The Sixth Mass Extinction Crisis and its Impact on Biodiversity and Human Welfare*

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"Earth provides enough to satisfy every man's needs, but not every man's greed" – **Mahatma Gandhi**

The vast number of species prevailing on planet Earth is the result of evolutionary processes that have been operating since life originated about 3.5 billion years ago. As new species evolved, a small number of species that became misfits in the prevailing environment became extinct (background extinction). However, the rapid increase in human population and humanity's greed for luxurious living have resulted in marked environmental degradation, particularly in the recent decades, increasing species extinction hundred or even thousand-fold compared to background extinctions, thus precipitating the 'sixth mass extinction' crisis. Unlike the past five mass extinctions that were due to natural catastrophes, the sixth mass extinction would be exclusively the result of human activities. Habitat loss and its degradation, overexploitation of bioresources and climate change have been the main drivers of the sixth mass extinction crisis. Amongst human-induced environmental changes, climate change is going to affect humanity more than any other changes. Apart from exterminating a large number of both terrestrial and aquatic species, these changes bring down crop productivity and quality substantially, thus seriously compromising ecosystem services essential for human welfare. Mitigating human-induced environmental changes has become one of the highest priorities for the humanity to sustain biodiversity and human welfare.

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Keywords
Biodiversity, climate change, conservation, habitat destruction, mass extinction of species, overexploitation.

*Vol.25, No.1, DOI: https://doi.org/10.1007/s12045-019-0924-z

Introduction

Biodiversity and associated ecosystem services are essential for the sustenance of not only wild species in their natural habitat but also of human welfare.

The vast biodiversity, comprising plants, animals and microbes, prevailing on the Earth at present is the result of evolutionary processes operating since life originated about 3.5 billion years ago. The best working estimate of the number of species that exist on the Earth is 8.7 million eukaryotic species, of which 2.2 million are marine [1]. However, only about 1.2 million species have so far been documented. Biodiversity and associated ecosystem services are essential for the sustenance of not only wild species in their natural habitat but also of human welfare. As new species evolved on the Earth as a result of mutations, recombination, and natural selection acting on heritable variations, some species that became misfits in the prevailing environment became extinct. However, the number of species that became extinct, referred to as the background extinction, has been very small when compared to the number of new species that have been evolving [2]. The rate of background extinction varies amongst different groups of organisms. It is estimated that the background extinction rate of bird species is one extinction in 400 years and of mammals one in 700 years. However, during each of the last five mass extinctions that happened in the geological history of the Planet, more than three-quarters of its species became extinct in a geologically short interval (*Figure* 1). Background extinctions refer to the normal extinction rates during the periods between mass extinction events.

The Sixth Mass Extinction Crisis

Modern humans have had an impact on the environment from early times. Even as hunter-gatherers for thousands of years, the capacity of humans to hunt large animals improved with gradual refinements in tools. The extinction of megafauna such as woolly mammoth, American bison and woolly rhinoceros have been attributed to humans, although there might also be a role of climatic events [3]. The establishment of agriculture about 11,000 years ago marked a dramatic change in lifestyle and eventually

Era	Period	Mass extinctions: million years ago (mya)	Estimated extinction (%) of* Genera	Species
Coenozoic	Quaternary			
	Tertiary	65 mya	40	76
Mesozoic	Cretaceous			
	Jurassic	205 mya	47	80
	Triassic	240 mya	56	96
Paleozoic	Permian			
	Carboniferous			
	Devonian	370 mya	35	75
	Silurian	435 mya	57	86
	Ordovician			
	Cambrian			
Proterozoic				
Archean				

*Based on Barnosky et al. 2014

Figure 1. Details of the last five mass extinctions.

led to the establishment of settlements in the form of villages, towns, and cities. The industrial revolution of the nineteenth century further increased the impact of humans on their environment. Concomitant with this, there has been a rapid and steady increase in world population. According to the UN's estimation (2017), the world population was 6.2 billion in 2000, reached 7 billion in 2012 and is 7.6 billion at present; it is expected to reach 8.6 billion in 2030, 9.8 billion in 2050 and 11.2 billion in 2100. This enormous increase in population combined with human greed for luxurious lifestyle have been placing a heavy burden on bioresources and ecosystems. Human dependence on and overexploitation of bioresources, particularly in recent decades have aggravated environmental degradation, pushing a large number of species towards marked decline and extinction thus seriously compromising ecosystem services essential for human welfare.

