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World Scientists' Warning to Humanity: A Second Notice

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Twenty-five years ago, the Union of Concerned Scientists and more than 1700 independent scientists, including the majority of living Nobel laureates in the sciences, penned the 1992 "World Scientists' Warning to Humanity" (see supplemental file S1). These concerned professionals called on humankind to curtail environmental destruction and cautioned that "a great change in our stewardship of the Earth and the life on it is required, if vast human misery is to be avoided." In their manifesto, they showed that humans were on a collision course with the natural world. They expressed concern about current, impending, or potential damage on planet Earth involving ozone depletion, freshwater availability, marine life depletion, ocean dead zones, forest loss, biodiversity destruction, climate change, and continued human population growth. They proclaimed that fundamental changes were urgently needed to avoid the consequences our present course would bring.

The authors of the 1992 declaration feared that humanity was pushing Earth's ecosystems beyond their capacities to support the web of life. They described how we are fast approaching many of the limits of what the biosphere can tolerate without substantial and irreversible harm. The scientists pleaded that we stabilize the human population, describing how our large numbers - swelled by another 2 billion people since 1992, a 35 percent increase - exert stresses on Earth that can overwhelm other efforts to realize a sustainable future (Crist et al. 2017). They implored that we cut greenhouse gas (GHG) emissions and phase out fossil fuels, reduce deforestation, and reverse the trend of collapsing biodiversity.

On the twenty-fifth anniversary of their call, we look back at their warning and evaluate the human response by exploring available time-series data. Since 1992, 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 (figure 1, file S1). Especially troubling is the current trajectory of potentially catastrophic climate change due to rising GHGs from burning fossil fuels (Hansen et al. 2013), deforestation (Keenan et al. 2015), and agricultural production - particularly from farming ruminants for meat consumption (Ripple et al. 2014). Moreover, we have unleashed a mass extinction event, the sixth in roughly 540 million years, wherein many current life forms could be annihilated or at least committed to extinction by the end of this century. Humanity is now being given a second notice, as illustrated by these alarming trends (figure 1). We are jeopardizing our future by not reining in our intense but geographically and demographically uneven material consumption and by not perceiving continued rapid population growth as a primary driver behind many ecological and even societal threats (Crist et al. 2017). By failing to adequately limit population growth, reassess the role of an economy rooted in growth, reduce greenhouse gases, incentivize renewable energy, protect habitat, restore ecosystems, curb pollution, halt defaunation, and constrain invasive alien species, humanity is not taking the urgent steps needed to safeguard our imperilled biosphere.

As most political leaders respond to pressure, scientists, media influencers, and lay citizens must insist that their governments take immediate action as a moral imperative to current and future generations of human and other life. With a groundswell of organized grassroots efforts, dogged opposition can be overcome and political leaders compelled to do the right thing. It is also time to re-examine and change our individual behaviors, including limiting our own reproduction (ideally to replacement level at most) and drastically diminishing our *per capita* consumption of fossil fuels, meat, and other resources.

The rapid global decline in ozone-depleting substances shows that we can make positive change when we act decisively. We have also made advancements in reducing extreme poverty and hunger (www.worldbank.org). Other notable progress (which does not yet show up in the global data sets in figure 1) include the rapid decline in fertility rates in many regions attributable to investments in girls' and women's education (www.un.org/esa/population), the promising decline in the rate of deforestation in some regions, and the rapid growth in the renewable-energy sector. We have learned much since 1992, but the advancement of urgently needed changes in environmental policy, human behavior, and global inequities is still far from sufficient.

