# Ecological Public Health for Nursing and Health Professionals in the Anthropocene

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By

Alice M.L. Li

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To my families with love

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# PREFACE

Global environmental and climate changes have imposed actual and potentially catastrophic implications on human health. An emerging paradigm of ecological public health is required to tackle all such broader changes, and a revolution in health systems is an urgent necessity. This new wave towards sustainable healthcare systems will be of compelling and pervasive relevance to the center stage of reform from multiple perspectives; it is not only about sharing professional development opportunities and responsibilities in healthcare, but offering revolutionary synergies with an interface for the next decade of changes under a new paradigm.

Ecological public health education and principles provide a framework for understanding the key influencing factors and driving forces of the underlying determinants that attributed to sustainable health developments and health-related problems on a global-scale. A transitional paradigm with ecological public health principles for sustainable health development is not just an idealistic way of thinking with anew paths but is rather a realistic course of actions and commitments that is meant to be advanced toward this new changing global context of public health needs. And this new transitional paradigm signifies the role of nursing and health professionals for educational reform as for the practical reason to proactively transform our intellectual understandings prospectively to encounter with those mediated health threats arising from these global environmental and climate crises under this new epoch of the Anthropocene.

A professional journey must be undertaken to enact action-oriented approaches and to allow the identification of the promising points of unfinished transformational agendas. These aspects can become an integral part of a synergistical roadmap for sustainable health developments and lead towards sustainable healthcare during this age of environmental and climate mediated health risks. Our planet and all living organisms, including us as "*Homo sapiens*", are what they are because of the elements that exist and the way they form. This 'age' poses many challenges at different levels in our globalized society, both theoretically and practically, which certainly affects our ways of knowing and doing concerning some of the fundamental characteristics of our humanity. It also indicates how our planet has conditioned the development of these characteristics. The current manifestations of these characteristics and our being in the midst of the Earth's sixth mass extinction crisis with the global environmental and climate changes underway. This new epoch of the Anthropocene combined together with the global ecological effects of anthropogenic pollutions that continuously imposed transitional health risks plus with actual and potential catastrophic public health impacts on a global-scale that further threaten our human health possibly across future generations. If these predicaments are not beyond our reach, intellectual and scientific tools can serve as the means of change through synergistical public health interventions. The educational platform is one of the ultimate way for this process of change through the connectivity of this transitional humanity in order to mitigate these adverse impacts and those future hazards of health threats that arise from the global and ecological determinants of health at the present time and in the future. We have to set the itinerary for re-kindling the virtuosity of our civilization. This is a journey of caring praxis which will allow humanity a new start.

Perhaps, it is also a journey keeping me moving with professional spirit towards 'life'. This idea is very much related to Albert Einstein's famous quote as written in a letter of 5th February 1930 to his son Eduard: "*Life is like riding a bicycle. To keep your balance, you must keep moving*".

This book presents a sensible hope and direction for our necessary journey towards an ecological civilization that could make possible a better eco-environments for our planet. Civilization comes not just from virtues; most importantly it comes from transforming our sense of interrelatedness, not just within human systems, but the emerging view of new revolution of extraordinary 'trans-reality' towards an understanding of how 'life' being formed for its co-existence and global interdependence. For the purpose of progressing the necessity of ecological dimensions of our wellness, it definitely requires a paradigm in transition for emerging ecological public health education, together with new waves of public health movements towards planetary health for global eco-environments, which is absolutely essential for the totality of this predicament in the Anthropocene. And therefore, we as health professionals have to understand such changing demands for blending sustainable health developments in the healthcare environment.

Scientific advancements in the 21st century are continuously widening our horizons and fostering insights into many complex issues with different perceptions and interpretations of responses, reactions, or even decisions. The dimensions of our intellectual and professional capacity may be one of the crucial factors affecting the ways in which we deal with those matters interrelated to transdisciplinarity in education. Sustainability development is the progressive position for further ecological public health education and represents the sum of the parts of healthcare reform through professional competencies in terms of applying this necessary knowledge for sustaining the full potential of healthy developments. Knowledge dissemination through educational reforms and an educative process directed at the necessary change of mentality and mindset ought to be cultivated in this sense.

