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An Economist's Ode to the Forests and the Sea

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Wim Naudé
RWTH Aachen University, University of Coimbra and IZA

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IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

An Economist's Ode to the Forests and the Sea

The field of economics ought to be based on the fact that planet Earth is a rare Earth that is fundamentally an Ocean and Plant World. The rapid and continuing bulldozing of biodiversity across ocean and land that has been a feature of human society's economic development over the past two centuries or so, demonstrates that the current political and economic response, framed by the narrow human-centric concept of sustainable development, has failed. Therefore, this paper calls for a fundamental planetary turn in perspective, moving beyond sustainability towards the biocentric concept of *Planetary Habitability*. The point is that fixing a slow leak in a spaceship (sustainability) is insufficient when the ship's entire life support system is collapsing due to a fundamental design flaw (anthropocentrism); instead, the focus must shift to ensuring the entire ship can support life (habitability), regardless of immediate human convenience.

JEL Classification: Q57, Q54, B52, O44
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Corresponding author:
Wim Naudé
RWTH Aachen University
Kackertstraße 7
52072 Aachen
Germany
E-mail: naude@time.rwth-aachen.de

1 Introduction

We live on a planet that is 70% ocean and where around 80% of all biomass is made up of plants. Yet, we call it Earth- not ocean - and we believe that we humans are the dominant species. Moreover, we believe that we are the pinnacle of evolution and the self-appointed masters of the world, even though we have been around for a minuscule fraction of the planet's existence. This anthropocentric view - and belief in human exceptionalism -underpins much of modern mainstream economics, which has relegated the rest of the planet to the category of resources to be used by humans to maximize their utility, and which resources are undervalued and believed to be essentially infinite - all that is required is "sustainable development."

This paper argues that to set these views right, we need to start by recognizing the rarity and fragility of the Earth and the foundational importance of nature. Earth is a *Rare Earth*, a planet where the emergence of life is "barely possible" due to highly specific and rare conditions. Life, once emerged, is exceedingly fragile, and intelligent species may not escape a *Great Filter*. The habitable Earth is also fundamentally an Ocean World and a Plant World. The ocean originated life, created the oxygen atmosphere, and stabilizes the climate. Plants constitute 80% of all biomass, provide almost all ecosystem energy and are the architects of the habitable Earth.

Moreover, the view that underpins modern economics and so-called sustainable development approaches to planetary crises (such as climate change) and human exceptionalism has become counter-productive, given that we are, against our own self-interest, destroying the ocean and decimating the diversity of plant (and other) life. The ecosystems from which we emerged, and on which we depend, took billions of years to form, yet we nevertheless value these at "next to nothing" (Murphy et al., 2021).

The core message of this paper is that the habitability of the planet requires a profound shift away from the narrow, human-centric perspective on sustainability toward a framework of Planetary Habitability. Habitability, unlike sustainability, is concerned with sustaining complex, multicellular life in general and is consistent with biocentric holism. The contribution of this paper lies primarily in its assertion that the foundation of economic thought must be radically redefined, based on astrobiological and Earth Systems Science facts, moving the debate beyond simple environmental policy and conventional critiques of human exceptionalism.

The rest of the paper is structured as follows. Section 2 describes the Earth as the *Rare Earth*, establishing that a habitable planet capable of supporting complex life is only barely possible and exceedingly rare, emphasizing the planet's fragility. Section 3 describes the Earth as an ocean world. It details the foundational role of the ocean in abiogenesis, in creating an oxygen-rich atmosphere, and in stabilizing the global climate system. Section 4 describes the Earth as a plant world. It details the dominance of plants as the primary producers that provide all ecosystem energy, and are the ultimate architects of the habitable Earth.

In juxtaposition to sections 2 to 4, which describe the habitability of our planet, section 5 catalogs the devastating ecological overshoot and biodiversity loss occurring across both terrestrial and marine environments, serving as empirical proof of the failure of the current economic system. Section 6 critiques the inadequacy of the anthropocentric concept of sustainability to change the economic system, and proposes the adoption of the more robust, biocentric concept of planetary habitability as the necessary framework for human-planetary co-existence. Section 7 concludes.

