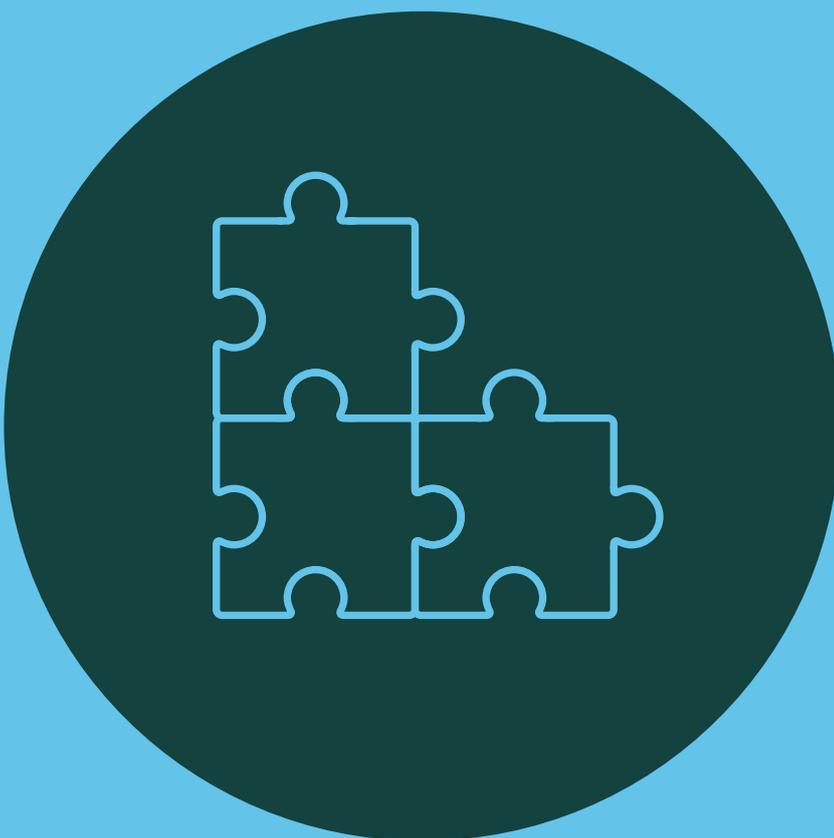

Preview of results from a book on
valuing the oceans and the economic
consequences of action or inaction

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The Impacts of Multiple Stressors

A complex web of challenges

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The Impacts of Multiple Stressors

No marine systems remain unaffected by human impacts. The intensity and spatial distribution of these anthropogenic threats is currently expanding to levels unprecedented in human history. Since many of these stressors – including rising temperatures, changes to ocean circulation and mixing, ocean acidification, ocean deoxygenation, coastal hypoxia, overfishing and pollution – co-occur in time and space, marine organisms and ecosystems are increasingly being subjected to the simultaneous impacts of multiple stressors. It is estimated that over 40 percent of the marine environment is already impacted by a combination of stressors.

The effects that the different stressors, and particularly their combination, will have on ocean organisms and ecosystems, and on the important services they provide to humanity, are currently poorly understood. Improving this situation, and defining management solutions, has been identified as one of the most important – and complex – challenges in marine ecology today. At the moment, information is rarely synthesised to convey where multiple threats are occurring, or whether their combined effects are antagonistic (less than the sum of their parts) or synergistic (greater than the sum of their parts) as opposed to simply additive. The vast majority of management strategies therefore proceed on a single issue-specific basis, with little consideration for the relationships and feedbacks between multiple stressors.

Global versus local stressors

Stressors of marine systems can be divided into two categories: those that act globally but with varying intensity, such as increased temperature, ocean deoxygenation (the global trend of decreasing oxygen as a result of ocean warming and increasing stratification) and ocean acidification; and those that act at a local to regional level but occur globally, such as overfishing, pollution and coastal hypoxia (low dissolved oxygen environments due to increased nutrient levels). The emission of CO₂ into the atmosphere is the primary driver for all the global scale stressors and needs to be addressed through global climate policy. At local to regional scales, the drivers are varied, but are all related to the expanding human population. Regional/local stressors can be addressed through policies and actions at these scales. The potential for interaction between global and local stressors, however, calls for coordination across all scales, something which is lacking in current ocean management.