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Box 1. IUCN Data on Extinct and Threatened Species

The International Union for Conservation of Nature and Natural Resources (IUCN) has been publishing *Red Data Books* and *Red Lists* of threatened species of animals and plants since 1964. These sources are recognized as the most comprehensive base line information on global conservation status of the species. Based on critical evaluation of each species, IUCN has categorized species into distinct categories: extinct (EX), extinct in the wild (EW), critically endangered (CR), endangered (EN), vulnerable (VU), near threatened (NT), least concern (LC), data deficient (DD), and not evaluated (NE) (see IUCN Red List for details of the criteria followed). CR, EN and VU categories are considered threatened. Percent of evaluated species of different groups threatened and of vertebrate species extinct or extinct in the wild are given in *Figure* 2. Out of 96,951 species evaluated by the IUCN, 26,500 are threatened. In the absence of any mitigation steps, IUCN predicts that 99.9 percent of critically endangered species and 67 percent of endangered species will be lost within the next 100 years.

Table A. Percent of evaluated species threatened (IUCN Version 2018-2)

Groups	No. species evaluated	% of evaluated species threatened
Cycads	307	63
Amphibians	6576	41
Selected dicots	1781	36
Selected reptiles	342	34
Conifers	607	34
Reef-forming corals	845	33
Sharks and rays	1091	31
Selected crustaceans	2872	27
Mammals	5593	25
Birds	10966	13
Selected gastropods	633	8
Selected bony fishes	2390	7

As early as 1992, as many as 1700 of the world's leading scientists, including 99 Nobel laureates, realized the seriousness of the situation, and urged humanity to curtail the environmental destruction that was threatening the life support system of the planet. They felt that humanity was pushing Earth's ecosystems beyond their capacities to support the web of life. These scientists identified "ozone depletion, freshwater availability, marine life depletion, ocean dead zones, forest loss, biodiversity destruc-

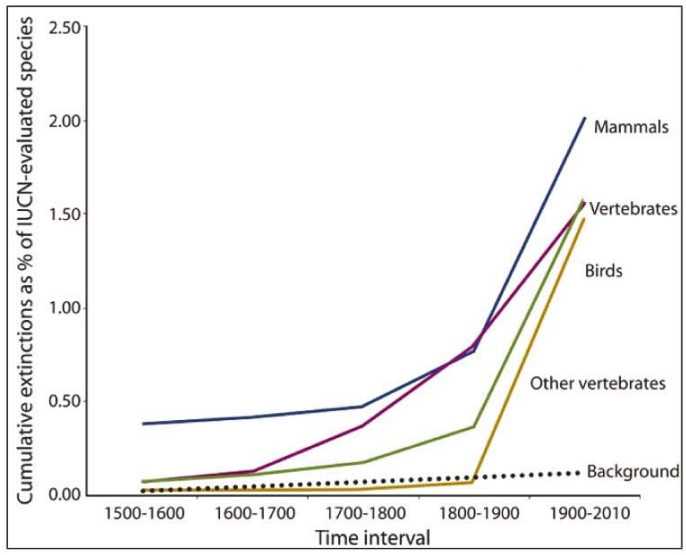

Figure 2. Cumulative vertebrate species recorded as extinct or extinct in the wild by the IUCN (2012).

tion, climate change, and continued human population growth" as causes for current, impending or potential damage on the planet Earth. In 2017, after 25 years of the first warning, as many as 15364 scientists from 184 countries sounded a second warning [4]. They stated that, since the first warning, "with the exception of stabilizing the stratospheric ozone layer, humanity has failed to make sufficient progress in generally solving these foreseen environmental challenges, and alarmingly, most of them are getting far worse".

