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Editorial Overview: Environmental Change Issues: Coral Reefs Sustainability and Its Challenges

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Coral Reef Sustainability and its Challenges

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Coral reefs are beleaguered ecosystems under a variety of threats. Stressors can be divided into three basic categories. First there are those acting locally, in the "near field". These are stressors and impacts caused by local phenomena and under the direct influences of the local populus. Point-source pollution, local overfishing and destructive fishery practises come to mind. While having localized impacts, they are ubiquitous and only the exceptional and remote reef systems are spared these impacts. However, being local in source, and local of impact, one may surmise that they could be addressed by local action and that concerted conservation action should have a fighting chance of bearing fruit (Rinkevich [1], D'Angelo and Wiedenmann [2], and Risk [3]).

The other family of stressors act over larger scales, some even globally, so are "regional field" and "far field" [4]. This is the entire family of problems faced by coral reefs due to the various environmental changes brought forth by the increasing modification of the Earth's surface, its climate and ocean chemistry. Global warming, sealevel rise and ocean acidification are much-discussed topics in the coral reef community and questions arise as to how much coral reefs can be resilient to these changes, especially when combined with "near field" stressors (Hoegh-Guldberg [5], Mumby [6], McClanahan [7], Graham [8], and Pandolfi [9]).

Different to the management of "near field" stressors, local action is largely impotent in the battle against climate change effects and large-scale environmental modification of the hinterland, primarily because they are caused by the sum total of the world's economy [10]. Thus the causative agents of reef decline, i.e. generators of pollutants may live in different latitudes on different continents and it may therefore be hard to convince them to change the way they do business in order to save a far-off reef. However, about half of the world's population, that is just over 3.5 billion people in 2013, live within 200km of the coast [11]. The economic footprint of coastlines generally reaches far inland, via the provision of transport, economic and employment opportunities anchored on coastal activities but benefitting the hinterland [12]. In many countries, such as Australia, the USA or the Maldives and other archipelagic nations, coral reefs are feted national treasures – much discussed, much cared-for and much researched. Thus, the understanding for the need of positive action in the face of climate change and local devastation should be relatively easily spread. And indeed, the plight of coral reefs has found much publicity in public and scientific media and an unprecedented number of managers and researchers work towards saving, or at least better understanding, coral reefs. So, maybe, we can expect much good news.

All of the threats to coral reefs outlined in this volume have humans either as proximal or distal cause. By living near coral reefs, sometimes directly on them, and by actively interfering with ecological processes, humans are very much an integral part of the coral reef ecosystem and must not be ignored in studies, especially those asking about sustainability of the ecosystem. Cinner [13] discusses the human societal aspect relating to coral reef sustainability.

Fisheries and coral reefs are well known to be a problematic combination. Human population growth and fisheries are intricately linked because resource consumption, and especially that of

fisheries products, has been growing even faster than the human population [14]. But Pauly and Zeller [15] show that catch records tend to be significantly underreported – a worrying prospect given that many coral reef fisheries, even under the reported extraction regime, are over-exploited. McClanahan et al. [7] show that fisheries have a strong effect on coral community structure. Reef fisheries are clearly a "near field" stressor, much of the fishing and the consumption being done by local communities. Even where strong export fisheries have developed, such as for grouper in Australasia and the Pacific, catch is usually done by locals. One might thus surmise that local action or legislation could show positive results with relative ease. While certainly many examples of successful fisheries management exist, the majority of the world's fisheries are overexploited and many are heading towards collapse [16], if they have not collapsed already. Concerted effort would be needed to change this widespread downward trajectory. But legal tools that regulate fisheries, or the protection of rare species, have their very own challenges (Weijerman et al. [17]).

However, even a cursory investigation of human demography hints towards difficulties in achieving better management of fisheries or any extraction of protein, or of coral reefs in general, since more people living near reefs will results in more "near field" pressures. Depending on the population forecast, by 2100 the world's population will either have stabilized at ~8 billion [18] or will have reached almost 11 billion [19]. At present, with a world population of ~7 billion, there are ~6 million reef fishers worldwide [20]. Thus, if a linear relationship between total population and reef fishers was to be assumed for argument's sake, then by the end of the century that number would have grown to between 7 and 10 million. Since the present number of reef fishers already causes unsustainable pressure on many, if not most, corals reefs, it will certainly be challenging for coral reefs to support an additional 1-4 million full-time fishers. And, as Pratchett et al. [21] show, when the reef suffers, fishers suffer too.

The above argument is further supported by the fact that situated within the tropical reef belt are countries with some of the highest birth rates in the world (Somalia with 7.1 children per woman in 2005-2010; Comores with 5.1, Ethiopia 5.6, Tanzania and Mozambique 5.5; Kenia and Madagascar 4.8), their populations consequently with some of the lowest median ages [19]. Fishing on reefs can be a physically demanding activity and therefore mostly an occupation of younger people – thus the number of fishers, and therewith the challenges associated with overexploitation, are set to rise significantly in the future. The steepest increases in the numbers of young people that could take up fishing will occur in East Africa and the Western Indian Ocean. The impacts of this increase will be somewhat tempered by the relatively low per-capita consumption of fish in this region (p.ex. Kenia with 2.8kg.y^{-1} of which 4% are marine [22]) and a presently lower overall number of fishers (1.5 million. [8]). While Asian countries have lower population growth (Malaysia 2.07; Philippines 3.27; Indonesia 2.5 children per woman in 2005-2010 [19]), they have higher per capita fish consumption, of which much is derived from reefs, (Philippines 29kg.y^{-1} of which 3.9kg are demersal and other non-pelagic marine fish; Indonesia 19kg.y^{-1} with 4 kg non-pelagic [23]) and so is the number of fishers (3.35 million, [20]). Therefore, although population growth will be slower in Asia and fewer new fishers and mouths-to-feed will be added than in the W-Indian Ocean, the net effect will likely be similar –increased pressure on the coral reef resources. Add to this that global seafood consumption rates are set to rise dramatically (faster than any other seafood category, [14]), and any hopes for improved management can only be realistic if they take the increased demographic pressure explicitly into account and find a way of dealing with it. The "near field" pressures seem to be key determinants in the survival of reefs, and these also hold great potential for management improvements, as in