2 The Rare Earth

The idea of planetary habitability may seem strange—a planet with life. To understand what makes a planet habitable - and hence by implication uninhabitable by its absence or destruction - one needs first to understand what life is. This seems to be something about which there is uncertainty (Silva et al., 2017; Schulze-Makuch, 2025) - not least because the laws of physics do not predict the emergence of life (Sharma et al., 2023). In 1994, a NASA committee defined life as a "self-sustaining chemical system capable of Darwinian evolution" (Benner, 2010, p.1022). Méndez and González-Espada (2016, p.3-1) discuss various definitions, concluding that what these have in common is that life refers to material objects that "sustain themselves chemically, self-reproduce and are capable of evolution."

The process of abiogenesis, by which life on planet Earth emerged from non-life, around 4,2 billion years ago, is still not understood, surely because "No instance of abiogenesis has ever been observed" (Bostrom, 2008, p.74). What has been observed is that all life on Earth shares a common ancestor, making it clear that humans are kin to all life on the planet and are not separate from it. As Méndez and González-Espada (2016, p.3-3) remind us, "Humans share approximately 90% of their genes with chimpanzees, 84% with dogs, 69% with platypi, 47% with fruit flies, 38% with round worms, 24% with wine grapes, 18% with baker's yeast and 7% with bacteria."

Earth is the only planet we know of that is habitable and inhabited. So far, NASA has cataloged[1] more than 6,000 exoplanets - that is, planets outside our solar system - since Wolszczan and Frail (1992) discovered the first exoplanet in 1992. That the Earth could be the only inhabited planet in the universe seems extremely unlikely. Consider, for instance, that there are $\approx$ 2 trillion galaxies in the universe (Conselice et al., 2016), each with more than a billion stars - most of which likely have planets (Cassan et al., 2012). Even if on only

[1]See the NASA catalog at: https://science.nasa.gov/exoplanets/exoplanet-catalog/

1% of these intelligent life arises, the universe would host billions of alien civilizations. If any one of these in our galaxy had at any time in the 13,8 billion years that the universe had existed so far used self-reproducing intelligent starprobes traveling at 1/10th the speed of light, the entire galaxy could be traversed in 500,000 years (Valdes and Freitas Jr, 1980). Such star probes were proposed by Game Theory co-founder John von Neumann (Von Neumann, 1966), hence labeled *Von Neumann Probes*. "From a technological point of view, there seems to be no obstacle to the ultimate terrestrial construction of Von Neumann probes" (Matloff, 2022, p.206).

The problem is that, despite the likely superabundance of planets and the feasibility of colonizing the galaxy in 500,000 years, there is not a jot of evidence for life elsewhere, including intelligent life. This is the Fermi Paradox, or more accurately, Fermi's Question, which is the question the physicist Enrico Fermi asked: "*Where is everyone?*" referring to the absence of any sign of alien intelligence in the universe despite the age of the universe and the abundance of planets (Cirkovic, 2018; Gray, 2015; Hart, 1975).

According to Ward and Brownlee (1999), an explanation for the Fermi Paradox is that the Earth is a *Rare Earth*, meaning that the factors that make it habitable are so specific that it may be rare to find life elsewhere in the galaxy. Without exhaustively covering all of the arguments of Ward and Brownlee (1999), it is helpful to focus on several of the most important conditions for planetary habitability - especially as these conditions on Earth seem to be under pressure from exponential economic and population growth.

One of the most important conditions or requirements for planetary habitability is a suitable and stable climate, not too hot or cold to sterilize the planet. This requires a combination of features to be in place. The first is that a planet must orbit a star within the galactic habitable zone (GHZ). Without the sun, the Earth would not be habitable - the radiative equilibrium temperature of the Earth without the sun would be around an icy -237.15 degrees Celsius (Kren et al., 2017). However, not a sun anywhere in our galaxy may be equally suitable for planetary habitability. Stars near the center of the galaxy may face dangers from supernovae, gamma-ray bursts, and collisions with other objects. Stars very far from the center of the galaxy, on the other hand, have been found to contain less metal (also because they are less affected by supernova explosions) and may therefore lack rocky planets such as the Earth (Kasting, 2010). Located at 25,000 light-years away from the 85,000-light-year diameter galaxy center, our Sun is right within the GHZ (Kasting, 2010).