Human-induced environmental destruction in recent decades has resulted in the extinction of a large number of species and pushed a high proportion of the remaining species to threatened category (*Box* 1). According to Birdlife International, an IUCN's partner organization, 13% of the total bird species are threatened with extinction. Based on an extremely conservative estimate, the rate of extinction of vertebrates over the past century has been 100 times greater than the background extinction rate, indicating that a sixth mass extinction is indeed underway [2]. Reports on the decline of biodiversity have been accumulating over the years. Arthropods comprise over two-thirds of the terrestrial species and have thrived over millennia. However, even arthropods are under threat in recent decades. In protected areas of Germany, the biomass of

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total flying insects has declined by 75% over 27 years [5]. In protected rainforests of Puerto Rico also, the biomass of insects and other arthropods has declined by 97% when compared to the 1970s [6]. This has affected the food web of the forest. The decline in the insect biomass has induced parallel declines in other animals such as insectivorous lizards, frogs and birds that feed on the insects. Similar results have been recorded in a Mexican forest.

In recent years, a number of investigations have reported a significant decline of wild pollinators and its impact on pollination services, leading to vulnerability of pollinator-dependent plant species in natural habitat and crop productivity in agricultural habitats.

Pollination—transfer of pollen grains from the anthers to the stigma —is one of the critical ecoservices as it is a prerequisite for fruit and seed development. Over 90% of the flowering plants use a range of animals [7], particularly insects, to achieve pollination, and the remaining use wind or water for this purpose. As fruits and seeds are the economic products of most of our crop plants, any constraint in pollination would affect crop productivity. In recent years, a number of investigations have reported a significant decline of wild pollinators and its impact on pollination services, leading to vulnerability of pollinator-dependent plant species in natural habitat and crop productivity in agricultural habitats. For example, in Britain and the Netherlands, bees have declined by about 30% since 1980, and there is a parallel decline in plant species pollinated by declining pollinators [8]. In the USA, the relative abundances of four species of bumblebees have declined up to 96% and their distributional ranges reduced by 23–87%, some within the last 20 years. According to Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (2016), 16.5% of vertebrate pollinators and over 40% of invertebrate pollinator species particularly bees and butterflies are facing global extinction.

Many scientists believe that we are in the midst of the sixth mass extinction [9], see also [10, 11]. Based on the estimation of population declines of 27,600 vertebrate species, and more detailed analysis of 177 mammal species, Ceballos and his co-workers [12] pointed out that apart from species extinction, there is a very high rate of population loss even in species of low concern to IUCN. All the 177 mammal species they analysed had lost over

30% of their geographic ranges, with more than 40% of them having experienced population declines of more than 80%. This amounts to the loss of as much as 50% of the number of vertebrates that once shared the Earth with us. They describe this as a 'biological annihilation' and concluded that the sixth mass extinction is more severe than perceived, and it will have negative cascading consequences on ecosystem functioning and services vital to sustain civilization. All the above evidences highlight the urgency for intensified conservation efforts to avert the dramatic loss of biodiversity. According to many scientists, the window of corrective action to tackle the crisis is very short, at the most 20–30 years.

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Drivers of the Sixth Mass Extinction Crisis

Habitat loss and its degradation including pollution and invasion of alien species, overexploitation of biological resources, and climate change are the major drivers for the sixth mass extinction crisis. All of them act synergistically on biodiversity, and their threats cannot be tackled in isolation.

Habitat Loss and its Degradation

Conversion of natural habitats for agriculture since the dawn of agriculture, and subsequently for urbanization, industrialization and mining has been steadily decreasing natural habitat. Further, extensive areas of virgin forests have been destroyed to grow plantation crops such as coffee, tea, oil palm and rubber. Rampant pollution and extensive use of pesticides and herbicides are additional drivers for habitat degradation. Alien species are spreading rampantly after intentional or unintentional introduction and are replacing native fauna and flora.

Recently, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (2018) released the summary of a 3-year assessment report on land degradation prepared by 100 experts from 31 countries and scrutinized by over 200 external reviewers. According to the report, worsening worldwide land

degradation is the main cause of species extinction; it is also the driver of mass human migration and increased conflict. It undermines the well-being of two-fifths of humanity. The report estimates that <25% of the land surface has remained free from substantial impacts of human activity, and by 2050 this will reduce to <10%. The report emphasizes that reducing and reversing this trend is an urgent priority to protect biodiversity and ecosystem services essential for sustenance of all life forms on Earth and for human welfare.