In healthcare as an academic field, our belief is that education is the vehicle for achieving necessary change. Through the process of education, knowledge transformation can serve meaningful change; it is my utmost hope that this book may serve as a catalyst of this necessary change, that it may aid in moving forward with ecological public health education as part of future professional competencies embedded with practical knowledge for sustainable health developments.

The content of this book intends to sharpen the ecological understanding of health-related problems arising as a consequence of the Anthropocene and to suggest a promising and coherent set of interventional strategies or visions with synergistical systems thinking based on values and meanings geared toward the collective actions and responsibilities in the form of a professional journey of learning. The ultimate goal is, yet again, to widen the intended roadmap towards sustainable healthcare. Perhaps, keeping moving in a direction with free minds, free spirits and free intellectuals will be the roadmap for a successful journey after all. Such an attitude can inspire our new ways of systems thinking, and reveal the importance of holistic views of ecological values and meanings that pave the way towards more harmonious and sustainable ways of living, acting, and being. It can motivate us to gain scientific understandings of how to foster sustainable healthcare with the aid of an ecological civilization, which in turn can preserve our common home for generations. Ecological public health education is also the roadmap for our professions to carry on in this journey of humanity, and to become more ecologically conscious health professionals for promoting sustainable health developments across future generations.

I will always cherish this opportunity of writing this book, and my sincere thanks certainly go to many scholars and scientific contributors for their devoted efforts in research and studies that have generated enormous inspirational scientific and insightful views in this area. They have opened up the furtherance of our professional horizons to tackle such a complex transitional risks and mediated health-related problems that arising under this age of global environmental and climate crisis in the Anthropocene.

I, also particularly wish to express my gratitude to Professor William Steffen, Professor Barry Popkin, Professor Jonathan Salk, Professor Jan Willem Erisman, Professor Matthew H. Bonds, and Professor Roland Geyer for their academic support and kind permission to use their intellectual and inspirational materials (as referred to in the cited Figures and graphical data), with which my points have been illustrated much more clearly together with many factual assertions. A special tribute is due to my late Professor Anthony J. Hedley, our research team supervisor of several decades ago; I feel privileged to use some of his inspirational material in this book, notably the concept of the "pyramid effect" (as cited later). Last but not least, I would certainly like to extend my utmost sincere thanks to the team at Cambridge Scholars Publishing for preparing this book for publication.

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# CHAPTER 1

# PLANETARY HEALTH FOR GLOBAL AND ECO-ENVIRONMENTS IN THE ANTHROPOCENE

Our universe is believed to have formed about 15 billion years ago. Planet Earth came into existence about 4.5 billion years ago, its atmosphere composed of a variation of geophysical origins, including the influence of cosmic impacts and the infusion of energy for the development of air, water and the substances that were to become early forms of food, which then became key ingredients for the origins of life (White, Stallones and Last, 2013). Earth is an old planet, a third of the age of the entire cosmos, with a geological record that unfolds over 4.54 billion years (Ga) (Heikkurinen, 2017). Fossil evidence indicates that these early photo-synthesizers existed at least 3.5 billion years ago and perhaps earlier; however, there was insufficient oxygen in the atmosphere for animal life to exist in the early history of the planet. Instead, Earth's primitive atmosphere contained large amounts of methane ($CH_4$), but these molecules were split apart by solar radiation, and the carbon combined with the little oxygen that existed to form carbon dioxide ($CO_2$).

The origin of life is one of the most intriguing, difficult, and enduring questions in science; our knowledge of the materials from which life originated, and where, when, and in what form it first appeared, stems from geological investigations of rocks and minerals that represent the only remaining evidence (National Research Council, 2008). Early life-forms, including bacteria, blue-green algae, and phytoplankton, used the $CO_2$ for metabolism, producing oxygen as a by-product that allowed the continued evolution and spread of plants, which increased the amounts of oxygen in the atmosphere and enabled oxygen-breathing animals to evolve (Merritts, Menking and de Wet, 2014).