The second feature that may be necessary for a suitable and stable climate is being located in the radiative habitable zone around a star (Shahar and et al, 2019). This zone is also known as the circumstellar habitable zone (CHZ) or liquid water zone, as liquid water can be present on the surface (Scharf, 2019). Whether a planet in the CHZ may be habitable will, however, depend on the nature of its star: in the case of small, cool stars, the CHZ may be so close to the planet, causing it to become tidally locked - like the Earth's moon. With very active stars, planets in the CHZ may be flooded with sterilizing solar radiation. The Earth's Sun is classified as a G2V star[2] with an effective surface temperature of more than 5,000 degrees Celsius. Given its size, the CHZ is between 0,95 and 1,4 Astronomical Units (AUs) from its centre, which is far enough not to lock the Earth tidally (Kasting, 2010).

In other respects, however, the sun seems not to be a typical G2V star. As Reinhold and et al (2020) found, the magnetic activity on the sun, which results in solar flares and coronal mass ejections, could threaten habitability.[3] It is significantly less than that of most other G2V stars that have been examined.

From the evolution of life on Earth, we can deduce that if life emerges on a planet in the CHZ,

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[2]Stars are classified using the Morgan–Keenan (MK) system based on their surface temperature, color and luminosity. In the case of our sun, the letter G indicates that it has a yellow-white color, and the 2 indicates that it is one of the hottest. The Roman *V* refers to its luminosity class, which, in the case of V, denotes a main-sequence star, which is a star that is actively fusing hydrogen into helium in its core for most of its lifetime. See: `https://www.britannica.com/science/G2-V-star`

[3]The most common type of star in the universe, M-type stars, or "red dwarfs", are much smaller than the sun, and much less luminous, which means their CHZ is closer to the star. This poses a danger to life: not only may the planet be tidally locked, but the planet in that zone may be sterilized by the star's magnetic activity (Scalo et al., 2007).

it will evolve and adapt to various temperate niches across the planet. It is not the case that everywhere on a habitable planet all types of life can exist - every planet has a habitability gradient. For humans on planet Earth, populations are overwhelmingly concentrated in regions with mean annual temperatures (MATs) of $\approx 13°C$ and $\approx 27°C$ (Lenton et al., 2023, p.1237). It has been estimated that climate change has already led to $\approx 9\%$ of the global population (>600 million) to live outside this niche, and if global warming increases to 2.7 $°C$ by 2100, around one-third of the world's population may end up outside of the human climate niche (Lenton et al., 2023).

A third factor necessary for a suitable and stable climate may be the presence of plate tectonics. Again, this has partly to do with a suitable climate. As explained by Shahar and et al (2019), plate tectonics moderates a planet's climate over the long term by recycling material between the surface and the deep, hot interior. Stern and Gerya (2024) describes how multicellular life was facilitated by plate tectonics, which supplied nutrients such as phosphorus to the oceans. This fed phytoplankton which in turn reduced atmospheric carbon dioxide levels and increased oxygen levels.

Given a good location of a star and planet, and plate tectonics, the maintenance of a suitable climate - its stability - may depend on the planet having a liquid-iron outer core which "produces the geomagnetic field that shields the atmosphere and protects the surface from the solar wind" (Shahar and et al, 2019, p.435). Mars, for example, has no such geomagnetic field, leaving the planet's atmosphere to be stripped away by solar flares and radiation.

Planetary habitability - emerging from the conditions described in the preceding paragraphs- is a "time-dependent property." This is because, according to Frank and Sullivan (2014, p.37) that "the variation of the sun's temperature and radius has been moving its habitable zone outward over billion-year timescales.' Consequently, "it is estimated that increases in the sun's luminosity of 10%/Gyr will render the Earth uninhabitable by most forms of present life as soon as ≈ 1.0 Gyr in the future."

The conditions described in the previous paragraphs for a suitable, stable climate in which life could emerge may be rare; conditions where life could evolve to become intelligent enough to establish a technological civilization, may be *very* rare indeed. Based on Carter (1983) and Watson (2008), this is known as the "hard steps" model (Mills et al., 2025). Frank and Sullivan (2014, p.33) calculates that if a planet is habitable for a period of t_h and if there are n hard steps required for life to emerge, denoted by λ_k where $\lambda_{t_h} \ll 1$, then the expectation of the time at which the k^{th} step will occur is $t_{(k/n)} = \frac{k}{n+1} t_h$.