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In recent years, pollution of the atmosphere, soil and water, has become a major threat to human health and environment, and to the survival of all other organisms. The WHO safety level of particulate matter (PM) below 2.5 μm in size in the air is 10 $\mu g/m^3$. However, in many of our cities, particularly during the winter, the level of such particulate matter reaches beyond 100 $\mu g/m^3$. Air pollution caused 3.8 million deaths globally in 2016. The major sources of water pollution are untreated sewage, industrial effluents and agricultural runoffs. Plastic pollution is prevalent from the top of Mount Everest to the bottom of the sea. About 8 million tons of plastic ends up in the ocean each year and kills $> 100,000$ marine mammals annually, along with millions of birds and fishes. The 'great Pacific garbage patch' is a massive floating island formed by the accumulation of nearly 80,000 tons of discarded plastic covering an area of about 1.6 million square kilometres. It is more than double the size of Texas and is increasing exponentially. According to Greenpeace, around 267 different animal species suffer from entanglement and ingestion of plastic debris.

Overexploitation of Biological Resources

Hunting has been one of the oldest activities of humans responsible for driving a large number of species to extinction. As mentioned above, some large mammals had been hunted down even when humans were hunter-gatherers. Hunting has continued on a much larger scale in recent decades and extended to a range of animal species. Animals are hunted/poached for their meat, hide,

medicinal/ornamental value, as game species, or for the export market. They are also hunted when they happen to be agricultural pests or predators of domestic animals. Many live animals, particularly birds, are collected for the pet trade. Many species have become extinct largely because of hunting (*Box* 2). Overexploitation has depleted populations of a large number of species beyond sustainability. Himalayan musk deer (*Moschus leucogaster*) occur in the high ranges of the Himalayas. The males produce musk pod in the abdomen which emits sweet persistent aroma. There is a great demand for musk pod in the cosmetic industry; according to IUCN, it fetches USD 45,000/kg. The animals are extensively poached particularly in Kedarnath Wildlife Sanctuary leading to a drastic decline in the population. *Cordyceps sinensis* (caterpillar fungus) is found along the Himalayas at 3000–5000 m in Tibet and parts of the Indian Himalayas. The club-shaped fruiting body of the fungus emerges from the ground during June–July. It has been used in a range of medicines (including what is often called Himalayan Viagra) for over 2000 years in Tibet. The fruiting body is in great demand in the international market and is more expensive than gold (> USD 100/g). Each spring, people come from miles around to search for these precious fruiting bodies. Because of overexploitation, the fruiting bodies have become extremely rare now.

Similarly, agarwood tree (*Aquilaria malaccensis*), which is endemic to Northeast India, Bangladesh, Bhutan and parts of Southeast Asia, is overexploited. The heartwood produces a dense fragrant resin in response to infection by a fungus. The resin, known as 'king of incense', is used to prepare perfume and incense. The high-end perfume prepared is described as liquid gold because of its price, ca HKD 300,000 per kg. Only about 7% of the trees get infected with fungus and develop resin; others do not develop resin. As infected trees cannot be recognized externally, the trees are cut indiscriminately. IUCN has now moved the species from 'vulnerable' to 'critically endangered' category. Legal and illegal timber extraction has been one of the major threats to plant resources. Because of increasing global demand for teak, many

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countries in Africa, and Central and South America, in which teak is not a native species, have started growing teak almost exclusively for export. For example, teak is now grown in about 50,000 hectares in Ecuador after converting the best agricultural and forest lands into teak plantations, exclusively for export to India.

Box 2. Recent Extinctions of Species Due Largely to Human Activities

Galapagos Islands were known for abundance of giant tortoises. Because of continued overexploitation of giant tortoises by whaling ships for decades, the population of tortoises went down drastically. The only one male tortoise, named Lonesome George (*Figure* 3), of the subspecies,*Chelonoidis nigra abingdonii*, left on Pinta Island died on 24 June 2012 at the age of about 100 years and thus this subspecies became extinct [see 19 for details].

Rhinoceroses are the second-largest land mammals after elephants. Northern white Rhino (*Ceratotherium simum cottoni*) became extinct on 19 March 2018 by the death of the last male, named Sudan, in a conservancy in Kenya. The species was heavily poached since 1970 because of the demand of Rhino horn in Chinese medicine and its use in making dagger handles in Yemen.