An issue of particular interest in the early Earth is this rise of atmospheric oxygen (Rollinson, 2009). Increased levels of oxygen in Earth's atmosphere allowed for the formation of the ozone in the upper atmosphere, which shields organisms from ultraviolet (UV) radiation given off by the sun. UV radiation can lead to sunburn, genetic defects, and cancer, so only when the atmosphere contained enough ozone could animals evolve on land (Merritts et al., 2014). This stratospheric ozone was in fact created in the atmosphere gradually around 3.5 billion years ago, and the ozone layer can be considered as a product of life on Earth to shield against solar ultraviolet radiation, which should not be confused with the ground-level ozone that is a harmful secondary air pollutant resulting indirectly from human activities (Poulopoulos and Inglezakis, 2016).

Most of us have wondered how our dynamic planet evolved, how it became a living world; and because of our remarkable and cumulative knowledge today, we know a great deal about Earth (Hazen, 2012). Around 400 million years ago, aqueous plants (the above-mentioned phytoplankton) were able to migrate onto the now-protected land and evolve into terrestrial plants, in other words becoming the beginning of the food chain. Animal life which fed on plants followed and life evolved via several evolutionary paths, through herbivorous and carnivorous dinosaurs, mammals, and omnivorous humans (Poulopoulos and Inglezakis, 2016). Some of these animals (herbivores) relied on consuming plant matter for energy, while others (carnivores) preyed on other animals to fuel their metabolism (Merritts et al., 2014).

The originally intuitive connection between organisms and their environment was ultimately translated into evolutionary theory; and today, our knowledge of the physical history of the Earth and other planets, and the physical limits for life, is increasing rapidly. Such questions as "How did life on Earth arise?" and "How have physical parameters constrained, molded and triggered the evolution of life on our planet?" continue to provide ample research topics (Rothschild and Lister, 2003). The structure of our planet is well known today based on seismic data and the oscillations of the Earth, in which the composition of external shells contains Earth's crust, hydrosphere, and atmosphere (Sorokhtin, Chilingarian and Sorokhtin, 2011). The biosphere interacts with other spheres, such as the lithosphere (i.e., the outermost surface of the Earth – Earth's crust), the atmosphere, and the hydrosphere.

The biosphere refers to all living organisms on Earth and is often called the global ecosystem of the Earth system, that is to say, the place where life exists. The composition of the biosphere is similar to that of Earth's other systems: it consists of 99% hydrogen, oxygen, carbon, and nitrogen, though its high percentage of carbon distinguishes it from all of the other major systems of the Earth. All fossil fuels (oil, coal, and natural gas) were formed from organic molecules that originated in the biosphere but were buried by sediments to become part of the lithosphere (Merritts et al., 2014).

In the Phanerozoic Eon is the backdrop to the extraordinary biodiversity of life at present, which includes our species, *Homo sapiens*, evolving some 195,000 years ago in Africa (Heikkurinen, 2017). The environmental conditions of the Holocene epoch that began approximately 11,700 years ago around the end of the last Ice Age, have been particularly conducive to human health; this is primarily due to its stable climate well-suited to human life across most of the globe, and its creation of predictable growing seasons that enabled the development of increasingly complex agricultural civilizations (Zywert and Quilley, 2020). The initial development of agriculture from about 10,000 years ago resulted in subsequent major modification of the landscape and the increasing influence of humans over species and ecosystems evolution (Heikkurinen, 2017). Since the Agricultural Revolution began some 10,000 years ago, human activities have had a significant impact on the distribution and types of forests of the world. The period before agriculture is known as the Paleolithic Era (*Paleo* = old + *lithic* = stone), and the period after the start of agriculture is known as the Neolithic Era (*Neo* = new + *lithic* = stone); the latter is the clear reason for the rise in the world's population.

With the increased ability to grow more food and feed a rising population, especially since 1750 or so, farmers have been able to grow more food with better seed varieties and farming techniques; use chemical fertilizers to boost soil nutrients; work with machinery to sow seeds, harvest crops, and process food stuffs; and store and transport food to urban cities (Sachs, 2015). We live on a human-dominated planet and the momentum of human population growth, together with the imperative for further economic development in most of the world, ensures that our dominance will increase; often it is the waste products and by-products of human activity that drive global environmental change (Curtin and Allen, 2018).