Suppose, for instance, there are between four and ten critical steps needed for intelligent life to emerge, as Watson (2008) estimates. In that case, it means that intelligent life will only appear at the "very end of a planet's era of habitability" (Frank and Sullivan, 2014, p.33). As indicated in the previous paragraph, Earth's of habitability is estimate to last another 1.0 Gyr (1 billion) years, which, as Watson (2008) reminds, is "a short time compared to the approximately 4 Ga since life began." Based on this estimate of the remaining habitability of the Earth, Snyder-Beattie et al. (2021, p. 272) estimates that the time-span required for all the hard steps to be overcome would typically be much longer than the time during which a planet such as the Earth is habitable, leading them to conclude that "intelligent life is highly improbable."

Not only may the time required be too long, but any one of the hard steps may be too hard and constitute what has been termed a *Great Filter*, which truncates the sustainability of intelligent life and civilizations (Hanson, 1998; Bostrom, 2008).

The search for extraterrestrial life is clearly important for improving our understanding of planetary habitability, including for contextualizing life on Earth. This would provide a better gauge of the fragility of life and the probability of intelligent life going extinct. For instance, Bostrom (2008, p.77) fears that if evidence of primitive life is discovered elsewhere in the universe, it may imply that "the emergence of life is not a very improbable event" and that "the Great Filter is less likely to occur in the early life of planets and is therefore more likely still to come. ”

In the search for extraterrestrial life, scientists have begun looking for possible habitable exoplanets, as mentioned. To aid identification, they have developed an Earth Similarity Index (ESI) to compare the degree to which an exoplanet resembles Earth's conditions. If ESI = 0, there is no similarity and if ESI = 1, the planet is identical to Earth (Méndez and González-Espada, 2016). Exoplanets with an ESI of 0,8 or higher are considered to be "Earth-like" (Schulze-Makuch et al., 2011). At the time of writing, 25 exoplanets have been located with an ESI of 0,8 or higher. An exoplanet discovered so far that seems very Earth-like is *Teegarden's Star B*, which orbits a M-type red dwarf located about 12,5 light-years away in the constellation Aries. It has an ESI of 0,90 (Dreizler et al., 2024). It is not known whether it is habitable or inhabited, although Boukrouche et al. (2025) published simulations suggesting that it may be habitable.

The upshot is that not only may habitable planets and life be exceedingly rare, but once life emerges, it may be very fragile, even if it does so soon after a planet becomes habitable. Species that build civilizations like humans do may not escape a *Great Filter*.

It is estimated that around 4 billion species emerged on Earth over the past 4,2 billion years, and that 99% have gone extinct (Barnosky et al., 2011; McCallum, 2015). It is not just random events (such as asteroid impacts) or competition from other life forms that drive species to extinction; it is also senescence against environmental changes - the longer a species has been alive, the higher its chances of extinction (Zliobaite et al., 2017). Based on this, Gee (2025) argues that modern humans, homo sapiens, are "on the edge of extinction." He estimates that humans will go extinct within 10,000 years. Thus, considering the span of habitability of the planet since around 4 billion years ago, our technological civilization will have been around for 0,00001% of the time.

To consider all the conditionalities for a technological civilization like ours to emerge, and from that calculate the possible similarly complex civilizations in the galaxy, which in principle we should be able to detect either bio-signatures[4] or techno-signatures[5] of, astronomer Frank Drake proposed the Drake equation in 1961 (Rheinstadter, 2025; Drake, 1965). As explained by Sandberg et al. (2018, p.2), the Drake equation for the number of technological civilizations (N) can be written as

$$N = R \times f_p \times n_e \times f_l \times f_i \times f_c \times L \tag{1}$$

Where R "is the rate of star formation per year, f_p is the fraction of stars with planets, n_e is the number of Earth-like (or otherwise habitable) planets per system with planets, f_l is the fraction of such planets with life, f_i is the fraction with life that develop intelligence, f_c is the fraction of intelligent civilizations that are detectable/contactable, and L is the average longevity of such detectable civilizations in years."

Typically, when using this, point estimates for the different probabilities or fractions in the equation are used. Sandberg et al. (2018), however, criticize this approach, arguing that one should instead use probability distributions for the parameters. When they do so, using these distributions "based on the variation in historical estimates and doing so based on the authors' best judgment of the scientific uncertainties for each parameter" (p.4) they conclude that "when our uncertainty is properly accounted for in the model, we find a substantial prior probability that there is no other intelligent life in our observable universe" (Sandberg et al., 2018, p.10). This result is similar to that of Snyder-Beattie et al. (2021) who uses a Bayesian model to estimate the probability that all of the hard steps needed for an intelligent civilization occur before the lifetime of a planet such as Earth.

