International Commission on Land Use Change and Ecosystems

Coral Reefs and Climate Change

Tropical coral reefs are the most diverse marine ecosystems on the planet. Half a billion people depend to some degree on the goods and services provided by coral reefs, which are estimated to be worth between US$172 - 375 billion per annum. In 2008, 19% of coral reefs had been lost and 35% were threatened through direct human impacts and climate change. However, climate change is already forcing coral reefs into an irreversible decline leading towards complete destruction in the next thirty years. To save them, drastic action to reduce atmospheric CO_2 concentrations is required immediately.

Current status and trends in coral reef ecosystems

Tropical coral reef ecosystems represent just 0.2% of the oceans in area but are the world's most diverse marine ecosystems, harbouring an estimated 1-3 million species, including one third of all described marine species[1] and more than a quarter of all marine fish species[2]. It is estimated that 19% of the world's coral reefs were lost by 2008, with a further 15% under imminent threat and 20% under threat of loss in the next 20 to 40 years[3]. However, these estimates did not take into account the combined effects of climate change on coral reefs such as acidification, increases in sea temperature, sea level rise and more frequent occurrence of large storms. When these are factored in, all remaining coral reefs are categorised as critically endangered or threatened with destruction[3]. As well as climate change, the major causes of coral reef degradation are: overfishing and destructive fishing practices, sedimentation and pollution arising from land use change, agriculture and industry; unsustainable and destructive coastal development; and diseases, plagues of coral predators and introduced species[3].

The value of coral reef ecosystems

More than 100 countries have coastlines with coral reefs[4]. Half a billion people (8% of the world's population) heavily depend on reefs for food, coastal protection, building materials and income from tourism, and 30 million are entirely dependent on reefs[3]. Coral reefs supply about 10% of the world's marine fisheries landings and are of particular importance to small-scale fishers[2,3]. Coral reef tourism provides substantial revenue for both developing and developed countries. For example, the Great Barrier Reef generates $3.9 billion dollars in revenue from tourism annually. Other goods derived from coral reef ecosystems include pharmaceutical products, lime for agriculture, jewellery and fish for the aquarium trade[4]. Coral reefs provide many services including the creation of favourable conditions for other ecosystems (e.g. seagrass beds), the provision of critical areas for the breeding, spawning, early life history stages and feeding of other marine species, cycling of nutrients such as nitrogen and carbon, and the removal or storage of wastes from human activities[4]. The total value of goods and services provided by coral reefs is estimated at between US$172 - 375 billion per annum[5-8]. This is undoubtedly a substantial underestimation because many of the benefits of coral reefs are used locally and pass through non-market economies[9].The cultural value of coral reefs to coastal communities across the world is also important.

Projections of the future status of coral reefs

The increasing human population means that development will impact 91% of the world's coastlines by 2050[10]. Population growth will also increase pressures on marine capture fisheries, as well as lead to increasing impacts from sedimentation and coastal pollution from land use changes, agriculture and industry. These activities will increase the threats to coral reefs[3]. A degraded environment, whether natural or human-induced, has a strong influence on the vulnerability of reefs to climate change impacts and on their resilience, the capacity of a reef to recover from major damage[11].

Global climate change will threaten all coral reefs through increased frequency of coral bleaching events, ocean acidification and increased frequency of serious storm events[3]. The predicted biological and ecological effects of climate change on coral reefs and associated ecosystems have been reported for the Great Barrier Reef in Australia[13]. The effects of mass bleaching events on coral reefs have been studied

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in detail over the past 30 years and are well known[14,15]. When there is extensive coral mortality caused by bleaching the complex structure of the reef collapses. If conditions are not favourable for coral growth and recovery, the three-dimensional habitat is lost resulting in the severe decline of many reef fish and invertebrate species. Ocean acidification will have a similar but far more widespread effect on coral reefs in that they will change from complex growing structures into degrading and eroding ones within a few decades under present rates of CO_2 emissions. The increasing acidity of the water will cause decreased growth rates and skeletal strength in reef-building corals and other calcifying organisms. Structurally weaker corals will be more susceptible to damage from wave action, particularly during storms, and shoreline erosion caused by this, leading to infrastructure damage, can be substantial (ref attached). A drop in growth rate of 14% has already been observed for corals of the Great Barrier Reef[16]. Other species critical to reef formation, such as calcareous algae, will be strongly impacted, compounding reef degradation[12]. In terms of atmospheric CO_2 concentrations, the exact 'threshold' for coral reefs is uncertain, but even at today's level of 387 ppm most reefs worldwide are committed to irreversible decline[11]. At current rates of CO_2 emission we can expect to reach 450 ppm in the atmosphere by 2030 [11]. At this concentration coral reefs will be in rapid and terminal decline across the globe from the combined effects of mass bleaching, acidification and other environmental impacts[11]. **To ensure the long-term viability of coral reefs it is now agreed by leading coral reef and climate change scientists that atmospheric CO_2 concentrations need to be significantly below 350 ppm**[11].

