COMMENT

THE OCEAN AGENCY/XL CATLIN SEAVIEW SURVEY

A green sea turtle (*Chelonia mydas*) swims over corals bleached by anthropogenic global heating.

Save reefs to rescue all ecosystems

An approach that tackles the underlying causes of coral-reef decline could be applied to other habitats, argue **Tiffany H. Morrison**, **Terry P. Hughes** and colleagues.

All the coral reefs in the world could be gone by 2070 if global heating continues on its current path[1,2]. Since 1998, heatwaves have bleached or killed corals in more than 90% of reefs listed as World Heritage sites worldwide (including in the Galapagos Islands, Hawaii and Australia)[2] (see 'Under pressure'). In the Great Barrier Reef, the world's largest reef system, half of the corals died in 2016 and 2017 alone[3].

Coral reefs cover only 0.5% of the ocean floor, but they support almost 30% of the world's marine fish species. Their loss has huge implications for biodiversity and for the roughly 400 million people who depend on them for work, food and protection from waves, storms and floods in more than 100 countries across Australasia, southeast Asia, the Indo-Pacific, the Middle East, the Caribbean and the tropical Americas.

We think a change in approach is urgently needed from the slew of groups striving to safeguard reefs: ecologists, conservationists, non-governmental organizations, national and regional policymakers, and philanthropists. Such groups must address the causes of reef ecosystem decline — not just focus on biodiversity, or on trying to restore a particular reef or region to some idealized 'prior state', for instance by establishing marine parks.

Policymakers in Australia, say, should try to change land use in the 425,000-square-kilometre catchment of the Great Barrier Reef. ▶

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Currently, they funnel some US$14 million each year into local-scale approaches such as coral gardening to restore damaged reefs. Instead, they should replace coal-fired power with renewable energy sources, develop land-based aquaculture (which avoids the release of animal waste and antibiotics into the sea), and restore or rehabilitate terrestrial vegetation, wetlands, mangroves and seagrass. All of these actions would simultaneously reduce emissions, capture carbon, curb agricultural runoff onto coastal reefs and enhance people's livelihoods and food security. Thus, the benefits would extend far beyond the preservation of coral reefs.

There is enormous interest in coral reefs worldwide, and growing concern about the pace of their decline. Done right, efforts to save reefs could protect other ecosystems by safeguarding coastal catchment areas and providing a model for similar approaches that could be applied to diverse systems. Indeed, the plight of coral reefs could finally help to push nations past a societal and political tipping point, where the protection of ecosystems, with their multiple services and functions, is seen as socially and politically necessary.

HEAT STRESS

Raised sea temperatures during heatwaves can kill sensitive corals or prompt them to expel the beneficial microscopic algae (*Symbiodinium* and related genera) living in their tissues, resulting in mass bleaching. Over one or two decades, most coral populations depleted by bleaching can recover. But the gap between consecutive bleachings has shrunk drastically — from an average of 25 years in the 1980s to just 6 years since 2010 (ref. 4).

Already, people in the 22 small-island nations and territories of the southwest Pacific have increased their reliance on imported foods, including canned meats and packaged products, in part because of depleted fish stocks. Food imports to countries such as Samoa and Tonga now exceed total exports[5]. What's more, deaths in the Pacific from preventable diseases, such as diabetes, cardiovascular disease and cancer, have risen in part because of the dietary and lifestyle changes that have accompanied people's increased reliance on imports. (Six years ago, these diseases caused 80% of all deaths; in 2017, they caused 86%[6].)

The decline of reefs, especially in the past five years, has prompted scientists, policymakers, non-governmental organizations and philanthropists to undertake increasingly desperate attempts to save or restore targeted coral species. (The most recent 2014–17 global bleaching event was the longest ever recorded, and caused around 70% of the world's reefs to bleach once or more in consecutive, record-breaking hot years[7].)

"Done right, efforts to save reefs could protect other ecosystems."

In Australia, engineers are using a robot to disperse coral larvae to degraded sites and experimenting with underwater fans to create cooling, artificial upwellings. In Florida, surviving corals are being transferred from degraded reefs to aquaria to rescue them from disease. In many countries, artificial reefs are being built to promote biodiversity, or corals are being reared in the laboratory or in underwater 'nurseries' and later transferred to reefs. Coral sperm are even being frozen in the hope that populations could be restored in the future[8].