Sustainability transitions come about in diverse ways, and all require civil-society pressure and evidence-based advocacy, political leadership, and a solid understanding of policy instruments, markets, and other drivers. Examples of diverse and effective steps humanity can take to transition to sustainability include the following (not in order of importance or urgency): (a) prioritizing the enactment of connected well-funded and well-managed reserves for a significant proportion of the world's terrestrial, marine, freshwater, and aerial habitats; (b) maintaining nature's ecosystem services by halting the conversion of forests, grasslands, and other native habitats; (c) restoring native plant communities at large scales, particularly forest landscapes; (d) rewilding regions with native species, especially apex predators, to restore ecological processes and dynamics; (e) developing and adopting adequate policy instruments

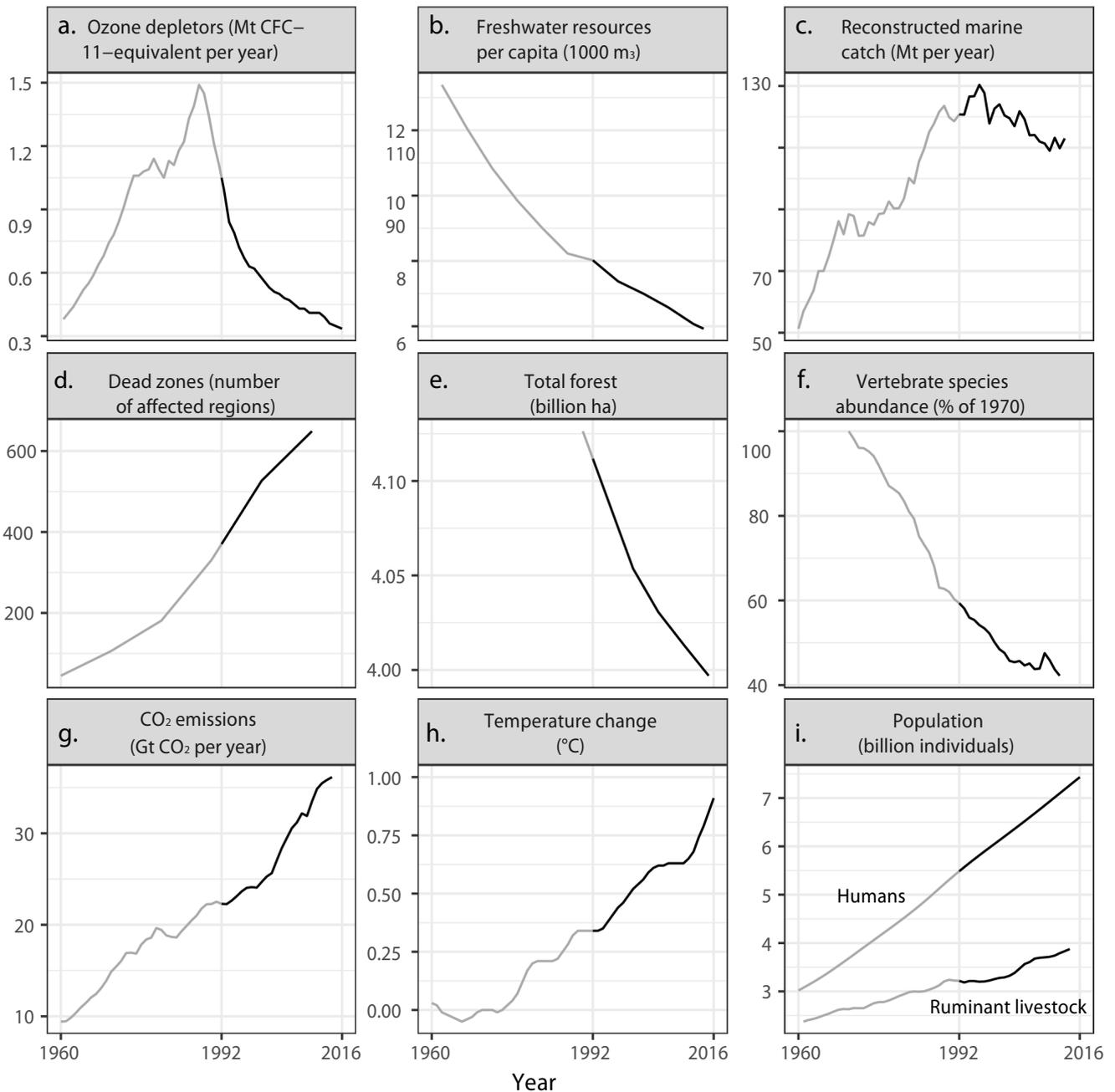


Figure 1. Trends over time for environmental issues identified in the 1992 scientists' warning to humanity. The years before and after the 1992 scientists' warning are shown as gray and black lines, respectively. Panel (a) shows emissions of halogen source gases, which deplete stratospheric ozone, assuming a constant natural emission rate of 0.11 Mt CFC-11-equivalent per year. In panel (c), marine catch has been going down since the mid-1990s, but at the same time, fishing effort has been going up (supplemental file S1). The vertebrate abundance index in panel (f) has been adjusted for taxonomic and geographic bias but incorporates relatively little data from developing countries, where there are the fewest studies; between 1970 and 2012, vertebrates declined by 58 percent, with freshwater, marine, and terrestrial populations declining by 81, 36, and 35 percent, respectively (file S1). Five-year means are shown in panel (h). In panel (i), ruminant livestock consist of domestic cattle, sheep, goats, and buffaloes. Note that y-axes do not start at zero, and it is important to inspect the data range when interpreting each graph. Percentage change, since 1992, for the variables in each panel are as follows: (a) -68.1%; (b) -26.1%; (c) -6.4%; (d) +75.3%; (e) -2.8%; (f) -28.9%; (g) +62.1%; (h) +167.6%; and (i) humans: +35.5%, ruminant livestock: +20.5%. Additional descriptions of the variables and trends, as well as sources for figure 1, are included in file S1.

to remedy defaunation, the poaching crisis, and the exploitation and trade of threatened species; (f) reducing food waste through education and better infrastructure; (g) promoting dietary shifts towards mostly plant-based foods; (h) further reducing fertility rates by ensuring that women and men have access to education and voluntary family-planning services, especially where such resources are still lacking; (i) increasing outdoor nature education for children, as well as the overall engagement of society in the appreciation of nature; (j) divesting of monetary investments and purchases to encourage positive environmental change; (k) devising