World Scientists' Warning to Humanity: A Second Notice

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and #,### co-signatories from ### countries (A full list of co-signatories can be found in the supplemental materials.)

Twenty-five years ago, the Union of Concerned Scientists and more than 1500 independent scientists, including the majority of living Nobel laureates in the sciences, penned the **1992 "World Scientists' Warning to Humanity"** (see supplemental materials). 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 fishery collapses, 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 planet 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 25th 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, supplemental table S1). Especially troubling is the current trajectory of catastrophic anthropogenic climate change due to rising GHGs from burning fossil fuels (Hansen et al. 2013), deforestation (Malhi et al. 2008), 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, halt defaunation,

and constrain invasive alien species, humanity is not taking the urgent steps needed to safeguard our imperiled 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 behaviours, 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. Twelve specific examples of diverse and effective steps humanity can take to **transition to sustainability** include:

1) prioritizing the enactment of connected well-funded and well-managed reserves for a significant proportion of the world's terrestrial, marine, and aerial habitats;
2) maintaining nature's ecosystem services by halting the conversion of forests, grasslands, and other native habitats;
3) rewilding regions with native species, especially apex predators, to repair damaged ecosystems;
4) developing and adopting adequate policy instruments to remedy defaunation, the poaching crisis, and the exploitation and trade of threatened species;
5) reducing food waste through education and better infrastructure;
6) promoting dietary shifts towards mostly plant-based foods;
7) 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;
8) increasing outdoor nature education for children as well as the overall engagement of society in the appreciation of nature;
9) divesting of monetary investments and purchases to encourage positive environmental change;
10) devising and promoting new green technologies and massively adopting renewable energy sources, while phasing out subsidies to energy production through fossil fuels;
11) revising our economy to ensure that prices, taxation and incentive systems take into account the real costs which consumption patterns impose on our environment; and
12) 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**.

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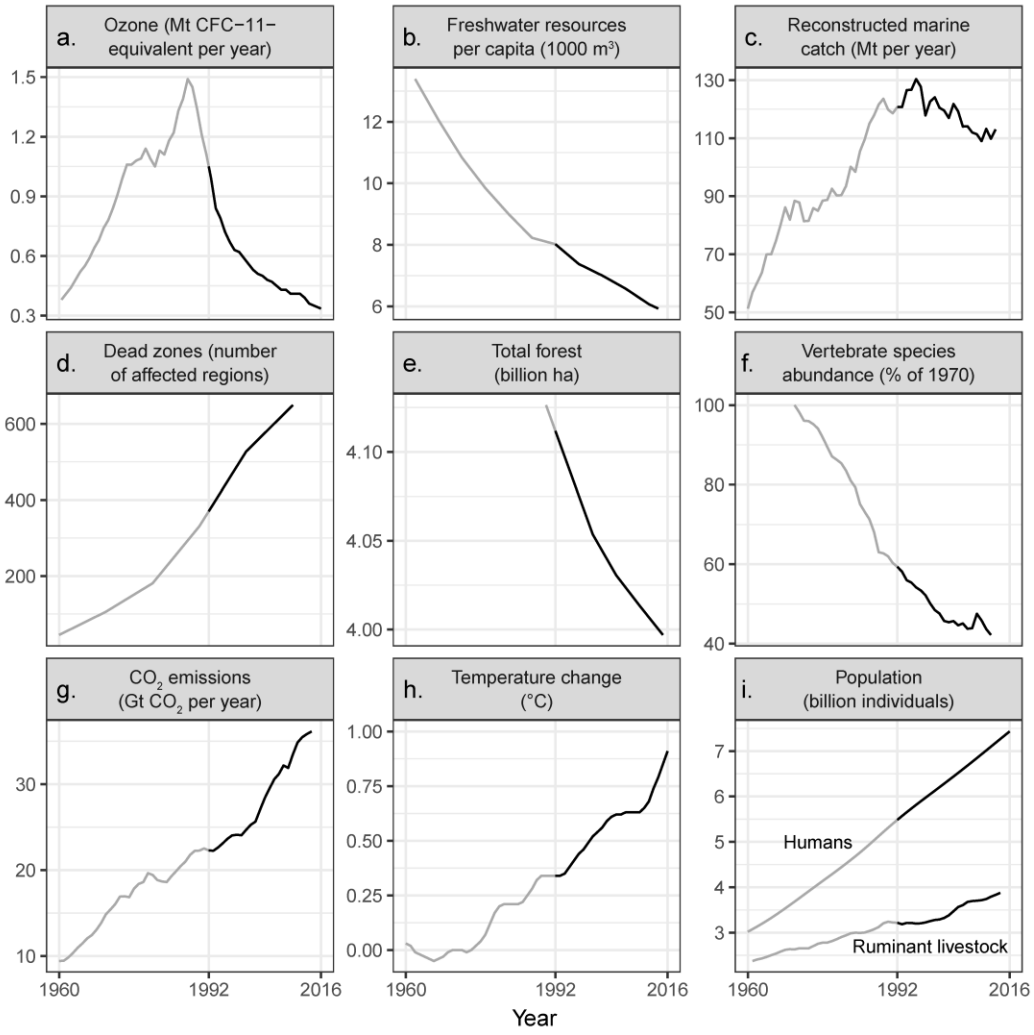