The history of the centuries-long effort of climate change science is now contributing to the foundation of a new interdisciplinary approach to understanding our environment (Le Treut, Somerville, Cubasch, Ding, Mauritzen, Mokssit, Peterson and Prather, 2007). Although global-scale human influence on the environment has been recognized since the 1800s, climate change has brought into sharp focus the capability of contemporary human civilization to influence the environment at the scale of the Earth and its planetary systems. It has been emphasized most acutely in the evolution of the Anthropocene as humanity proceeds into the twenty-first century, with the extent of these profound changes to our relationship with the rest of the living world becoming clearer (Steffen, Grinevald, Crutzen and McNeill, 2011). There is scientific consensus that our planet is in danger and that climate change is the most compelling public health challenge of our time: a warming planet has negative consequences in terms of environmental degradation, extreme weather events, social disruption and drastic health and economic consequences (Hellerstedt et al., 2017). In light of the evidence, the American Association for the Advancement of Science (AAAS) has affirmed the "What We Know Initiative" with three key messages (Hellerstedt et al., 2017):

1. **Reality**: About 97% of climate scientists have concluded that human-caused climate change is happening,
2. **Risks**: We are at risk of pushing our climate system toward abrupt, unpredictable, and potentially irreversible changes with highly damaging impacts, as Earth's climate is on a path to warm beyond the range of what has been experienced over the past millions of years.
3. **Response**: The sooner we act, the lower the risk and cost.

## The New Epoch of the Anthropocene

The Anthropocene represents humanity's entrance into a new era of sustainability challenges, in which the planet's environment is under significant pressure from social, economic, and demographic forces. These impacts will also be mediated through nonlinearity effects which threaten the human and environmental systems on an ecological and biogeochemical level, as coevolving systems which are inextricably coupled with human anthropogenic interferences in a wide range of ways. While our flow of production continues to keep up with this ever-expanding web of resource consumption, our stocks have approached scarcity, our waste absorption capacity through ecosystems is limited, and the carbon emissions into our atmosphere are worrisome (Layer, 2006). Thus, this challenge is complicated because the problem of greenhouse gases (GHG) emissions goes to the core of this modern economy and the solutions to climate change are indeed inherently complex (Sachs, 2015). In striving to prevent our society and future generations from tipping into disastrous states, sustainable development has remained one of the primary policy goals in the large majority of countries all over the world (Fang, Heijungs, Duan and de Snoo, 2015).

The term "Anthropocene" has in fact been coined three times: the first time was in 1922 by the Soviet geologist Aleksei Petrovich Pavlov, who proposed "Anthropocene" or "Anthropogene" as a name for the time since the first humans evolved about 160,000 years ago (Angus, 2016); the second time was in the late 1980s by the American marine biologist Eugene Stoermer who used it in some published articles (Malhi, 2017; Angus, 2016); and the third, which is when the term became more popular, was by the Dutch chemist and Nobel recipient Paul Crutzen who published, with Stoermer, a paper in the *Global Change Newsletter* entitled "The Anthropocene" in the year 2000 (Malhi, 2017). However, the formalization of the Anthropocene as a new geological epoch was officially confirmed back in 2016 by the Anthropocene Working Group (AWG) of the Sub-commission on Quaternary Stratigraphy (Heikkurinen, 2017).

In fact, this modern history of the Anthropocene starts with a small meeting of the International Biosphere-Geosphere Programme (IGBP) in Cuernavaca, Mexico, in February 2000, which had been formed in 1987 to coordinate research into what scientists call "global change", that is not just climate change, but all matters involved with the Earth's functions as an integrated system of interacting physical, chemical, biological and human components (Lewis and Maslin, 2018). This knowledge is vitally important for providing essential clues to its present physical, chemical, and biological state and leads to an understanding of the large-scale processes that bring about change in and on our planet.

Humans are the greatest evolutionary force, for that reason we have named this changing environment the Anthropocene Epoch and positioned it on the geologic timescale, because of the reality of human domination and evolutionary pressure (WHO, 2009). A key finding in this regard is the rapidly increasing population growth accompanied by profligate consumption and the proliferation of anthropogenic human activities that are continuously impacting the environment. Many scientists and studies have suggested that excessive unsustainable consumption will exceed the long-term carrying capacity of our environment as part of an ecological overshoot that could lead to resource depletion, environmental degradation, and reduced ecosystem health. So far, looking back in time, the human population took hundreds of thousands of years to reach the one billion mark, attained it in around 1820, took another 110 years (c. 1930) to add the next billion, but since 1960 it has required only 12–13 years to add almost each subsequent billion (Oosthoek and Gills, 2008).