Policy implications

New policies regarding coral reefs and climate change will need to be put into practise with immediate effect in order to firstly try to save corals reefs as a functional ecosystem and secondly to plan for the anticipated consequences of further coral reef degradation. A number of management interventions can increase the resilience of coral reefs in the short-term (next 20 years) and the following actions should be a priority: reducing the fishing of herbivorous fish to sustainable levels; protecting sharks and other top predators to maintain effective trophic pyramids in the ecosystem; managing all aspects of water quality especially pollutants that can lower seawater pH and minimising any other direct human impacts and stressors[11]. For the last point, improved management and control of direct human impacts such as overfishing, destructive fishing, coastal pollution and uncontrolled development are priorities. Since many coral reefs are located within the waters of developing countries, technical and financial assistance to improve the management of these ecosystems will be required. These actions can be supported through the use of large networks of no-take marine protected areas and other direct management interventions, such as the improved control of watershed-based activities whose effects on coastal water quality can be severe. A number of other policy and management actions have also been recommended[17]. However, these actions cannot offer long-term protection from the consequences of increasing atmospheric CO_2 levels as they pass critical thresholds[11]. Carbon emissions to date have already committed atmospheric CO_2 to remaining above 330 ppm for at least the next millennium[18]. **A major reduction of CO_2 emissions combined with active removal of atmospheric CO_2 through the use of carbon sinks and geoengineering techniques is critically needed to ensure the long term future of coral reef ecosystems**.

The predicted socio-economic consequences of a large-scale collapse of coral reef ecosystems are not fully understood yet, but severe consequences are already occurring. Forecasting and planning for these socio-economic effects is an absolute priority if we are to minimise the impacts on coastal populations of increased levels of poverty, migration, malnutrition, insecurity and conflict for resources. Initial forecasts for the climate change induced loss of fisheries in the tropics indicate that catches could decrease by up to 40% by 2100 at present rates of greenhouse gas emissions[19] on top of declines caused by overfishing. However this study does not factor in the increased degradation of coral reefs by climate change meaning that fisheries losses in tropical coastal areas will be significantly higher. Future economic losses for Caribbean coral reefs in terms of fisheries, tourism and shoreline protection were estimated at US $350-870 million per year up to 2015 [20], even without the predicted effects of climate change highlighted in this paper. Values lost will, as with many measurable indices, rise with increasing scarcity of reefs.

Key Policy Recommendations

Plan A – Save Coral Reef Ecosystems

1. Reduce emissions to stabilise atmospheric CO_2 concentrations.
2. Once stabilised, reduce atmospheric CO_2 concentrations to below 350 ppm (ideally <320 ppm) through the use of Carbon Dioxide removal methods, namely:
    a. Enhance carbon sinks through management of land-based and aquatic carbon sinks;
    b. Direct engineered capture of CO_2 from the atmosphere using safe and reliable techniques;
    c. Fund research and development to fast-track the production of reliable and cost-efficient CO_2 capture techniques.
3. Reduce or eliminate all other anthropogenic impacts on coral reef ecosystems so that they are in the healthiest (least stressed) condition possible to cope with the effects of climate change (CC).
4. Ensure the protection of all remaining remote and near pristine coral reef systems to prevent all non-CC impacts.

Plan B – Plan for the consequences of coral reef collapse

1. Provide funding for research into the likely biophysical and socio-economic consequences of the loss of coral reefs as a functioning ecosystem.
2. Provide funding for research into the feasibility and use of techniques to artificially raise the pH levels of coastal waters on coral reefs to mitigate the effect of ocean acidification on reef organisms and to shade or otherwise cool reefs to prevent bleaching.
3. Plan for the predicted consequences of coral reef collapse such as:
    a. increased poverty and food security issues;
    b. human population migration and effects on associated environments;
    c. overfishing of remaining marine resources in coastal waters;
    d. effects on trade and markets – loss of small-scale fisheries;
    e. increased coastal flooding through loss of protective reef barriers (in combination with sea level rise and increased storm incidence);
    f. large-scale loss of marine biodiversity – e.g. use of coral reef species cryogenic repositories to store reef fauna and flora until favourable conditions return;
    g. Any effects on associated marine ecosystems and biota – estuaries, mangroves, seagrass beds, deep or pelagic waters, marine mammals, reptiles and seabirds.

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