Institution: University of Bedfordshire

Unit of Assessment: 7- Earth Systems & Environmental Sciences

Title of case study: Stabilising the resilience of the coral reefs to global environmental change

1. Summary of the impact

Our award-winning work (Aviva/Earthwatch International Award 2006) on measuring growth of corals in relation to climate and environmental changes linked to capacity building has informed managers and policy-makers in developing countries of the measures required for an integrated system of conservation and management. In Jamaica, our research on modelling coral growth linked to discussions with local stakeholders and the National Environmental Protection Agency (NEPA) showed that implementation of co-operative management plans can allow reef ecosystems to withstand major physical effects; these plans have been implemented. In Belize, we worked with local Non-Governmental Organisations (NGOs) and the Fisheries Department to enable them to both measure and model coral reef growth, and so develop methods for sustaining their reefs. Our work has enabled reef managers in Jamaica and Belize to monitor their reefs and they have put in place new Marine Protected Areas (MPAs) so that their reefs can be protected in times of climate and environmental change. This has resulted in increased fishing yields in both countries.

2. Underpinning research

Research on coral reef systems was started at the University of Bedfordshire (UoB) in 2005 with the appointment of Professor James Crabbe from the University of Reading. Novel computational models for coral growth were developed, working initially on reefs in Indonesia in the Coral Triangle. This was possible because of the equipment, expertise in computing, and facilities available at UoB. We quantified the size-structure of populations and the growth rates of corals in the Caribbean from 2000-2008 to test whether coral colonies on fringing reefs near Discovery Bay (Jamaica) or those on the Meso-American Barrier Reef (Belize) showed resilience in the face of multiple acute stressors of hurricanes and bleaching, in addition to overfishing and land development (3.1). There was a major Caribbean-wide bleaching event in 2005, which resulted in major losses of living coral on Jamaican reefs in 2006 and 2007. At many reefs live coral cover increased in both 2007 and 2008. These studies indicated good levels of coral resilience on the fringing reefs around Discovery Bay in Jamaica. We also collaborated with an Australian coral reef scientist (Mallela) in work on Tobago reefs which supported the previous work in Jamaica and Belize (3.2). We then collaborated with other coral reef scientists and the USA National Oceanic and Atmospheric Administration (NOAA) linking orbiting satellite data with underwater observations to develop a predictive tool for coral bleaching and mortality (3.3).

Work at the University of Bedfordshire then showed that there were significant linear relationships between reef rugosity (three-dimensional complexity) and the growth and survival of young corals. Our findings suggested that three dimensional topography and complexity is important for reef resilience and viability in the face of environmental stressors such as bleaching, and also supported the idea that aggregated spatial arrangements of corals can influence the outcome of inter-specific competition and promote species coexistence, important in times of reef recovery after disturbance (3.4). Our work using capacity building in Belize (3.5) linked environmental and social science techniques to produce action plans for reef managers. We developed a collaboration with scientists at the Key Laboratory of Biodiversity and Systems Biology at Fudan University (ranked 5th of all Chinese Universities) in Shanghai, and studied metabolic robustness under environmental stress – including high CO_2 concentrations - using a novel method - Minimization Of Metabolic Adjustment Dynamic Flux Balance Analysis (M-DFBA). Our work suggested that highly cooperative regulation assures the robustness of biological systems, and that there is closer cooperation under perturbation conditions than under normal conditions (3.6). Further developments of modelling coral reef growth and resilience in the Caribbean ensued (e.g. 3.6). Our collaboration with Fudan University has extended to other environmental areas of high impact, for example using modelling to show industrial pollution in China due to transfer of industry (Zheng, W., *et al*. 2013. *Scientific Reports* 3, 1031; DOI:10.1038/srep01031), working with environmentally challenged organisms, where we have shown horizontal gene transfer (Li, X. *et al*. 2013. *PLoS ONE* 8(3): e58747), and environmental regulation of gene expression (Yang, Z., *et al*. 2012. *BMC Genomics* 13, doi:10.1186/1471-2164-13-S7-S14).