The Earth systems paradigm is now strongly influencing issues in global change (Rollinson, 2009). The key features of these changes that propelled the Anthropocene often have an emphasis on their global and pervasive nature (Malhi, 2017):

a. the multifaceted nature of global change beyond just climate change, including biodiversity decline and species mixing across continents, the alteration of global biogeochemical cycles and large-scale resource extraction and waste production;
b. the two-way interactions between humans and the rest of the natural world, such that there can be feedbacks at a planetary scale such as climate change; and
c. an imminent fundamental shift in the functioning of our planet as a whole.

Crutzen thought the epoch should be renamed from the “Holocene” to the “Anthropocene” to reflect the impact of humans (Frumkin, 2017). In this sense, it is important to point out the broad implications of the Anthropocene, which emphasizes (i) the acceleration of degradation of the biosphere in recent decades and (ii) concludes that humanity has already abandoned the previous period of stability (Franchini, Voila and Barros-Platiau, 2017).

It connotes a time when humans have become agents of geological change, driving significant global chemical, physical and biological modifications to the atmosphere, landscape and oceans, in addition to climate change. As suggested, the threshold of ~2ºC, if crossed, could cause continued warming and a “Hothouse Earth”, even if and as human emissions are reduced; therefore humanity is now facing the need for critical action (Steffen et al., 2018).

These changes are global and viable not just in terms of the geological time of the Earth, but the profound influence of humans across the planet can be recognized with a broader spatial and deeper temporal understanding of life (Heikkurinen, 2017). This marks the important implication that human activity now rivals geological forces in its ability to affect essential planetary processes, which is deemed the beginning of the “Great Acceleration”. And this age is marking the history of our species by referencing to the facts of many human anthropogenic activities are indeed dated back to the mid-twentieth century, to around 1950.

## The Great Acceleration

The transition to the Anthropocene is a new geological epoch that dates from the commencement of the time period coinciding with the Great Acceleration in the mid-twentieth century. The rapid growth of the world economy since 1750 is the result of 250 years of technological advances, starting with the steam engine and steam-powered transportation, and progressing with the internal combustion engine, electrification, industrial chemistry, scientific agronomy, aviation, and nuclear power, as well as culminating in today's information and communications technologies (ICTs), which are the main driver of long-term global economic growth throughout our study of sustainable development in the world economy. However, coincidentally, these advances also come with negative side effects, such as damage to the planet (Sachs, 2015). As the sum of the planet's physical, chemical and biological processes is known as the Earth system, which comprises many interconnected processes (such as evaporation, transpiration, and photosynthesis) that store, transfer, and transform matter and energy according to the laws of physics and biogeochemistry (Meyer and Newman, 2018).

Therefore, we continually need environmental footprint indicators to measure emissions and the use of natural resources while the planetary boundaries provide levels of perturbation that are believed to ensure that the Earth system is kept in Holocene-like conditions that are favourable for humanity (but which are now apparently over the limit). As according to the indicators of "Socio-economic trends" and "Earth system trends" that indicated the increase of unprecedented environmental breakdown. And it covers the age when the rate and scale of changes in global environmental degradations quickened significantly. As the WHO has stated, the scale of change ranges from microscopic to planetary and affects the basic supports of life – air, water, food and fire; in addition the rate of change is now being measured in decades versus the millennia of previous epochs (WHO, 2009). Such accelerations are largely driven by population growth, economic development, and lifestyle changes, and which also a prime driver of changes in the Earth system and resulted in severe environmental degradation beyond acceptable global limits, leading to the anthropogenic perturbation of crucial Earth system processes. It thus marks a move away from a safe planetary operating space for human activities (Häyhä, Lucas, van Vuuren, Cornell and Hoff, 2016).