Of course, we know that we do indeed inhabit the universe - there is thus at least one inhab-

[4]See: https://tinyurl.com/4tk9mecw
[5]See: https://www.newscientist.com/definition/technosignatures/

ited planet. According to Ward and Brownlee (1999), this is due to a large set of properties of the Earth-Sun system, which makes it the Rare Earth where this is possible. The Rare Earth argument, and the conclusion of Sandberg (2018) that there is a "substantial" prior probability that "there is no other intelligent life in our observable universe," resonates with the argument of physicist Dennis Sciama that we live in a universe where life is "only barely possible" (Wang and Braunstein, 2024). According to Sciama, if the fundamental constants[6] that describes our universe, such as the strength of gravity or electromagnetism, were selected at random, the resulting universe would almost certainly have a negligible chance of supporting life (Wang and Braunstein, 2024). The inhabited Earth is barely possible, and rare indeed.

3 The Earth as an Ocean World

> "*How inappropriate to call this planet Earth when it is quite clearly Ocean*" - Sir Arthur C. Clark

Given that Earth's surface is 70% ocean and given that the ocean contains 95% of the possible livable space on the planet, it should perhaps have been called Ocean, as Sir Arthur C. Clark remarked.[7] "It regulates rainfall and droughts, holds 97% of our planet's water, and absorbs CO_2, helping keep the carbon cycle in balance. From food to jobs, it's a lifeline for billions of people, too" (Fleming, 2019). The Rare Earth is an Ocean World. From space, it is a "pale blue dot" (Sagan, 1994). Where the ocean - water - came from, is still a puzzle - it is thought that Earth received its water early in its formation from collisions with chondritic (unmelted) meteorites (Newcombe et al., 2023).

[6] "It takes 26 dimensionless constants to describe the Universe as simply and completely as possible" (Siegel, 2015).

[7] The quote "How inappropriate to call this planet Earth when it is quite clearly Ocean" is widely attributed to the science fiction author Sir Arthur C. Clark -see `https://tinyurl.com/494tbdra`

Without its ocean, life as we know it on Earth would not exist. Abiogenesis occurred in ancient Earth's oceans, most likely in and around hydrothermal vents,[8] roughly 4,6 to 4 billion years ago[9] (Georgieva et al., 2021; Martin et al., 2008). One of the most famous active hydrothermal vents is the so-called Lost City Hydrothermal Field, at a depth of around 700 meters in the Atlantic, just south of the Azores, and was only discovered in 2000. It has been an active vent for more than 30,000 years and is seen as "a contemporary analogue of conditions where life may have originated" (Johnson, 2019, p.1). It is even a legacy of the origin of life in the oceans that today our bodies contain saltwater with a mineral composition similar to the ocean's. Fagan (2021) recalls Rachel Carson's words, in her book *The Sea Around Us*, that we still "carry the sea in our bodies."

At some stage around 4 billion years ago, the chemical processes in these hydrothermal vents enabled ribonucleic acid (RNA) to form, allowing the copying of genetic information. RNA, in turn, formed enzymes known as ribozymes, which catalyzed biochemical reactions. Pomeroy (2024) postulates that marine planktonic cyanobacteria "might have moved up the [ocean's] water column, eventually rising to the photic zone, where the Sun's light is strong enough to provide energy. They evolved the ability to photosynthesize, producing oxygen as a byproduct."

Photosynthesis[10] caused the oxygenation of the ocean, including the oxygenation of deep ocean basins, known as ocean ventilation (Ostrander and et al, 2025), and eventually the entire atmosphere to its current share of 21% oxygen. This happened over a long span of time, first through the Great Oxidation Event (GOE) that took place around 2,4 billion years ago, and the Neoproterozoic Oxidation Event (NOE), roughly 800 to 600 million years ago (Sánchez-Baracaldo and Cardona, 2020). The deep ocean basins were eventually ventilated,

[8]See: `https://tinyurl.com/xtpsk4b8`

[9]The majority view among scientists is that life originated on Earth through chemical reactions, likely around hydrothermal vents. Some have, however, posited that life may have chemically originated in outer space and was delivered to Earth via meteorites - the panspermia hypothesis (Rheinstadter, 2025).

