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Editorial overview: Environmental change issues: Coral reefs 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•], this issue).

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 *et al.* [6•], McClanahan *et al.* [7•], Graham *et al.* [8•], and Pandolfi and Kiessling [9•], this issue).

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, that is, 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 200 km 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 toward 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 special issue 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•], and Stevenson and Tissot [14•] in this issue, discuss 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 [15]. But Pauly and Zeller [16•] 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 overexploited. McClanahan *et al.* [7•], in this issue, 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 toward collapse [17], 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.* [18•], in this issue).

However, even a cursory investigation of human demography hints toward 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 result in more 'near field' pressures. Depending on the population forecast, by 2100 the world's population will either have stabilized at ~8 billion [19] or will have reached almost 11 billion [20]. At present, with a world population of ~7 billion, there are ~6 million reef fishers worldwide [21]. 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.* [22•], in this issue 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 [20]. 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 (e.g. Kenia with 2.8 kg y^{-1} of which 4% are marine [23]) 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 [20]), they have higher per capita fish consumption, of which much is derived from reefs (Philippines 29 kg y^{-1} of which 3.9 kg are demersal and other non-pelagic marine fish; Indonesia 19 kg y^{-1} with 4 kg non-pelagic [24]) and so is the number of fishers (3.35 million, [21]). 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, [15]), 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.* [18•], Risk [3•], Bruckner [25•], Pauly and Zeller [16•], in this issue).

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 [20]). 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 [26,•27] are set to be repeated at a gigantically larger scale. And impacts will not be restricted to reefs in shallow water, as deep reefs are at threat as well (Roberts [28•], Kahng *et al.* [29•], in this issue).