3. References to the research

3.1. Crabbe, M.J.C. (2009) Scleractinian coral population size structures and growth rates indicate coral resilience on the fringing reefs of North Jamaica. *Marine Environmental Research* 67, 189-198. (3*; IF= 2.48)

3.2. Mallela, J. and Crabbe, M.J.C. (2009) Hurricanes and coral bleaching linked to changes in coral recruitment in Tobago. *Marine Environmental Research.* **68**, 158-162. (3*; IF= 2.48)

3.3. Eakin C.M. et al. (2010) Caribbean Corals in Crisis: Record Thermal Stress, Bleaching, and Mortality in 2005. *PLoS ONE* **5**(11*), e13969. doi:10.1371/journal.pone.0013969* (4*; IF= 3.73)

3.4. Crabbe, M.J.C. (2010) Topography and spatial arrangement of reef-building corals on the fringing reefs of North Jamaica may influence their response to disturbance from bleaching. *Marine Environmental Research* 69, 158-162. (3*; IF = 2.48)

3.5. Crabbe, M.J.C., Martinez, E., Garcia, C., Chub, J., Castro, L. and Guy, J. (2010) Is capacity building important in policy development for sustainability? A case study using action plans for sustainable Marine Protected Areas in Belize. *Society and Natural Resources.* 23, 181-190 (3* IF= 1.1)

3.6. Luo R. et. al. (2009) Photosynthetic metabolism of C_3 plants shows highly cooperative regulation under changing environmental conditions: a systems biological analysis. *Proceedings of the National Academy of Sciences USA*. **106**, 847-852. (4*; IF= 9.74)

Average IF for the field = 2.2

4. Details of the impact

REACH:

Coral reefs are the most diverse ecosystems on the planet, and are the most threatened from climate change. Coral reefs provide a habitat from which 6 million tons of fish are caught annually, providing income and food for local communities. Reefs also act as breakwaters, protecting the land and nearby coastal communities. Economists estimate that the reefs are worth several billions of dollars in the Caribbean alone. Our work has been important throughout the Caribbean, for example Jamaica, and the second largest barrier reef in the world – the Meso-American Barrier Reef, from Mexico through Belize to Guatemala and Honduras. As a result of our research, Crabbe, as research leader, was invited to take part in the EDGE programme by the Zoological Society of London (5.1) and the Coral Reef Crisis Working Group, by the Royal Society (5.2). The former produced a new scheme for funding conservation of coral reefs throughout the world, and the latter produced a report that was a major environmental consideration at the 15th Conference of Parties in Copenhagen in 2009 and produced the Copenhagen Accord.

SIGNIFICANCE:

Our research informed policymakers throughout the Caribbean, and as a result Crabbe was invited to develop management action plans for policy developers in the Caribbean, concentrating on two countries, Jamaica and Belize. In Jamaica, in 2010, this led to work with the National Environmental Protection Agency, part of the Government, to develop their plans for marine protected areas (MPAs). In June 2013 this involved working with government officials from the wider Caribbean and the USA. The Jamaican government has now agreed to the development and implementation of more effective MPAs around its coastline, as discussed at the recent Caribbean Challenge Initiative (5.3). To inform public debate, Crabbe has often been interviewed on Jamaican radio about environmental issues, most recently in August 2013 concerning the Portland Bight Reserve near Kingston.

In Belize, this led to a capacity-building exercise around MPAs in the Meso-American Barrier Reef, which involved both local NGO community workers and the government fisheries department, the last so that community engagement could be directly interfaced with fisheries operations and policy. Personal action plans were developed to facilitate the future of sustainable MPAs in the MesoAmerican Barrier Reef system. An NGO participant said ‘For the first time we were able to engage with someone from the Fisheries Department to make a significant change to reef preservation’. A fisheries manager said ‘As a result of this exercise we can collaborate to protect

our reefs and enhance our fisheries'. The capacity building case study, uniquely involving the participants to directly make measurements of coral growth and recruitment on coral reefs, has produced new ideas to improve organisation, management, education, support, and policy development in MPAs in Southern Belize (5.5). All participants felt that training and capacity building to key staff members was important, since this enabled them to enhance their skills in the field thus raising their standards to a certain level so as to perform better. The participants have agreed to maintain iterations among and between their constituent groups to ensure continued sustainability of both the reef and the fishing practices.