Passenger pigeons (*Ectopistes migratorius*), one of the most popular birds, endemic to North America, were hunted down for cheap meat after the arrival of Europeans. The last known surviving member of the species, Martha, died in the Cincinnati Zoo in 1914. Climate change and diseases are considered to be the causes for its extinction. Golden toad (*Incilius periglenes*), endemic to Elfin cloud forest of Costa Rica, was last spotted in Costa Rica in 1989. It is now considered as extinct by IUCN, probably because of climate change. Tasmanian wolf (*Thylacinus cynocephalus*) is one of the largest known marsupials, native to Tasmania, New Guinea, and the Australian mainland. The last known wolf died in Hobart Zoo in Tasmania in 1936. Intensive hunting is considered as the cause for its extinction. Crescent nailtail wallaby (*Onychogalea lunata*) that lived in the woodlands and scrubs of western and central Australia became extinct in 1956 (IUCN), probably because of the spread of the red fox.

Thus, India's demand for teak is endangering Ecuador's rain forests and agricultural land. Collection of non-wood forest products, such as gums, resins, fruits, and plants/plant parts of medicinal value is another major threat. As most of them are collected from plants growing in natural habitat, populations of most of these species have gone down beyond sustainability.

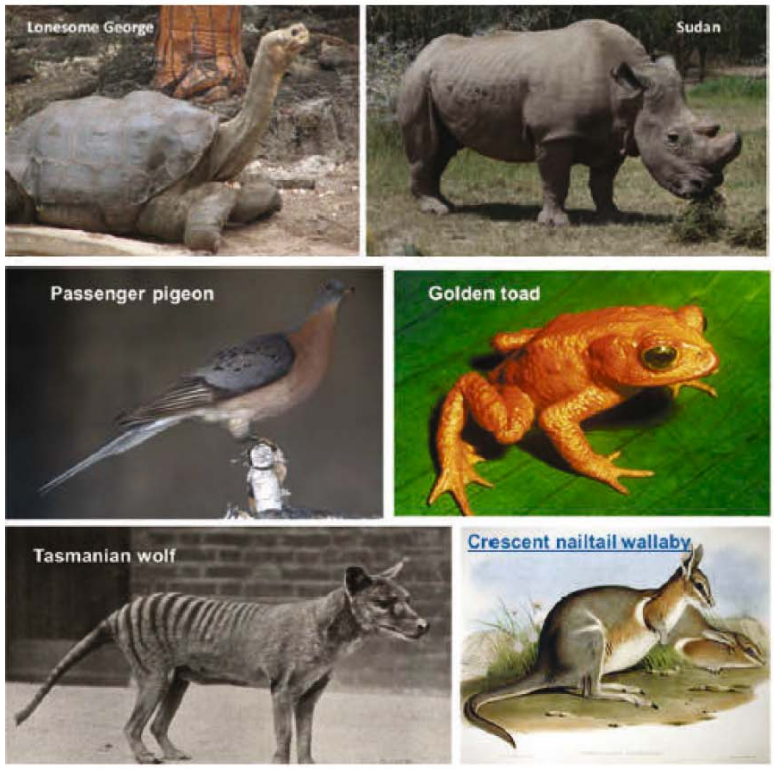

Figure 3. Some recently extinct species (Credit: Wikipedia Commons).

Climate Change

Deforestation and extensive use of fossil fuels have led to an increase in the level of atmospheric CO_2, methane and nitrous oxide. These gases, along with water vapour, trap the radiated heat from the Earth leading to global warming. Nitrous oxide is over 300 times more effective than CO_2 in heat-trapping. Heat-trapping not only increases the atmospheric temperature but also results in ocean warming and ocean acidification. The level of CO_2 in the atmosphere has increased from a preindustrial level of 280 ppm to 407 ppm in 2017. Oceans have become 30% more acidic when compared to 1985. Humanity has eroded marine wilderness. Based on systematic mapping, only 13% of the oceans have been reported to retain wilderness [13]. The Intergovernmental Panel on Climate Change (IPCC), in its *Fifth Assessment Report* (2014), projected an increase in the mean

global temperature of 3.7 to 4.8°C relative to preindustrial (1850) levels by 2100, in the absence of new policies to mitigate climate change. This would trigger the disappearance of most of the remaining glaciers and cause melting of the Arctic ice cap, leading to a rise in the sea level and submergence of smaller islands and most of the coastal areas. When this happens, the biodiversity in such islands and coastal areas will become extinct without a chance for their conservation.