In the studies by Rockströmet et al. (2009) and Steffen et al. (2015), both sets of researchers identified nine critical processes that regulate the functioning of the Earth system (as cited in Vanham et al., 2019). Such records demonstrate how human activity has pushed the Earth's ecosystem beyond the boundaries of its natural course (Lambin, 2012). Figure 1-1 presents a framework for the limits of these planetary boundaries in the Earth system process, comparing its current state against its pre-industrial state, but excluding atmospheric aerosol loading and chemical pollution (as they cannot be determined as of yet).

| Planetary Boundaries | | | | |
|---|---|---|---|---|
| **Earth system process** | **Parameters** | **Proposed boundary** | **Current value** | **Pre-industrial value** |
| Climate change | Atmospheric CO2 concentration (parts per million by volume) | 350 | 387 | 280 |
| Rate of biodiversity loss | Extinction rate (number of species per million species a year) | 10 | >100 | 0.1 – 1 |
| Nitrogen cycle | Amount of N2 removed from atmosphere for human use (millions of tons per year) | 35 | 121 | 0 |
| Phosphorus cycle | Quantity of P flowing into oceans (millions of tons per year) | 11 | 8.5 – 9.5 | -1 |
| Stratospheric ozone depletion | Concentration of ozone (Dobson unit) | 276 | 283 | 290 |
| Ocean acidification | Global mean saturation of aragonite in surface sea water | 2.75 | 2.90 | 3.44 |
| Global freshwater use | Consumption of freshwater by humans (km3 per year) | 4000 | 2600 | 415 |
| Change in land use | Percentage of global land cover converted into cropland | 15 | 11.7 | Low |

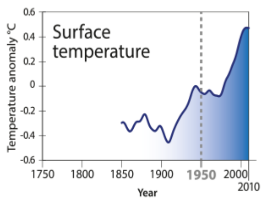
Figure 1-1: Limits of Planetary Boundaries (Li, 2017b as adapted based on Schroeder, Thompson, Frith & Pencheon, 2013).

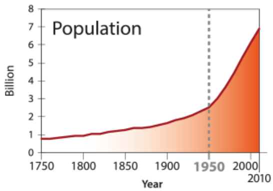
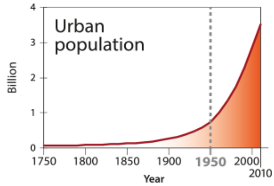
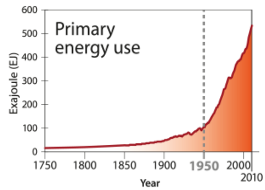
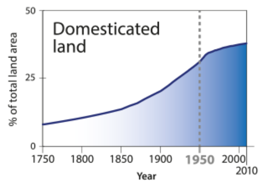
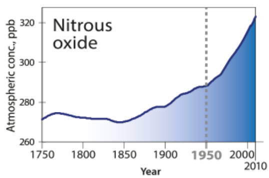
The current values of the footprints above are in fact indicators of the pressure of human activities on the environment; they are quantified based on life cycle thinking along the whole supply chain (from producer to consumer, and sometimes to waste management), which aimed to give a comprehensive picture of each footprint regarding a particular environmental concern, being measured either by resource appropriation, pollution/waste generation, or both (Vanham et al., 2019). As the values illustrate, environmental degradation is caused by human anthropogenic activities that evidentially constitute profound and unprecedented challenges in human history. The potential consequences from the intensity of continuous demands on ecosystems will eventually lead to ecological deterioration, as the ecosystem services have only a limited amount of "fuel" or "production factor" within the planet's biocapacity. This planet's biocapacity is its renewable natural capital that can only be provided through ecosystem services.

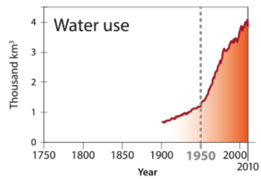
Over the past 50 years, a broad agreement has been arrived at that humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, freshwater, timber, fiber, and fuel. Human activities are thus dominating many aspects of the Earth's natural environment (Angus, 2016). The Anthropocene implies that the human imprint on the global environment is now so large that it can be seen from the structured formula "Population x Affluence x Technology = Human Impact" (or the "IPAT formula") that has been growing steadily since the industrial revolution and began to grow exponentially after World War II. This was the commencement of the phase scientists call the Great Acceleration (Steffen et al., 2011).

