistic given the diversity of islands globally, intra-basinal variability in sea-level and a lack of quantitative case studies, particularly those on atoll reef rims, which support the majority of the population in the Maldives. Here, we use a time-series (2005, 2008, 2010, 2011 and 2014) of high-resolution multi-spectral satellite imagery to measure changes in shoreline position, island area and planform morphology (shape) of uninhabited reef rim islands within Lhaviyani atoll, Maldives. We show that under very low rates of sea-level rise (1 mm y^{-1}), rapid shoreline change and island mobility occurred over the nine year time-series (mean end point rate up to 0.8 m y^{-1}), with maximum net shoreline erosion calculated at 140 m. Most islands showed very little change in net island area (3-8%), but large shifts in island shape. Our findings therefore suggest that short-term island mobility is independent of sea-level, and occurs naturally on platforms, even those associated with healthy coral communities and high sediment production regimes. Central to determining island instability is an assessment of the current stage of island evolutionary development based on the proportion of platform infill and platform size relative to island area. Understanding the controls on island dynamism will inform predictions of island morphological responses to future environmental change, and allow for mitigation and adaptation strategies to be established.

Speed talk: Host preference of the flamingo tongue snail *Cyphoma gibbosum* and its implications for the spread of aspergillosis.

Vanessa Lovenburg, University of Oxford

Authors: Vanessa Lovenburg, Dan Exton, Michelle Taylor, Martin Speight, and Alex D. Rogers

Cyphoma gibbosum, the flamingo tongue snail, is an octocoral generalist parasite that has been suspected as a possible secondary vector of disease transmission of the fungal pathogen, Aspergillosis. Fungal spores of *Aspergillus* are initially transported via African winds from the Sahara, to the Caribbean where they settle into the marine environment. Previous research implicated the *C. gibbosum* as a likely candidate for further spread of the infection based on passage through the snail's gut of fluorescently-tagged viable fungal spores. Outbreaks of these snails have historically caused mass die-offs of sea fans and Aspergillosis is the most common coral disease in the Caribbean.

Research conducted around the island of Utila, Honduras, in this study, investigates the communities of octocorals and flamingo tongue snails in relation to reef health. Prior research conducted in the Caribbean suggested a preference of *C. gibbosum* for coral colonies infected with Aspergillosis. SCUBA-assisted data collection did not support the working hypothesis that *C. gibbosum* preferentially selects diseased hosts.

Host preference of *C. gibbosum* not covered by earlier literature was revealed in this study. Previous research has never looked at the host preference of juveniles of *C. gibbosum*, and this study demonstrates an overwhelming host preference for one species, *Antillogorgia americana*, the slimy sea-plume. This is an interesting finding, especially considering the pelagic larvae of *C. gibbosum* must be using chemical cues for settlement and *A. americana* incidentally is a highly bioactive species. These snails are able to harvest and incorporate bioactive weaponry of the octocorals used as a defence for most other reef predators. Feeding by the snails has even been shown to stimulate the production of these biochemical compounds in the colonies. This research highlights the importance of the focus on this species for future conservation of reef health.

Speed talk: Status and Management of the Red lionfish (*Pterois volitans*) in the Cayman Islands.

Henry Gunning, Bangor University

Authors: Croy McCoy[1, 2], Henry Gunning[2], Michela Lever[2], Bradley Johnson[1] John R Turner[2]
[1]Department of Environment, Cayman Islands Government, Georgetown, Grand Cayman, [2]School of Ocean Sciences, Bangor University LL59 5AB UK.

The invasive red lionfish (*Pterois volitans*) has been documented to indiscriminately consume large quantities of prey thereby reducing abundance of fish species on coral reefs and associated habitats. Lionfish (LF) were first sighted in the Cayman Islands in February 2008, and a management strategy was developed of public education and removal by training and licenced culling programmes and tournaments. The status of LF was surveyed in 2012 and 2014 and 2015 at 179 sites across the three island archipelago, inclusive of mangroves, sea-grass beds, patch reefs; shallow terrace reefs, deep terrace reefs and deep walls, in which their density, biomass, size, prey availability and diet were assessed. Further, densities of LF were compared between culled and unculled sites. Little Cayman (LC) is most actively culled and exhibited lowest densities (48.13±10.96, ind. ha^{-1}), followed by Grand Cayman (GC) (142.56±25.38 SE, ind. ha^{-1}) and Cayman Brac (CB) (139.81±28.38 SE, ind. ha^{-1}), where culling is infrequent. Temporal comparisons demonstrated a fluctuating trend in LF density across island and habitat. LC had the lowest biomass (13.45±3.78 SE, kg ha^{-1}), with GC (31.10±6.81) and CB (34.71±4.30) showing a value threefold over LC. Mean LF Total Length for the Cayman Islands was 23.40 cm ±0.58 SE with largest individual recorded in CB of 40 cm. Stomach content analysis showed that teleost fishes were the preferred diet at all sites. However, micro habitat, rather than prey availability appears to be a more important driver influencing LF density. Some 400 individuals and 30 dive companies are licensed to cull LF, and their efforts appear to be containing the invasion.