many cases current management follows political considerations rather than expert recommendations (Weijerman et al. [17], Risk [3], Bruckner [25], Pauly and Zeller [15]).

While coastal human populations will grow significantly, the majority of new people to be born until 2100 will not live on the coast. In particular Africa will see strong population increases (over 1 billion until 2050, the majority inland [19]). Metropolitan areas will see the strongest increases (70% of the world's population living in a metropolitan area by 2050) but rural populations will obviously increase too and can, in the absence of careful land management, lead to increased watershed degradation and therewith increased silt and pollutant transport toward the coast, and its coral reefs, by rivers and canals. The changes in hydrographic regime and sediment loads experienced by the Great Barrier Reef and the East African coast with the onset of European farming in the Australian and African highlands [25, 26] are set to be repeated at a gigantically larger scale. And impacts will not be restricted to reefs in shallow water, also deep reefs are at threat (Kahng [27]).

Sea-level rise has the potential to cause significant coastal flooding with concomitant sediment and pollutant (re)mobilisation. But ~35% of the world's mangrove forests, important buffers acting as sediment and nutrient traps between land and reef, have already vanished. They served as sources for wood or had to make space for aquaculture ponds, providing commodities that primarily benefit the hinterland. Their demise leaves little to abate the erosive action of even slightly raised sea-level. Thus, reefs must expect more pollutant- and sediment stress. Any hopes of managing point-source pollution, especially by rivers, will have to take altered demographic realities in the hinterland into account. Thus, "far field" pressures (population growth, altered precipitation patterns, sea level rise) and "regional field" pressures (devastation of individual watersheds, higher pollutant and sediment point source release from individual rivers) augment the threats to reefs posed by "near field" pressuress like fisheries. Either have equal potential to disrupt coral reef ecosystem functioning.

Not only have human populations grown in numbers, they have also grown in wealth. The biggest increases have been seen in Eastern Asia where GDP growth from 1975 to 2002 averaged ~8%. The world's population of high-net-worth individuals (with >1 million $ in investable assets) has steadily grown and reached about 12 million in 2012, with a total worth of 46.17 trillion $ [28]. It is not surprising that such amounts of disposable cash (~30% of HNWI wealth is held in cash) can drive luxury markets. This has shown marked effects on the exploitation of coral reef resources, from precious coral to living sea trout that a sought-after high-end consumer goods. Wealth thus becomes a bridge between "near field" and "far field" pressures. Far-field money can drive near-field dynamics of exploitation. Given the vast amounts of money available, any attempts at controlling over-exploitation of coral reef resources will need a well thought-out economic background. Since increased rarity tends to increase price, luxury value of declining resources increases. Thus, the future pressure on rare coral reef resources is likely to increase in a vicious cycle of more money being offered to a greater population of people (fishers or others) to procure the sought after, but rarer, luxury item. This may not bode well for precious corals, groupers, coral trout and others (Bruckner [24], Rhyne et al. [29]).

The Intergovernmental Panel on Climate Change (IPCC) clearly shows [30] that human activity has caused the majority of the climate change phenomena. Climate change, clearly a "far field" driver, has been amply demonstrated to be potentially lethal for coral reef ecosystems, be it via increased heat-induced mortality or changes in ocean alkalinity that have significant

physiological effects like decreased calcification ability of reef organisms and behavioural changes in reef fishes. Heat and changed acidity, alone or in tandem, are "far-field" drivers that are likely to have knock-on effects on "near-field" drivers. For example, average size of fishes may decline and the latitudinal distribution of fishes is also likely to change [31]. If important food fish are concerned, this may result in altered local exploitation effort and changed local fisheries dynamics. A wholesale demise of coral reefs due to global change would most certainly translate to significantly altered local human dynamics. Whatever the effects, coral reefs of the future may look very different from what we know today (Graham [8]).

But climate change, to a large extent driven by CO_2 emissions, is of course intimately linked to the size of the human population for which energy is produced and its consumption of raw materials. The overall increase in wealth also means that by 2050 there may be up to 4 billion motor vehicles in service [32]. That added to increased power production needed for a bigger population makes it hard to see how emissions can be reduced without serious political commitment. In sum, it appears very clear that the sustainability of coral reefs is linked more or less directly to what we, as a species, decide to do with our reproductive tracts and what we then decide to do in our later lives. As societies, we may be required to revisit attitudes and values, for example whether the paradigm of unlimited economic growth might be modified into one of sustainability (itself a fraught term), or wether that of profit could be more firmly augmented by one favouring quality of life, ideally for all [10]. Better management of all above mentioned aspects is required if a positive opinion on the sustainability of coral reefs is to be warranted.

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