and promoting new green technologies and massively adopting renewable energy sources while phasing out subsidies to energy production through fossil fuels; (l) revising our economy to reduce wealth inequality and ensure that prices, taxation, and incentive systems take into account the real costs which consumption patterns impose on our environment; and (m) estimating a scientifically defensible, sustainable human population size for the long term while rallying nations and leaders to support that vital goal.

To prevent widespread misery and catastrophic biodiversity loss, humanity must practice a more environmentally sustainable alternative to business as usual. This prescription was well articulated by the world's leading scientists 25 years ago, but in most respects, we have not heeded their warning. Soon it will be too late to shift course away from our failing trajectory, and time is running out. We must recognize, in our day-to-day lives and in our governing institutions, that Earth with all its life is our only home.

Epilogue

We have been overwhelmed with the support for our article and thank the more than 15,000 signatories from all ends of the Earth (see supplemental file S2 for list of signatories). As far as we know, this is the most scientists to ever co-sign and formally support a published journal article. In this paper, we have captured the environmental trends over the last 25 years, showed realistic concern, and suggested a few examples of possible remedies. Now, as an Alliance of World Scientists (scientists.forestry.oregonstate.edu) and with the public at large, it is important to continue this work to document challenges, as well as improved situations, and to develop clear, trackable, and practical solutions while communicating trends and needs to world leaders. Working together while respecting the diversity of people and opinions and the need for social justice around the world, we can make great progress for the sake of humanity and the planet on which we depend.

Spanish, Portuguese, and French versions of this article can be found in file S1.

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Supplemental material

Supplementary data are available at BIOSCI online including supplemental file 1 and supplemental file 2 (full list of all 15,364 signatories).

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Descriptions of variables and trends in Figure 1.

Ozone depletion, Figure 1a. During the 1970s, human-produced chemicals known as ozone-depleting substances, mainly chlorofluorocarbons, were rapidly depleting the ozone layer. In 1987, governments of the world came together and crafted the United Nations Montreal Protocol as a global attempt to address this issue. With protocol compliance, emissions of halogen source gases (ozone-depleting substances and natural sources) peaked in the late 1980s and since then they have significantly decreased (Figure 1a). Global ozone depletion is no longer increasing, and significant recovery of the ozone layer is expected to occur by the middle of this century (Hegglin et al. 2014).