Effects of climate change on crop productivity has been a major concern as it affects the food security of the steadily increasing human population. There are intrinsic difficulties in predicting crop productivity due to climate change because of uncertainties in (i) the extent of temperature increase, in the light of mitigation measures being undertaken, (ii) the possible interaction between CO_2, temperature, and precipitation on crop productivity, and (iii) the extent of progress being made by scientists to make crops and cropping systems resilient to climate change. Nonetheless, many attempts have been made to assess the impact of climate change on crop productivity based on different statistical models. Although there are marginal variations between reports, all of them consistently show the negative effects of global warming on crop productivity [14]. According to one estimate, increase in global mean temperature by 1°C would, on average, reduce global yields of wheat by 6.0%, rice by 3.2%, maize by 7.4%, and soybean by 3.1% [15]. Another report, based on 65 years of weather records and wheat and barley yield data from France, predicts that the yields of these crops would decline by 17 to 33 per cent by the end of the century [16]. Apart from decreasing the yield, global warming is also expected to result in the decline of nutritional value of crop species. Based on *in situ* free air CO_2 enrichment studies, rising atmospheric CO_2 has been shown to result in a decline in protein, iron, zinc and vitamins (B1, B2, B5, and B9), in diverse varieties of rice currently grown throughout Asia [17]. Globally, these declines can contribute to nutritional deficiencies among 2 billion people in developing and developed countries and affect human health directly and indirectly. Such declines are

likely to be manifested in other cereal crops also.

Australia experienced one of the worst population depletions of several species in recent months due to climate change. It experienced record-breaking temperatures of > 42°C in November 2018 resulting in the death of least 23,000 individuals, amounting to a third of the species, of the fruit-eating bat, *Pteropus conspicillatus*. In January 2019, between 100,000 and 1 million fish suffocated to death in Darling River due to depleted dissolved oxygen levels in the water. Low water flow, the result of drought and excessive use of water for irrigation, could not flush nutrients of farm runoff, triggering algal bloom and consequent oxygen depletion.

Recent studies report that the oceans have been warming at a faster rate than previously thought. Significant increase in the frequency and intensity of cyclones and tsunamis, floods and droughts, forest fires, heat waves, and unseasonal extreme weather conditions in recent years around the world are believed to be the result of global warming. It could be pointed out that tsunamis are not always caused by earthquakes alone, but could also be caused by massive landslides and glacier calving. They cause huge loses to life and property every year, and affect millions of people.

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The Paris agreement on climate change, adopted in 2015, formally recognized the need to limit the temperature increase to 1.5°C above preindustrial level by 2100. However, the possibility of achieving this goal was seen almost impossible based on the present emission scenario. The realistic aim has been to limit the warming to 2°C. However, a landmark report from the UN Scientific Panel on climate change, released in October 2018, emphasized that overshooting a 1.5°C rise in temperature by the end of the century compared to preindustrial levels will be disastrous and will have devastating effects on ecosystems, communities and economies. It is likely to result in global food shortages by 2040, inundation of coastal cities and a refugee crisis unlike any the world has ever seen. Even a 1.5°C warming would increase sea levels by 26–77 cm by 2100. 2°C would add another 10 cm which would affect millions of people living in coastal regions. At 2°C,

99% of coral reefs would be ravaged (*Box* 3). The report warns that there is no time to delay action to mitigate this crisis. Limiting global warming to 1.5°C (compared to 2°C) is projected to lower its impacts on terrestrial, freshwater, marine and coastal ecosystems. The chances of avoiding climate change impacts on sustainable development, eradication of poverty and reducing inequalities would be greater if global warming is limited to 1.5°C rather than 2°C. The highlight of the UN report on climate change is that the world cannot afford a 2°C rise. The coming decade could be one of humanity's last chances to avert these devastating impacts. Several scientists contend that even this report was not strong enough as it downplayed the full extent of the real threat.