Involvement of the Department of Fisheries in our capacity building has resulted in direct transfer of information to the communities and the Government. The Director of Fisheries later said 'This was an important undertaking which has resulted in increased GDP from our fishing industry'. The personal action plans that were produced have been implemented, and taken back into their constituent communities. A key outcome of our work has been that in Southern Belize three NGOs TASTE (Toledo Association for Sustainable Tourism and Empowerment), TIDE (Toledo Institute for Development and Environment) and Friends of Nature have been incorporated into a single self-governing organisation, which spans four MPAs (Marine Protected Ares). This means that areas between MPAs which were previously subject to illegal fishing activity are now monitored and policed. The merger has enabled assessment and enforcement across four different MPAs. It also means greater efficiency per unit area in terms of MPA management. In summary, our approach as part of a complex relationship linking an ecosystem-based approach to fisheries management has resulted in greater engagement from all stakeholders (5.4 – 5.6).

CONTRIBUTION:
Both these examples, in Jamaica and Belize, have important economic impacts, based on our work at the University of Bedfordshire. Belize has the highest annual capture production - the annual volume of aquatic species caught by country for all commercial, industrial, recreational and subsistence purposes, in 2010, for countries in the Caribbean for which data is available. In 2010, Belize had 11.86% of its territorial waters as MPAs (compared to <2% in 2000), again, the highest value in the Caribbean where data is available. Having a large percentage of its territorial waters as MPAs, and in a coordinated network, reflects in the value of a country's fishing industry. Our research has influenced the increasing development of MPAs in the Caribbean.

In Belize, the fishing industry contributed 7.2% of the county's GDP in 2001, and our new measures (implemented in 2012) have enabled more efficient use of marine staff time, by employing NGO staff, as well as increasing the numbers of fish and invertebrates caught legally and sustainably by Belize fishermen. This has increased the valuable lobster, conch and snapper catches by c. 15% by mid-2013 from its value of c. 850 tonnes in 2007. In Jamaica, fishing is more a cottage industry, while the reefs are an important part of the tourist industry. The new co-operative management plans as a result of our research have multiple benefits - increase in yields for the local fishermen, and help preserve the reefs as a part of Jamaican ecosystems, while attracting increasing numbers of international tourists, now approaching 2 million per annum (5.6). In both countries, the measures adopted as a result of our research have promoted the resilience of the coral reefs to increasing global warming and climate change as well as increased income from fisheries.

5. Sources to corroborate the impact

5.1. Zoological Society of London. *EDGE of Existence for coral reefs 2011* (see www.edgeofexistence.org/coral_reef/default.php)

5.2. Report of the Coral Reef Crisis Working Group, 2009, The Royal Society, to COP 15, UN Climate Change Conference, Copenhagen, 27pp.

5.3. See: The Caribbean Challenge Initiative. The Nature Conservancy. www.nature.org/ourinitiatives/regions/caribbean/caribbean-challenge.xml

5.4. Report Card for the MesoAmerican Barrier Reef 2012. Healthy Reefs for Healthy People (M. McField et al.) (see www.healthyreefs.org/cms/wp-content/uploads/2012/12/2012-Report-Card.pdf)

5.5. Coral reef policy proposals, part 2 of the GLOBE Marine Ecosystems Recovery Strategy (MERSII) for the GLOBE Ecosystems Commission meeting at the CBD COP (Convention on Biological Diversity), Nagoya, 2010, 8pp.

5.6. *The Marine Professional.* Reef Resilience in the Caribbean. March 2013, p.8.

Contact Head of Marine Sciences, University of the West Indies, Mona Campus, Kingston, Jamaica; and Discovery Bay Marine Laboratory - for the impact of our work in Jamaica and the wider Caribbean, with the National Environmental Protection Agency and local stakeholders, on the development and implementation of new marine protected areas leading to sustainable management of coral reefs and increased income from fishing.

Contact Executive Vice-President, the Earthwatch Institute (www.earthwatch.org) - for the impact of our knowledge transfer and capacity building work in Belize and elsewhere, with the Fisheries Department and local non-governmental organisations, linked to the development and implementation of new marine protected areas leading to sustainable management of coral reefs and increased income from fishing.