Figure 1. Trends over time for environmental issues identified in the 1992 scientists' warning to humanity. The years before and after the 1992 scientists' warning are shown as gray and black lines, respectively. Figure 1a shows emissions of halogen source gases, assuming a constant natural emission 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 table S1). The vertebrate abundance index in (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 (supplemental table S1). Five-year means are shown in (h). In (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 include (a) -68.1%, (b) -26.1%, (c) -6.4%, (d) +75.3%, (e) -2.8%, (f) -28.9%, (g) +62.1%, (h) +167.6%, (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 supplemental table S1.

Supplemental Material

Supplemental table S1. 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 heath, 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 (Pauley 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 CO_2 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.

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 billon people now to between 9.6 and 12.3 billon 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.

References for figure 1 and Supplemental table S1.

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Figure 1b, AQUASTAT. 2017. AQUASTAT - FAO's Information System on Water and Agriculture. http://www.fao.org/nr/aquastat/.

Figure 1c, Pauly, D., and D. Zeller. 2016. Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining. Updated. Nature Communications 7:10244.

Figure 1d, Diaz, R. J., and R. Rosenberg. 2008. Spreading Dead Zones and Consequences for Marine Ecosystems. Updated. Science 321:926–929.

Figure 1e, Food and Agriculture Organization of the United Nations. 2015. Global forest resources assessment 2015. http://www.fao.org/forest-resources-assessment/en/.

Figure 1f, World Wildlife Fund. 2016. Living planet report 2016: risk and resilience in a new era.
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Figure 1h, NASA's Goddard Institute for Space Studies (GISS). 2017. Global Temperature. https://climate.nasa.gov/.

Figure 1i, FAOSTAT. 2017. FAOSTAT Database on Agriculture. http://faostat.fao.org/.

World Scientists' Warning to Humanity (1992)

UNION OF CONCERNED SCIENTISTS

World Scientists' Warning to Humanity

Union of Concerned Scientists

This 1992 document was signed by 1,575 of the world's most prominent scientists (including 99 of the 196 living Nobel laureates) and was sent to governmental leaders all over the world. The document asks people to take immediate action to stop the ever-increasing environmental degradation that threatens global life support systems on this planet. The appeal was coordinated by Dr. Henry Kendall, Nobel laureate (1990, Physics), and former Chairperson of the Union of Concerned Scientists.

"World Scientists' Warning to Humanity"

Introduction
Human beings and the natural world are on a collision course. Human activities inflict harsh and often irreversible damage on the environment and on critical resources. If not checked, many of our current practices put at serious risk the future that we wish for human society and the plant and animal kingdoms, and may so alter the living world that it will be unable to sustain life in the manner that we know. Fundamental changes are urgent if we are to avoid the collision our present course will bring about.

The Environment
The environment is suffering critical stress:

The Atmosphere
Stratospheric ozone depletion threatens us with enhanced ultra-violet radiation at the earth's surface, which can be damaging or lethal to many life forms. Air pollution near ground level, and acid precipitation, are already causing widespread injury to humans, forests, and crops.

Water Resources
Heedless exploitation of depletable ground water supplies endangers food production and other essential human systems. Heavy demands on the world's surface waters have resulted in serious shortages in some 80 countries, containing 40% of the world's population. Pollution of rivers, lakes, and ground water further limits the supply.

Oceans
Destructive pressure on the oceans is severe, particularly in the coastal regions which produce most of the world's food fish. The total marine catch is now at or above the estimated maximum sustainable yield. Some fisheries have already shown signs of collapse. Rivers carrying heavy burdens of eroded soil into the seas also carry industrial, municipal, agricultural, and livestock waste—some of it toxic.

Soil
Loss of soil productivity, which is causing extensive land abandonment, is a widespread byproduct of current practices in agriculture and animal husbandry. Since 1945, 11% of the earth's vegetated surface has been degraded—an area larger than India and China combined—and per capita food production in many parts of the world is decreasing.

Forests
Tropical rain forests, as well as tropical and temperate dry forests, are being destroyed rapidly. At present rates, some critical forest types will be gone in a few years, and most of the tropical rain forest will be gone before the end of the next century. With them will go large numbers of plant and animal species.