Consumption of natural resources on a global scale has increased rapidly in recent decades. The original Great Acceleration graphs of social and environmental trends from 1750 to 2000 were published in 2004 and in 2015. Steffen and other associates updated the data and extended the planetary dashboard to show the "Great Acceleration" in human activity up to 2010, in which the evidence of large-scale shifts in the Earth system's functioning prior to 1950 is weak. However, the post-1950 acceleration in the Earth system indicators remains clear and shows a start date for the Anthropocene; the beginning of the Great Acceleration is by far the most convincing from an Earth system science perspective (Steffen, Broadgate, Deutsch, Gaffney and Ludwig, 2015).

The scientific evidence unfolds our understandings with evidential indicators as shown in the "Socio-economic trends", "Earth system trends" and "Ecological footprint" of human influence on the planetary Earth system through human anthropogenic processes, which are summarized below in Figure 1-2.

| Increasing human anthropogenic influences* | Graphical data of Socio-economic trends and Earth system trends** |
|---|---|
| The surface temperature has been rising (with few anomalies) from 1951 onward, which is one of the most obvious signals of climate change over the past several decades. There were also more high and fewer low temperature extremes than nearly the entire extremes recorded dating up to the mid-20th century. In 2014, the Intergovernmental Panel on Climate Change (IPCC) indicated that Anthropogenic greenhouse gas emissions (GHGe) (mainly carbon dioxide, methane and nitrous oxide) were extremely likely to be the dominant cause of the observed global warming since the mid-20th century, and there is strong scientific consensus about the threat posed by unabated climate change. Levels of GHGe rose to new highs, including carbon dioxide, methane and nitrous oxide—all of which reached record levels. |   |

| | |
|---|---|
| Historically, John Graunt (1662) is credited as the first demographer to describe population growth in the 17th century as a doubling rate and this later became the basis for Malthus (1888). There has been a tenfold human population growth in three centuries. This global growth amounts to over 80 million annually from 1 billion in 1800. Now the population is more than 7.5 billion in the 21st century. |   |
| Urban transitions are underway with increasing resource intensity of the energy, materials and water required to produce units of goods and services, and the ways in which each society adapts to this change, e.g., the process through which cities grow due to further urbanization. The urban population has increased from 43% in 1992 to 50% in 2012. |   |
| We are in the process of exhausting fossil fuel reserves that were generated over several hundred million years. There has been a 16-fold increase in energy use in the twentieth century, raising air pollutants such as sulphur dioxide, nitrogen oxides, carbon monoxide, ozone, particulate matter and lead emissions to over twice natural levels. |   |
| Nearly 50% of the Earth's land surface has been transformed by direct human action and even wetlands have shrunk by one-half, which has had significant consequences for biodiversity, nutrient cycling, soil structure and biology, as well as climate. Humans have claimed more and more land to grow grains, raise livestock, and provision ourselves with forest products and fibers from the natural capital of the ecosystem. Population dynamics and land cover change have been intrinsically linked. |   |
| Nitrous oxide ($N_2O$) is the third most important long-lived GHG after carbon dioxide ($CO_2$) and methane ($CH_4$), which is also one of the main stratospheric ozone depleting substances on the planet. Nitrous oxide levels are on the rise from the use of nitrogen-fixing fertilizer and combustion of fossil and biofuels. |   |