[10]"In its simplest form, photosynthesis is adding water to CO_2 to produce sugars and oxygen" (See `https://en.wikipedia.org/wiki/Evolution_of_photosynthesis`)

relatively recently in geological time, around 380 million years ago (Ostrander and et al, 2025).

The oxygenation of the sea and the atmosphere was central to the evolution of life and the planet's habitability. As Ostrander and et al (2025, p.1) explains, "widespread ocean ventilation is invoked to explain nearly every important event in early animal evolution." Photosynthesis remains "the only significant solar energy storage process on Earth and is the source of all of our food and most of our energy resources" (Blankenship, 2010, p.434). It allowed for "aerobic respiration and the evolution of large, complex and ultimately intelligent organisms" (Buick, 2008, p.2731). Half the oxygen breathed today is estimated to come from marine organisms (Morsink, 2017).[11]

Photosynthesis by phytoplankton in the ocean not only changed the entire Earth system by providing oxygen but also is part of the biological carbon pump, affecting atmospheric CO_2 levels. This is because photosynthesis leads to phytoplankton growth, which uses carbon during that growth - removing it from the ocean, allowing the ocean to absorb more carbon from the atmosphere. This carbon eventually sinks, becoming sequestered once it sinks more than 500 meters. The amount of carbon currently sequestered by the biological carbon pump annually is estimated to be a quarter of all carbon emitted (Shadwick et al., 2025). Climate change is set to change this: it is estimated that, at current carbon emissions rates, the ocean may lose its ability to absorb carbon dioxide by 2100 (Chikamoto et al., 2023).

Thus, not only did life evolve in the ocean, but ocean-based life also created the oxygen-rich atmosphere needed for "large, complex and intelligent organisms," and it is part of the biological carbon pump that removes carbon from the atmosphere. Moreover, the ocean is "the largest solar energy collector on Earth [...] This tremendous ability to store and release heat over long periods of time gives the ocean a central role in stabilizing Earth's climate system" (Lindsey and Dahlman, 2025). The ocean stores about 91 per cent of the excess

[11] See also: `https://oceanservice.noaa.gov/facts/ocean-oxygen.html`.

heat energy trapped on the planet (Lindsey and Dahlman, 2025). It is the Earth's "Big Heat Bucket' (Scott, 2006).

As Bradley (2025) evocatively describes, the ocean is complicit in slowing the Earth's rotation and in helping to establish the current 24-hour length of a day:

> "O*ver the great span of planetary time, the tidal drag of the Moon upon the ocean's waters has helped slow Earth's rotation, lengthening the day and allowing the Moon to orbit further and further away. Over billions of years, this may have doubled the length of a day – a change recorded in the bodies of marine animals. Each chamber in the shell of a modern nautilus has about 29 laminations, or roughly one for each day of the lunar month. As one moves back through the fossil record, this number decreases until, in the Palaeozoic, nautiloid fossils have only eight or nine laminations per chamber.*"

The ocean has always taken a central place in human society and in the economies that various societies have built over time. An excellent account of this is Abulafia (2019)'s magisterial work "*The Boundless Sea: A Human History of the Oceans.*" Today, the direct economic contribution of the Ocean to the world economy is immense and growing. The Food and Agricultural Organization (FAO) in its *2024 State of World Fisheries and Aquaculture* note that fisheries and aquaculture production globally was worth around US$ 472 billion, employing almost 62 million people directly in primary fishing, and involving more than 230 countries and territories in trade valued at US$ 195 billion (FAO, 2024). "The ocean is deeply embedded in our societies and daily lives", according to Giron (2025) as 80% of global trade crosses the ocean and 95% of international data is carried by undersea fiber-optic cables. To this one can add that 30% of the world's oil is produced in offshore fields, and more than 28,000 offshore wind turbines contribute to the energy transition (Paolo et al., 2024).

Moreover, according to OECD (2025) "the global ocean economy doubled in real terms in 25 years from US$ 1.3 trillion of GVA in 1995 to US$ 2.6 trillion in 2020, growing at an annual average rate of 2.8% [...] If historical trends were to continue, the global ocean economy could be nearly four times larger by 2050 than in 1995."

