

FOREWORD

Management of marine resources; combining industry and research

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Modern day conservation requires a research approach that is truly trans-disciplinary to ensure that natural resources are effectively managed from a bottom-up and top-down perspective. Numerous opportunities potentially exist to better manage aspects of the aquaria trade such as coral farming for conservation outcomes, or the utilization of industry data for the optimization of coral growth, thereby enhancing our understanding of environmental regulation of coral productivity. However such collaborations, partnerships and initiatives need to be very carefully and transparently managed for the good of all parties. In particular, the use of an exploitative industry for direct ‘in the field’ conservation impact is likely to be politically sensitive. It is therefore essential that full knowledge of the biology and ecology of the system as well as all possible system implications of exploitative activities are known and that the conservation benefits of research–industry partnerships are fully communicated to and understood by all stakeholders. These actions will reduce the risk of miscommunication and inadequate socialization of the project; these being the greatest possible threats to any partnership.

Considering the ever increasing threat of over-extraction of marine resources it is a priority to implement management strategies which are designed to support the economic requirements as well as the day to day needs of local communities. Without real and achievable alternative livelihood practises being put in place, management initiatives are likely to have limited conservation success. Detailed understanding of the biology of systems along with local and regional socio-economic characteristics that can all be contextualized within an area’s political framework should lead to more pro-active and successful management outcomes (Smith *et al.*, 2007).

Conservationists, fisheries biologists and those involved with the aquaria trade have mutual concerns and aim to ensure, or otherwise require, a productive and biodiverse reef environment; in this sense all parties are inextricably linked. Addressing key research priorities often requires resources outside those available to the research and conservation community but can be readily available within the different industrial sectors. Historically academics and industry

have operated in parallel addressing similar questions but without combining resources, expertise and experiences. Through collaboration and resource sharing it is most likely that the reef community as a whole (herein defined as all stakeholders) will be much better placed to investigate common areas of interest such as active growth, increased fecundity, reduced mortality and enhanced resilience (Forsman *et al.*, 2006; Shafir *et al.*, 2006).

Despite mutual interests and perhaps due to different agendas, pressures and time-scales there has been limited engagement between the different stakeholders although there is a high probability of synergistic outcomes. This Special Issue of the *Journal of the Marine Biological Association of the United Kingdom* (JMBA) examines aspects of reef and reef resource usage from both a research and industry point of view. The production process of the Issue in itself has led to new relationships between academia and industry and is one way in which synergism can be demonstrated leading to the better understanding of reef processes and key conservation issues. Publications herein have been brought together through the JMBA remit for those readers interested in coral reef ecology, physiology, climate change, reef resource usage, the maritime industry, reef communities, conservation and the aquaria trade.

In the past, opportunities to capitalize on the international standard of coral reef research being undertaken have been limited. Where partnerships were previously formed they tended to be transient and project specific, thus reducing the capacity to enable the identification of new activities and mutually beneficial projects. The Coral Aquarist Research Network (CARN) was launched in 2009 through the Knowledge Exchange Fellowship Programme funded by the Natural Environment Research Council (NERC). CARN was designed as a platform to facilitate direct engagement of coral reef researchers and those involved in coral industries with the research agenda being identified and developed by all associated parties. Evidence of the impact of CARN has been demonstrated in many of the articles published within this Special Issue including those by Crabbe (2012), D’Angelo & Wiedenmann (2012), Hartle-Mougiou *et al.* (2012), Hoeksema *et al.* (2012), Osinga *et al.* (2012a, b), Schutter *et al.* (2012) and Sweet *et al.* (2012); which were all initially presented at the first CARN conference held in June 2010 at the Royal Geographical Society in London.

Conservation management can use a top-down, legal regulatory as well as a bottom-up, participatory approach. Both of

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which require management strategies to be fundamentally based on a clear understanding of system mechanisms such as the drivers of biodiversity and ecosystem stability as well as consequences of disturbance and impacting factors. Detailed understanding and appreciation of biology is therefore key although surprisingly is often considered secondary to other management drivers be they biological, political or economic with much of the biology of reef systems being largely unknown and non-described. Symbiotic interactions are a fundamental part of most biological systems with the subsequent relationships having a major impact on the biodiversity of coral reefs (Hoeksema *et al.*, 2012). Outside of the tropics, rocky coralligenous regions have a large number of taxa co-existing that provide an ideal habitat for rich molluscan assemblages (Urre *et al.*, 2012) and biodiversity rich regions of biogenic reefs in the UK are being protected to preserve the community composition contained within (Chapman *et al.*, 2012). By establishing how 'natural' the responses seen in captivity actually are will provide researchers with vital information that could answer many questions that simply cannot be achieved over a similar timeframe in the field (Hartle-Mougiou *et al.*, 2012) although field studies will occasionally highlight new species or provide additional information to that already known such as that shown in Guzman & Breedy (2012) and Kleeman & Baal (2012).

Growth of species, populations and their potential influence on community structure is dependent upon the way in which a species interacts with its physical, chemical and biological environment. Species tend to live within environmental optima. However, as the pressure on our environments increases and diversifies in terms of conditions, the implications for species and communities are wide ranging. We therefore need to gain a better understanding of how environments regulate the growth and fitness of individual species and in turn how these species interact at higher levels of system complexity (Carr *et al.*, 2002). Key to the success of tropical reef systems and therefore primary drivers of biodiversity are the reef building corals. Research has demonstrated that environments greatly regulate rates of growth but also architecture of coral colonies. Changes to architecture have great influences on the associated biodiversity and consequently knowledge of environmentally regulated growth across taxon and bioregions is crucial to understanding the fundamental process of high biodiversity and maintenance of diversity mechanisms. Environmental and climatic disturbances can have significant impacts on our global ecosystems with many factors influencing species growth; by investigating the conditions required to optimize coral growth under laboratory conditions, these benefits can be transferred to the aquaculture industry to improve sustainability (Shutter *et al.*, 2012). A key priority action for field researchers and conservation managers is to enhance the rates of growth and net reef development. Difficulties arise however when trying to identify the key drivers of changing dynamics which can be supported by laboratory-based studies. Enclosed aquaria systems will never provide an exact comparison to the variability of conditions within a field environment; however, the information obtained can strongly enhance studies of the drivers of coral growth.