<table>
<tr>
<td>More than half of all accessible freshwater is used directly or indirectly by humankind, and underground water resources are being depleted rapidly. Humanity has consumed huge amounts of water, especially to grow food, and now faces water crises in many parts of the world. Adverse effects on water availability and quality are impacting biodiversity, the functioning of ecosystems, human health and food security.</td>
<td>
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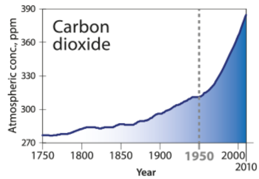
<td>According to the limits of planetary boundaries seen in Figure 1-1, the proposed boundary atmospheric $CO_2$ concentration is 350 parts per million (ppm) by volume. And evidence now shows the record average global $CO_2$ concentration was reached in 2018 at 407.4 ppm. This is the highest ever level in modern 60-year measurement records and those created from ice-core samples dating back as far as 800,000 years.</td>
<td>
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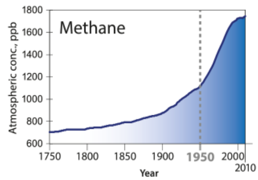
<td>Methane ($CH_4$) is mainly produced in the guts of ruminant livestock, such as cattle and sheep, who have a fore-stomach containing microbes called methanogens that are capable of digesting coarse plant material with by-products of methane. The dietary trends are of environmental concern for livestock productions, given their maintenance of 1.4 billion methane-producing cattle. The impact on climate change of one unit of methane is roughly 30 times greater than that caused by one unit of $CO_2$ over a 100-year period.</td>
<td>
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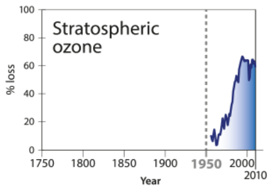
<td>The stratospheric ozone layer absorbs ultraviolet radiation, preventing dangerous UV rays from hitting the Earth's surface and harming living organisms. Ozone depletion in the stratosphere is caused by ozone depleting chemicals/substances (ODSs). There are some examples of banning ODSs, such as the 1987 Montreal Protocol, which was then being initiated for controlling chlorofluorocarbons (CFCs) production.</td>
<td>
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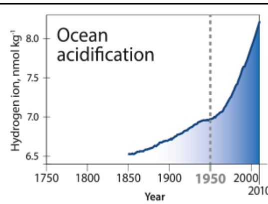
<td>Oceans cover three-quarters of the Earth's surface area. Ocean acidification is the drop in seawater pH. Industry is responsible for a large proportion of incineration and combustion processes which do not emit $CO_2$ alone, but also large amounts of other gases that act as acids when they come into contact with water, especially nitric and sulfur oxides ($NO_2$ and $SO_2$) which contribute to</td>
<td>
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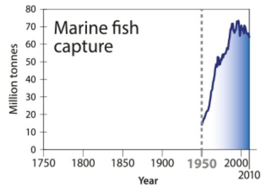
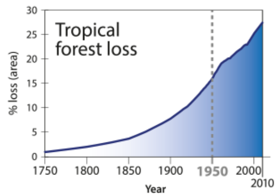
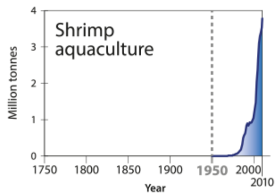
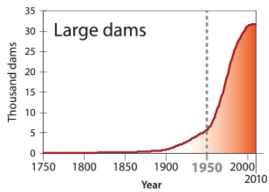
| Oxonium ($H3O^{+}$) formation. Other human-caused changes in marine ecosystems occur through poisoning the ocean with pollution, changing ocean chemistry, the physical destruction of ocean features such as sea beds and coral reefs, and the overfishing and overharvesting of marine life. | |
| About 22% of recognized marine fisheries are overexploited or already depleted, and 44% are at their limit of exploitation. Overfishing and overharvesting of marine life have had an adverse effect on marine biodiversity and disrupted the food chain. One of the highlighted unexpected consequences of human activity has been the lack of recovery of cod populations on the Grand Banks despite nearly two decades of fishery closures. |  |
| Forests remain one of the major parts of terrestrial ecosystems on the planet, covering 31% of the total land area. Destruction of tropical rainforests and deforestation have imposed serious consequences on environmental degradation and ecological disruptions. Mangroves are also a type of tropical forest with a unique position at the dynamic interface of land and sea. The functioning of their ecosystems is invaluable, and the losses of mangroves have escalated in the past 50 years. |  |
| Shrimp farmers have to destroy mangroves to create shrimp ponds for shrimp aquaculture, which has imposed permanent damage on an enormous amount of the world's mangroves. Yet, mangrove forests are among the most productive and biologically important ecosystems with high ecological value. Despite this, the integrated mangrove-shrimp aquaculture is theoretically a sustainable farming system and was only initiated in 2006. |  |
| Coastal and marine habitats are being dramatically altered, including mangroves which have been removed for widespread dam building and river diversion. Nearly 700 dams were built every ten years up to the 1950s, with this number growing rapidly after the 1950s. Dams have both positive and negative effects, as on one hand they control stream regimes and prevent floods, obtaining domestic and irrigation water. On the other hand, they are complicated in terms of climatic hydraulic, biological, social, cultural, archaeological etc., effects. |  |