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Box 3. Effects of Global Warming on Coral Reefs

Corals live in symbiotic relationship with algae which provide colour and photosynthates to the corals (*Figure* 4). Corals are very sensitive to heat. Even under a marginal rise in ocean temperature, corals expel the symbiotic algae from their tissues, resulting in their bleaching. When this bleached condition continues for several weeks, corals die and this may gradually extend to a large proportion of corals in the reef. The Great Barrier Reef in Australia is the world's largest coral reef system which provides about 70,000 jobs and billions of dollars annually in tourism revenue. Huge sections of the Great Barrier Reef are presently dead or dying by overheated seawater, unfolding one of the major calamities of global warming [20]. According to the UNESCO World Heritage Centre, 21 of the 29 World Heritage reefs have been subjected to severe heat stress resulting in some of the worst bleaching ever observed. The analysis predicts, under the current emissions scenario, all 29 world heritage site coral reefs would cease to exist as functioning ecosystems by the end of the century. As coral reefs support vast ecosystems, providing food, shelter, and breeding grounds for hundreds of marine species, death of coral reefs would result in the collapse of all dependent ecosystems.

To keep temperature rise below 2°C requires enormous efforts at a global scale [see 18]. The net anthropogenic CO_2 emissions must come down by 45% by 2030 from 2010 levels and reach net zero around 2050. A speedy transformation of the world's energy systems is needed to avoid breaching that limit. The share of coal in global electricity production, which is at 37% now, must be cut to no more than 2% by 2050. Renewable power must be greatly expanded. National Research Council (2015) of the Na-

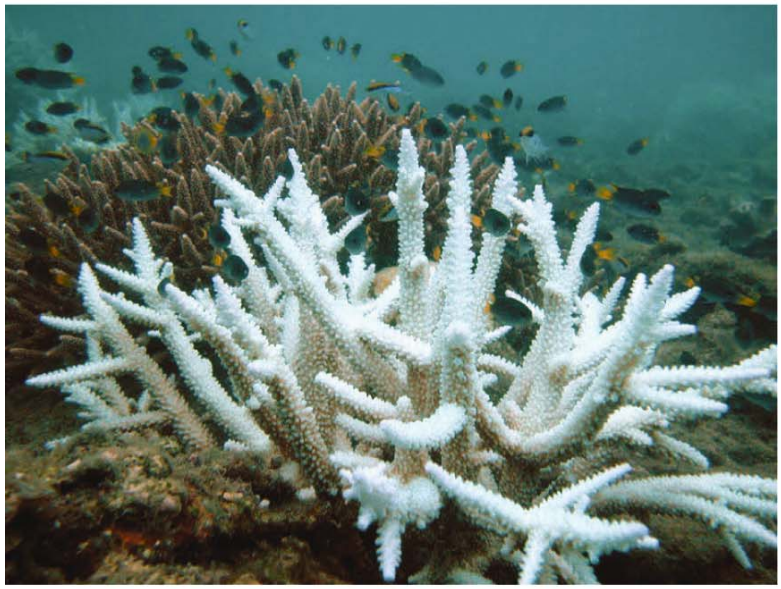

Figure 4. Bleached (white, foreground) and normal (coloured, background) branching coral (Credit: Wikipedia Commons).

tional Academies of Sciences, USA has suggested Climate Intervention in the form of removal of atmospheric CO_2 and reliable sequestration, and reflecting sunlight to cool the earth as additional possible approaches even though we still do not have the technology to do so in an economically viable manner. The Committee recommends research and development investment to improve methods of carbon dioxide removal and disposal.

Conclusions

The devastating signs of human-induced environmental changes, especially climate change, initiating the sixth mass extinction crisis are clearly visible all around us. The UN summary report on biodiversity, released on 6 May 2019, finds that around one million animal and plant species are now threatened with extinction, many within decades, and the average abundance of native plant and animal species has fallen by 20% or more mainly over the last century. These changes would have catastrophic effects not only on the sustenance of biological diversity and ecosystem functioning but also on human welfare itself. It is the duty of all countries

to take urgent steps to mitigate the situation. Protection of environment as 'Fundamental Duties' (42nd Constitutional amendment under Article 51A) is rather a unique feature in the Indian constitution: "It shall be the duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wildlife, and to have compassion for living creatures." India has also adapted 'The Biological Diversity Act' in 2002. The Act provides a mechanism for conservation of biological diversity, sustainable use of its components and equitable sharing of benefits arising out of biological diversity. However, implementation of these provisions has been unsatisfactory.