Such interventions are difficult, expensive and labour-intensive. Replanting coral fragments grown in a nursery costs between $1 million and $4 million per hectare[9]. Thus, even without factoring in ongoing maintenance, restoring 10 km^2 of reef would cost in the region of $1 billion[9]. None of these approaches will restore the ecological functions of reefs at a meaningful scale. (Indeed, given the current levels of human influence on the environment, restorations to past ecological conditions and past levels of biodiversity are no longer possible[10].) What's more, small-scale attempts at coral gardening, aquarium breeding and cryopreservation can convey a misleading message: that the decline of coral reefs is solvable without rapid, coordinated action on climate change caused by human activity.

We think that a bolder approach to the governance of coral reefs should be inspired in part by ecological theory on synergistic effects[11].

MAKE CHANGES ON LAND AND SEA

Over the past decade, ecologists have found that the response of reefs to any one pressure, such as overfishing or pollution, is typically non-linear. Numerous feedbacks and multiple drivers reinforcing each other can lead to new stable states[11]. For example, agricultural runoff can promote the growth of algae that compete with corals for space — a problem that is exacerbated by the overfishing of herbivores. Under many pressures, the capacity of corals to reassemble after disturbances might be so reduced that a new stable ecosystem results, often consisting mainly of mats of algae or cyanobacteria.

The sustained protection of coral reefs similarly requires making many changes at once: reducing greenhouse-gas emissions, rebuilding fish stocks and improving water quality. This requires policymakers to work with a much broader range of social actors, including commercial and recreational fishers, farmers, the tourism industry, mining companies, energy providers, property developers and individual citizens.

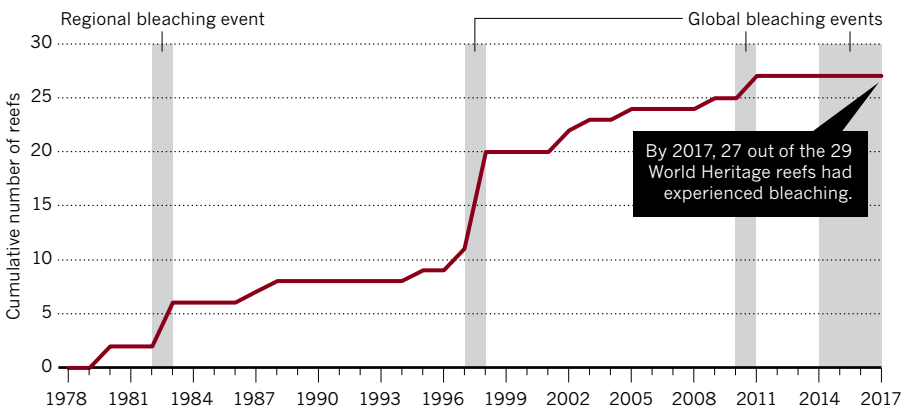
The importance of such broader-scale, synergistic policy interventions to protect ecosystems is starting to be recognized in multilateral policy agreements; by major environmental non-governmental organizations and international aid agencies; and even by some countries.

The Ramsar Convention on Wetlands of International Importance, for example, now highlights how the conservation of wetlands can help to achieve multiple goals. They can conserve biodiversity, act as carbon sinks and provide ecosystem services such as protection against flooding. (In 1971, when the convention was established, it focused much more on the conservation of species than on the broader benefits of wetlands.)

Likewise, non-governmental organizations are beginning to combine ecological, economic and social interventions to help sustain ecosystems. For instance, environmental charity the Nature Conservancy in Arlington, Virginia, is considering funding the installation of sewage-treatment plants and other infrastructure that would improve public health as well as prevent sewage from reaching coral reefs[12]. And agricultural research and development agencies, such as CGIAR in Montpellier, France, are supporting integrated national policies for agriculture and the environment in Pacific island nations to address the declining supply of reef fish and the altered movement of pelagic stocks due to climate change.

UNDER PRESSURE

Coral reefs listed as World Heritage sites have been increasingly affected by regional and global bleaching since 1980.



SOURCE: SEE SUPPLEMENTARY INFORMATION

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ALEXIS ROSENFELD/GETTY

Biologists track corals in nurseries amid renewed bleaching in French Polynesia.

(Historically, agricultural and environmental ministries in most countries have operated in silos, or even in opposition[13].)

Meanwhile, the Philippines, Indonesia, Malaysia, Papua New Guinea, the Solomon Islands and Timor-Leste have formed the Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security. Established formally in 2014, this transnational partnership initially focused on the conservation of marine biodiversity, megafauna and coastal resources. Since August 2017, the six governments have also begun to address the management of mangroves, seagrass meadows and tidal marshes to help sequester carbon. A similar initiative called the Global Environmental Facility Pacific Ridge to Reef Programme is seeking to promote sustainable energy and food production, while reducing global greenhouse-gas emissions and pollutant runoff into coastal waters, in 14 Pacific island nations[14].