Hotspots and vulnerabilities

While the chemical and physical changes associated with ocean warming, acidification and deoxygenation occur globally, the imprint of these global stressors will have a strong regional and local nature. The coalescence of the different global stressors in certain regions is already creating a number of 'hotspots' (Fig. 1), among which the Eastern Boundary Upwelling Regions stand out, but the high-latitude North Pacific, the Arctic, and the Southern Ocean also deserve attention.

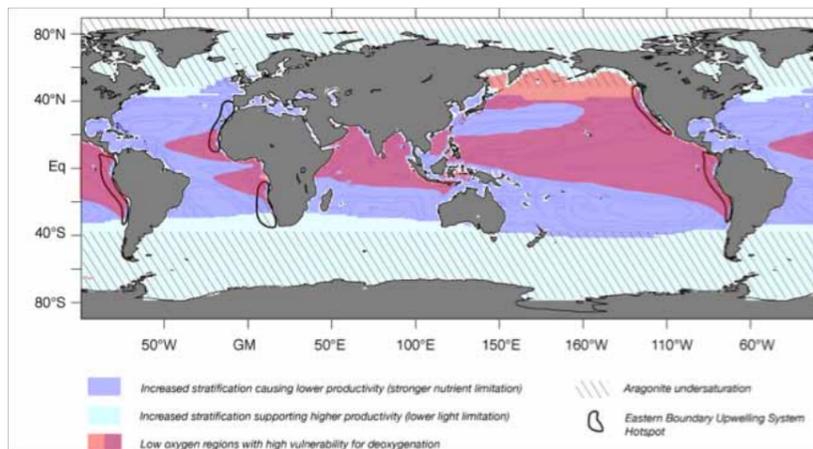


Figure 1 Global map showing regions of particular vulnerability to the three main global stressors – ocean warming (which increases vertical stratification), acidification (indicated by aragonite undersaturation), and deoxygenation. From Gruber, N. (2011), Warming up, turning sour, losing breath: Ocean biogeochemistry under global change, *Phil. Trans. R. Soc. A*, 369, 1980-1996, doi:10.1098/rsta.2011.0003.

In addition to these regional 'hotspots', certain marine ecosystems are also showing signs of particular vulnerability to multiple stressors. Foremost among these are coral reefs, which are among the most diverse ecosystems on earth and estimated to contain approximately one third of all described marine species. The mass bleaching of coral reefs has been shown to occur more frequently, largely in response to ocean warming, but this condition may have been enhanced by a combination of stressors acting simultaneously – and often synergistically. Recent studies indicate that future predictions of bleaching must also take into account the additional effects of ocean acidification, and point out that any potential adaptation of corals to thermal stress may be offset by further decreases in the pH of the ocean. In addition, a number of local/regional scale stressors, such as pollution, overfishing and fragmentation of reefs by destructive fishing and coral mining could affect coral reefs, particularly since they are found primarily in coastal areas where local anthropogenic impacts often occur. The potential for these local/regional scale stressors to interact with global scale stressors such as increased temperature and ocean acidification is high. In many cases, these local stressors undermine the resilience of coral reef ecosystems to other stresses, diminishing their capacity to provide services such as storm surge protection, which itself is increasingly vital in the face of global environmental change.

The combination of global and local/regional stressors can also threaten particular species, including some economically and nutritionally important ones. One example described in the chapter comes from the Eastern Tropical Pacific where the combination of decreasing pH, increasing temperature and deoxygenation have the potential to significantly impact one of the top predators in the region. Studies have found that the jumbo squid exists at the edge of oxygen limitation and is not believed to be well poised to adapt to changes in oxygen supply and demand. This in turn has the potential to impact not only the fishery for jumbo squid but also the larger ecosystem within the Eastern Tropical Pacific, as the jumbo squid are an important component of the diet of birds, fish and mammals.

Multiple global stressors at the ecosystems level can also impact fish populations and fisheries catches. Recent scenario modelling studies on the impact of decreased pH and oxygen content on the important fisheries of the northeast Atlantic have projected

catch potential reductions of 20 to 30 percent by 2050 under business-as-usual carbon emissions. This would have serious economic consequences for fishing communities.