Apart from the Government and Non-Government Organizations of all the countries, it is imperative for each one of us to do our best to reduce human-induced environmental degradation to preserve, protect and conserve our biological diversity. This has to become one of the highest priorities for humanity in the coming decades. We are sitting on a timebomb; the world needs to act now to prevent its explosion.

Suggested Reading

[1] Camilo Mora *et al.*, How many species are there on earth and in the ocean? *PLoS Biology*, Vol.9, No.8, e1001127 DOI: 10.1371/journal.pbio.1001127, 2011.

[2] G Ceballos *et al.*, Accelerated modern human-induced species losses: Entering the sixth mass extinction, *Science Advances*, Vol.1, No.5, e1400253. DOI: 10.1126/sciadv.1400253, 2015.

[3] D A Burney, T F Flannery, Fifty millennia of catastrophic extinctions after human contact, *Trends in Ecology & Evolution*, Vol.20, pp.395—401, 2005.

[4] W J Ripple *et al.*, and 15,364 scientist signatories from 184 countries, World Scientists' Warning to Humanity: A Second Notice, *BioScience*, Vol.87, pp.1026–1028, 2017.

[5] C A Hallmann *et al.*, More than 75 percent decline over 27 years in total flying insect biomass in protected areas, *PLoS ONE*, Vol.12, No.10, https://doi.org/10.1371/journal.pone.0185809, 2017.

[6] B C Lister, A Garcia, Climate-driven declines in arthropod abundance restructure a rainforest food web, *Proceedings of the National Academy of Sciences*, USA, Vol.b115, E10397–E10406 . www.pnas.org/cgi/doi/10.1073/pnas.1722477115, 2018.

[7] J Ollerton, R Winfree and S Tarrant, How many flowering plants are pollinated by animals?, *Oikos*, Vol.120, pp.321–326, 2011.

[8] J C Biesmeijer, S P M Roberts, M Reemer *et al*., Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands, *Science*, Vol.313, pp.351–354, 2006.

[9] A D Barnosky *et al*., Has the Earth's sixth mass extinction already arrived? *Nature*, Vol.471, pp.51–57, 2014.

[10] Rachel Carson, *Silent Spring*, Houghton Mifflin Harcourt Publishing Company, Boston, Mass, 2002.

[11] Elizabeth Kolbert, *The Sixth Extinction: An Unnatural History*, Bloomsbury, London, 2014 (reviewed in *Resonance*, Vol.20, No.8, pp.748–450, 2015).

[12] G Ceballos, P R Ehrlich, R Dirzo, Biological annihilation via the ongoing sixth mass extinction signalled by vertebrate population losses and declines, *Proceedings of the National Academy of Sciences*, USA, www.pnas.org/cgi/doi/10.1073/pnas.1704949114, 2017.

[13] K R Jones *et al*., The location and protection status of earth's diminishing marine wilderness, *Current Biology* Vol.28, pp.1–7, 2018.

[14] J Gornall *et al*., Implications of climate change for agricultural productivity in the early twenty-first century, *Philosophical Transactions of the Royal Socety B*, Vol.365, pp.2973–2989, 2010.

[15] C Zhao *et al*., Temperature increase reduces global yields of major crops in four independent estimates, *Proceedings of the National Academy of sciences*, USA, Vol.114, pp.9326–9331, www.pnas.org/cgi/doi/10.1073/pnas.1701762114, 2017.

[16] M Gammans et al., Negative impacts of climate change on cereal yields: statistical evidence from France, *Environmental Research Letters*, DOI: 10.1088/1748-9326/aa6b0c, 2017.

[17] C Zhu*et al*., Carbon dioxide (CO_2) levels this century will alter the protein, micronutrients, and vitamin content of rice grains with potential health consequences for the poorest rice-dependent countries, *Science Advances*, Vol.4, eaaq1012. DOI: 10.1126/sciadv.aaq1012, 2018.

[18] F H Shu, Stopping and reversing climate change, *Resonance*, Vol.24, No.1, pp.51–72, 2019.

[19] K R Shivanna, Galapagos Islands and Darwin's theory of evolution, *Resonance*, Vol.23, No.4, pp.465–478, 2018.

[20] T P Hughes *et al*., Spatial and temporal patterns of mass bleaching of corals in the Anthropocene, *Science*, Vol.359, pp.80–83, 2018.

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