Declining Freshwater availability, Figure 1b. Per capita freshwater availability is less than half of levels of the early 1960s (Figure 1b, AQUASTAT 2017) with many people around the world suffering from a lack of fresh clean water. This decrease in available water is nearly all due to the accelerated pace of human population growth. It is likely that climate change will have an overwhelming impact on the freshwater availability through alteration of the hydrologic cycle and water availability. Future water shortages will be detrimental to humans, affecting everything from drinking water, human health, sanitation, and the production of crops for food.

Unsustainable marine fisheries, Figure 1c. In 1992, the total marine catch was at or above the maximum sustainable yield and fisheries were on the verge of collapse. Reconstructed time series data show that global marine fisheries catches peaked at 130 million tonnes in 1996 and has been declining ever since (Figure 1c). The declines happened despite increased industrial fishing efforts and despite developed countries expanding to fishing the waters of developing countries (Pauly and Zeller 2016, updated).

Ocean dead zones, Figure 1d. Coastal dead zones which are mainly caused by fertilizer runoff and fossil-fuel use, are killing large swaths of marine life. Dead zones with hypoxic, oxygen-depleted waters, are a significant stressor on marine systems and identified locations have dramatically increased since the 1960s, with more than 600 systems affected by 2010 (Figure 1d, Diaz and Rosenberg 2008, updated).

Forest loss, Figure 1e. The world's forests are crucial for conserving carbon, biodiversity, and freshwater. Between 1990 and 2015, total forest area decreased from 4,128 to 3,999 million ha, a net loss of 129 million ha which is approximately the size of South Africa (Figure 1e). Forest loss has been greatest in developing tropical countries where forests are now commonly converted to agriculture uses (FAO 2015).

Dwindling biodiversity, Figure 1f. The world's biodiversity is vanishing at an alarming rate and populations of vertebrate species are rapidly collapsing (World Wildlife Fund 2016). Collectively, global fish, amphibians, reptiles, birds, and mammals declined by 58% between 1970 and 2012 (Figure 1f). Here, we display a diversity-weighted Living Planet Index that has been adjusted for taxonomic and geographic bias by accounting for the estimated number of species within biogeographical regions, and the relative species diversity within them. (McRae et al. 2017). Freshwater, marine, and terrestrial populations declined by 81%, 36%, and 35% respectively (McRae et al. 2017).

Climate change, Figure 1g, Figure 1h. Global fossil-fuel carbon dioxide emissions have increased sharply since 1960 (Figure 1g, Boden et al. 2017). Relative to the 1951-1980 average, global average annual surface temperature, in parallel to CO₂ emissions, has also rapidly risen as shown by 5-year mean temperature anomaly (Figure 1h, NASA's Goddard Institute for Space Studies (GISS) 2017). The 10 warmest years in the 136-year record have occurred since 1998. The most recent year of data, 2016, ranks as the warmest on record. Temperature increases will likely cause a decline in the world's major food crops, an increase in the intensity of major storms, and a substantial sea level rise inundating major population centers.

Population growth, Figure 1i. Since 1992, the human population has increased by approximately 2 billion individuals, a 35% change (Figure 1i, FAOSTAT 2017). The world human population is unlikely to stop growing this century and there is a high likelihood that the world population will grow from 7.2 billion people now to between 9.6 and 12.3 billion by 2100 (Gerland et al. 2014). Like the change in human population, the domestic ruminant population, which has its own set of major environmental and climate impacts, has been increasing in recent decades to approximately 4 billion individuals on Earth (Figure 1i, FAOSTAT 2017).

Note that the loss of soil productivity was listed as a concern in the 1992 scientists' warning, but this variable was not analyzed here due to a lack of global data on changes in soil productivity. For each variable listed below, we calculated percentage change since 1992 using the values for 1992 and the most recent year available. When data were unavailable for 1992, we used linear interpolation to estimate the value there. These change results are in the caption for Figure 1. See original data sources shown above for any statements on levels of uncertainty associated with the variables in Figure 1. Some sources describe this uncertainty and others do not.

References for figure 1

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