Local actions, global impact

One example of the potential for the interaction between global and local stressor is the combined impact of increased temperatures and exposure to commonly used herbicides on coral species. Studies have shown that the presence of commonly used agricultural herbicides have a negative impact on certain corals, and a synergistic response with rising temperatures, which serves to exacerbate thermal stress. Similarly, increased nitrate concentrations can amplify temperature stress in corals, so controlling nutrient concentrations can raise the upper thermal bleaching limits of corals, making them more resilient to ocean warming. This is demonstrated in Fig. 2 which shows how the impact of increased nutrients from land use changes alters the threshold temperature for coral bleaching.

This example highlights the conclusion that management of local stressors has the potential to buffer – at least temporarily – the impact of global stressors. By aggregating these local actions up to a global scale, through coordinated networks of initiatives, such interventions can help increase ecosystem resilience and buy valuable time to deal with the global stressors.

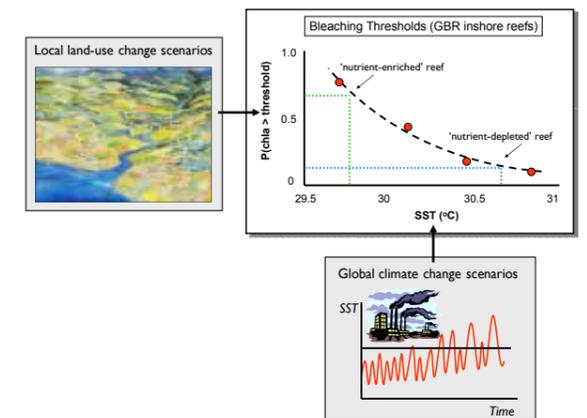


Figure 2 Conceptual modelling framework that enables the impact of 'local' (i.e. water quality improvement) and 'global' (i.e. CO₂/temperature reduction) management strategies to be assessed in terms of their joint (conditional) potential to reduce the future likelihood of mass coral bleaching on the GBR. From Wooldridge, S.A., (2009), Water quality and coral bleaching thresholds: Formalising the linkage for the inshore reefs of the Great Barrier Reef, Australia, *Marine Pollution Bulletin* 58, 745-751.

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Implications for marine policy and governance

Research into where multiple stressors are occurring and how they are affecting the functioning and resilience of marine ecosystems should be prioritised. Although many details remain unclear, a number of fundamental insights are firmly established, particularly with regard to the global stressors. We know that much of the increased CO₂ released into the atmosphere has been absorbed by the ocean and has led to acidification; most of the excess energy flux stemming from increased greenhouse concentrations in the atmosphere is taken up by the ocean, which causes warming that will lead to increased stratification which then tends to enhance oxygen depletion in the open ocean; acidification and oxygen depletion can synergistically interact to enhance negative impacts. Though the interactions between these global stressors are complex, they are all driven by the same process, i.e. increasing levels of CO₂ in the atmosphere, thus requiring a single policy response, i.e. a reduction of our CO₂ emissions.

At the local and regional level, many of the key issues associated with local and regional stressors are also well understood. It is known how such local stressors need to be addressed individually. What is sorely lacking is the combined perspective that looks

simultaneously at the impact of multiple stressors.

There is an urgent need for the global community to address multiple stressors affecting marine systems by making policy decisions aimed at optimising outcomes for these complex systems, and approaching ocean governance from strategic perspectives that utilise multi-management schemes and networks. Creating such a cross-scale governance system for marine resources that actually works is an urgent and intricate challenge, but one that is far from impossible to achieve.

Local governments should act to reduce local stressors wherever possible. At the national level, efforts should strive to support well-informed decisions and effective action at the local level that appreciate the complexity of multiple stressors, and that aggregate up to the regional and global level.

While much remains unknown and unpredictable we should adopt a precautionary approach in the context of these unprecedented multiple stressors. The words of Agenda 21 may be twenty years old but they ring truer today than ever; ocean management strategies must be “integrated in content, and precautionary and anticipatory in ambit.”