Improved husbandry of captive corals is the key to a more sustainable coral trade; investigating the optimal feeding regimes for captive corals (Osinga *et al.*, 2012b) or determining the effect of light, food supply and water flow will provide

a better insight into the growth of corals in captivity (Kimokeo *et al.*, 2012). Experiments performed in captivity provide opportunities by which conditions can be adapted to simulate future seawater conditions based on climate change and ocean acidification for example (Toonen *et al.*, 2012) and for the fertilization success of corals in areas that have increased turbidity (Erfemeijer *et al.*, 2012). Experiments that examine the influence of varying environmental conditions on coral growth and nutrition will provide insights into the fundamental biology of coral species and their ability to acclimate across a range of conditions. Such responses are likely to be critical in the near future (Crabbe, 2012). These studies can provide experimental study data that can be used to construct and validate models that will enable researchers to examine likely outcomes of changing environments and industry to identify optimal growth conditions. The CORALZOO project has also benefited the aquaria industry immensely by improving the methodologies used to grow and maintain corals kept in captivity. Numerous partners from research, industry and aquaria organizations collaborated in this four year European Union funded project that was completed in 2010 (Osinga *et al.*, 2012a).

Environmental growth conditions may or may not be constrained but what is apparent is that species have to cope with periodic environmental stress events. Many climatic models are predicting an increased occurrence of these events meaning that understanding how species and communities are regulated by environmental conditions is extremely important (Randall *et al.*, 2007). We also need to know how a species' competitive ability is influenced by its stress biology; species that are competitive under optimal conditions may not be the same species that are able to cope and dominate systems when stress events become more frequent (Suggett & Smith, 2011; Pandolfi *et al.*, 2011; Russell *et al.*, 2011). The ability of a species to acclimate to stress environments is a function of both the genetic footprint and also its environmental growth histories. Consequently the future of marine communities is a combination of this ability to acclimate and the way in which individual components of the system react during such events. New molecular methods and techniques looking at the stress physiology of corals are being tested under strictly controlled conditions at the National Oceanography Centre, Southampton, UK (D'Angelo & Wiedenmann, 2012). The invasion of warm/tropical marine alien species often associated with warmer water temperatures and subsequent changes in the respective ecosystem has been documented for decades; the relationship between new alien species and global temperatures is discussed in Pancucci-Papadopoulou *et al.* (2012). Environmental growth also includes disease and consequently research into coral disease has also been on the increase in recent years. Those found naturally in the environment do not translate directly to those in captivity. By determining the relationship between the two could dramatically improve the understanding and benefits of coral husbandry, improve opportunities for coral culture, reduce mortality within a closed system, and reduce environmental impacts on our natural resources (Sweet *et al.*, 2012). Despite its common presence on reefs globally, outbreaks of the starfish *Acanthaster planci* can occasionally have a major impact on coral reefs. There is still a large amount of research required to provide explanations for the increased recruitment and subsequent outbreaks of these species (Lane, 2012).

Regardless of the winners and losers and the overall resilience of a system, it is clear that with ever expanding populations and the changes in the utilization of marine resources as a provider of food, income and livelihoods for millions of the world's population, marine resources will always be exploited. Depleted fisheries stock, reduced system diversity, and decreased habitat quality, productivity and functionality are all evidence for the increasing pressures on coral reef resources. Changes to the way in which reef resources are utilized and managed are a top conservation priority and tighter regulation which is embedded in working policy is required. For example, current regulations within many global commercial shrimp fisheries are resulting in exploitation and significant stock reductions. Further assessments are hoping to initiate new fisheries policies aimed at reducing this impact (Paramo & Saint-Paul, 2012) and these policies must consider the fundamental biology of the system and in particular the population genetics and dynamics (De Croos & Pálsson, 2012). Another example of changing policies is that seen within some examples of the sea cucumber fishery, by estimating natural mortality rates based on stock reduction and species exploitation (Dissanayake & Stefansson, 2012). Mass reductions in populations is evident throughout the sector, for example, the yellow eel, *Anguilla anguilla* with the latest figures showing a reduction in the population to only 1% of 30 years ago and insufficient recruitment to compensate (Henderson *et al.*, 2012). The direct impacts of commercial fisheries have very much become the centre of discussion over the years along with the controversial subject of indirect impacts such as by-catch of marine life such as turtles. Improvements to the fishing equipment and techniques used as well as awareness campaigns are required to decrease unnecessary and detrimental by-catch (Echwiki *et al.*, 2012).

In this changing world constant changes and adaptations are being made to the utilization of our depleting natural resources. To date there has been limited engagement between research and industry with limited mechanisms in place to enable, or stimulate, industry to capitalize on the international standard of research being undertaken by academic institutes. By capitalizing on future engagement opportunities and incorporating knowledge exchange with the sharing of responsibilities and expertise, the efforts from all sectors of society can be collaborated in a synergistic manner. This participatory approach will enable key projects to be identified and ensure stakeholder buy-in, participation and willingness. These factors are the basis of successful partnerships, sustainable management and improvement of the conservation of marine systems and their associated marine resources.

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