So, on many fronts, the approach we endorse is gaining traction. The major challenge now is establishing the governance, organizations, mechanisms and funding to realize broad, synergistic goals at scale.

Conventional governance — for instance, of fisheries or agriculture — is typically uncoordinated, competitive and short-sighted[15]. We think that catchment-based agencies could better integrate environmental, social and economic planning. A good example is the 86-year-old Tennessee Valley Authority in the United States. This agency led innovations in education, agriculture and energy use in the 1930s to help lift the region out of the Great Depression[15].

Also, various nascent and underused funding schemes could complement conventional, popular ones. These underused schemes include green economic stimuli, such as public–private partnerships to facilitate the development of renewable-energy systems[16]; and 'debt-for-change' schemes, whereby organizations such as the Nature Conservancy help to pay off a country's debt in exchange for the nation reducing its environmental impact. More-controversial industrial and philanthropic payments for ecosystem services and ecosystem insurance schemes, such as the coral reef insurance programme deployed in Mexico in the past year[17], could also help.

Already, key agencies are extending the responsibility for safeguarding coral reefs beyond local reef governments, managers and users. For example, in a major departure from the past (see Supplementary information), the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Centre is beginning to focus on the long-term and distant drivers of reef decline[2], not just on the symptoms of reef degradation. So, too, are the US National Oceanic and Atmospheric Administration and the Great Barrier Reef Marine Park Authority. In July, the latter called for immediate reductions in global greenhouse-gas emissions and acknowledged that local actions on water pollution and fishing pressure cannot reverse the ongoing decline of reefs.

That same month, the Climate Vulnerability Index (cvi-heritage.org) was presented at the World Heritage Committee's annual meeting in Baku. The index assesses the risk to individual World Heritage sites (29 of which are coral reefs) from extreme climate events and changes in climate over the next 30 years. Some environmentalists are suggesting that this type of index could also be used to track accountability. Specifically, such tools could compare the vulnerability of a country's World Heritage site with its national policy on carbon emissions and its progress on achieving Paris climate agreement commitments. Conceivably, a World Heritage site at high risk in a country reneging on its promises could be classified as 'in danger'. Such a development would represent a radical expansion of UNESCO's oversight, and would highlight for the first time the responsibilities of individual nations for protecting World Heritage sites from climate change.

THE WORLD IS WATCHING

Ultimately, coral reefs will be lost unless global carbon emissions are slashed to 45% of 2010 levels by 2030 (ref. 1). Yet a bolder, scaled-up approach to the stewardship of land and sea — focused initially on coral reefs — could itself help society to meet this goal.

International attempts to address climate change have repeatedly derailed[1]. At a national level, vested interests, entrenched priorities and social inertia are enormous barriers to change. Australia's lock-in to coal is a case in point[18]. But individual countries such as Bhutan and Costa Rica, states such as California and Tasmania, and even certain cities such as Copenhagen and Canberra are setting powerful examples for the rest of the

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GARY CRANITCH, QUEENSLAND MUSEUM/GREAT BARRIER REEF FOUNDATION

A tethered robot — LarvalBot — disperses coral larvae on 3 hectares of the Great Barrier Reef.

world with mitigation and adaptation initiatives. California, the world's fifth-largest economy, has set a target date of 2045 for carbon neutrality. In August, the state brokered a deal with four leading carmakers to reduce air pollution, despite strong criticism from US President Donald Trump.

Powerful efforts to protect coral reefs could similarly set an example for the world. Reefs are revered worldwide. Their loss has even inspired 'last-chance tourism'[19] and what psychologists and others are labelling 'ecological grief'[20]. The plight of these charismatic and stunningly beautiful systems, and of the people who depend on them, is rapidly galvanizing a broad spectrum of support — from the United Nations to film stars, youth movements and industry barons.

In 2017, the Leonardo DiCaprio Foundation in Beverly Hills, California, began to install a self-funding system of renewable energy in coral-reef communities across Fiji, in partnership with the Fijian government and others. In 2018, the charity Bloomberg Philanthropies in New York City announced that it would provide $86 million to help build the resilience of coral-reef and fishing communities in ten countries, including Australia, Fiji, Indonesia and the United States. And in May this year, when students in more than 1,600 cities across 125 countries walked out of school to encourage more climate action, coral reefs were the centrepiece of many of the protests.

We urge scientists, policymakers, non-governmental organizations and philanthropists to tap into this energy and develop a bold strategy to protect reefs, other ecosystems and people in our warming world. ■

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