Living Species
The irreversible loss of species, which by 2100 may reach one third of all species now living, is especially serious. We are losing the potential they hold for providing medicinal and other benefits, and the contribution that genetic diversity of life forms gives to the robustness of the world's biological systems and to the astonishing beauty of the earth itself.

Much of this damage is irreversible on a scale of centuries or permanent. Other processes appear to pose additional threats. Increasing levels of gases in the atmosphere from human activities, including carbon dioxide released from fossil fuel burning and from deforestation, may alter climate on a global scale. Predictions of global warming are still uncertain—with projected effects ranging from tolerable to very severe—but potential risks are very great.

Our massive tampering with the world's interdependent web of life—coupled with the environmental damage inflicted by deforestation, species loss, and climate change—could trigger widespread adverse effects, including unpredictable collapses of critical biological systems whose interactions and dynamics we only imperfectly understand.

Uncertainty over the extent of these effects cannot excuse complacency or delay in facing the threats.

Population
The earth is finite. Its ability to absorb wastes and destructive effluent is finite. Its ability to provide food and energy is finite. Its ability to provide for growing numbers of people is finite. And we are fast approaching many of the earth's limits. Current economic practices which damage the environment, in both developed and underdeveloped nations, cannot be continued without the risk that vital global systems will be damaged beyond repair.
Pressures resulting from unrestrained population growth put demands on the natural world that can overwhelm any efforts to achieve a sustainable future. If we are to halt the destruction of our environment, we must accept limits to that growth. A World Bank estimate indicates that world population will not stabilize at less than 12.4 billion, while the United Nations concludes that the eventual total could reach 14 billion, a near tripling of today's 5.4 billion. But, even at this moment, one person in five lives in absolute poverty without enough to eat, and one in ten suffers serious malnutrition.

No more than one or a few decades remain before the chance to avert the threats we now confront will be lost and the prospects for humanity immeasurably diminished.

Warning
We the undersigned, senior members of the world's scientific community, hereby warn all humanity of what lies ahead. A great change in our stewardship of the earth and the life on it, is required, if vast human misery is to be avoided and our global home on this planet is not to be irretrievably mutilated.

What We Must Do
Five inextricably linked areas must be addressed simultaneously:

1. **We must bring environmentally damaging activities under control to restore and protect the integrity of the earth's systems we depend on.**

We must, for example, move away from fossil fuels to more benign, inexhaustible energy sources to cut greenhouse gas emissions and the pollution of our air and water. Priority must be give to the development of energy sources matched to third world needs—small scale and relatively easy to implement.

We must halt deforestation, injury to and loss of agricultural land, and the loss of terrestrial and marine plant and animal species.

2. **We must manage resources crucial to human welfare more effectively.**
   We must give high priority to efficient use of energy, water, and other materials, including expansion of conservation and recycling.

3. **We must stabilize population. This will be possible only if all nations recognize that it requires improved social and economic conditions, and the adoption of effective, voluntary family planning.**

4. **We must reduce and eventually eliminate poverty.**

5. **We must ensure sexual equality, and guarantee women control over their own reproductive decisions.**

The developed nations are the largest polluters in the world today. They must greatly reduce their overconsumption, if we are to reduce pressures on resources and the global environment. The developed nations have the obligation to provide aid and support to developing nations, because only the developed nations have the financial resources and the technical skills for these tasks.

Acting on this recognition is not altruism, but enlightened self-interest: whether industrialized or not, we all have but one lifeboat. No nation can escape from injury when global biological systems are damaged. No nation can escape from conflicts over increasingly scarce resources. In addition, environmental and economic instabilities will cause mass migrations with incalculable consequences for developed and undeveloped nations alike.

Developing nations must realize that environmental damage is one of the gravest threats they face, and that attempts to blunt it will be overwhelmed if their populations go unchecked. The greatest peril is to become trapped in spirals of environmental decline, poverty, and unrest, leading to social, economic, and environmental collapse.

Success in this global endeavor will require a great reduction in violence and war. Resources now devoted to the preparation and conduct of war—amounting to over $1 trillion annually—will be badly needed in the new tasks and should be diverted to the new challenges.

A new ethic is required—a new attitude toward discharging our responsibility for caring for ourselves and for the earth. We must recognize the earth's limited capacity to provide for us. We must recognize its fragility. We must no longer allow it to be ravaged. This ethic must motivate a great movement, convincing reluctant leaders and reluctant governments and reluctant peoples themselves to effect the needed changes.

The scientists issuing this warning hope that our message will reach and affect people everywhere. We need the help of many.

We require the help of the world community of scientists—natural, social, economic, political;
We require the help of the world's business and industrial leaders;
We require the help of the world's religious leaders; and
We require the help of the world's peoples.
We call on all to join us in this task.