Unfortunately, this is not necessarily good news. Despite living on an Ocean World and carrying the sea in our bodies, we live in our minds and economy very far from the sea, and allow the expansion of the global economy to take a hugely destructive toll on the oceans. As a 2025 editorial in Nature magazine warned "Over the past few years, world leaders have put their names to several ocean related treaties and agreements. However, scientists have warned that compliance is a serious problem" (Editorial, 2025, p.821).

4 The Earth as a Plant World

> "*Every thought that has ever passed through your brain was made possible by plants*" - Schlanger (2025, p.28)

The third aspect of planetary habitability, as we know it, in addition to being rare and the outcome of an ocean world, is that its primary life form is what we call plants. The ocean world, inappropriately called Earth, is the Kingdom of Plants. Plants constitute the vast majority of Earth's biomass - 80% of all living matter on the planet - and are found in every ecosystem (Schlanger, 2025). Estimates suggest that global plant biomass is around 450 gigatons of carbon, dwarfing the approximately 2 gigatons of animal biomass - making the plant kingdom the dominant kingdom on Earth (Bar-On et al., 2018).

According to the UN's Food and Agricultural Organization (FAO), forests alone cover roughly 31% of the global land area. However, plants are found in nearly every conceivable habitat, from scorching deserts to frozen tundra, and from freshwater lakes to the margins of the oceans (in the form of sea-grasses and mangroves). Plants are the primary producers, the foundational layer of almost every terrestrial and many aquatic ecosystems (Bastviken et al., 2023).

Given their dominance, it is necessary to answer the question, What is a plant? The scientific term is "Plantae", which, if used broadly, is synonymous with *Archaeplastida*, encompassing all land plants as well as red algae, green algae, and glaucophytes[12] (Bowles et al., 2023; McCourt, 2016). Archaeplastida are a line of eukaryotes[13] - like humans - that have plastids (membrane-bound parts of cells) containing chlorophyll and that can perform photosynthesis - and with plastids that resulted from what is called primary endosymbiosis. Bowles et al. (2023, p.351) trace the emergence of Archaeplastida around 1030 million years ago from the "primary endosymbiosis of an ancestral eukaryote engulfing an ancestral cyanobacterium." They stress that such events are very rare in evolutionary history - it is a "hard step" in the evolution of life. Today, there are an estimated 500,000 species of Archaeplastida (Bowles et al., 2023).

The most defining and dominant characteristic of Archaeplastida - henceforth plants - is their ability to "eat light" - through the process of photosynthesis, which is the cornerstone of life's energy budget (Schlanger, 2025). Photosynthesis - the most important biological process on Earth - refers to the process whereby plants use chlorophyll to capture solar energy and convert it into glucose, a sugar molecule that provides energy for their own growth and reproduction.[14] This process not only sustains plants but also forms the base of the food web, including providing, in addition to the oxygen human brains need, the glucose required for human thought.

The process of "eating light" is what gives plants their green color. The sun emits most of its energy in the green part of the spectrum, but plants do not absorb all of this, reflecting

[12]Bowles et al. (2023)describe the six groups that comprise all Archaeplastida: rhodophytes, glaucophytes, prasinodermatophytes, chlorophytes, paraphyletic charophytes, and embryophytes (land plants).

[13]Eukaryotes are organisms whose cells have a nucleus and other membrane-bound organelles.

[14]See: `https://education.nationalgeographic.org/resource/photosynthesis/`

green light. If plants absorbed all of the sun's green light, they would have appeared black. It is a puzzle why plants do not absorb all of the most energetic light: (Arp and et al, 2020, p.1490) suggests that this is to "mitigate internal and external fluctuations in energy transfer, minimizing noise in output power."

Ultimately, almost all energy flowing through terrestrial ecosystems originates from sunlight captured by plants. Humans are no exception; whether they eat plants directly or consume animals that have eaten plants. Hence the reference at the top of this section to Schlanger (2025), who further describes the centrality of plants in the energy needs of humans and human civilization pointing out that "all the glucose in the world, whether it arrives in your body packages inside a banana or a slice of wheat bread, was manufactured out of thin air by a plant in the moment after photons from the sun fell upon it" (Schlanger, 2025, p.28). Indeed, without plants, and their oxygen and glucose, you would not be reading this paper and thoughts written on this page would not exist.

Through carbon sequestration, plants, particularly large forests and peatlands, act as vital carbon sinks, mitigating climate change by absorbing atmospheric carbon dioxide. It is estimated that the carbon stored in all forests is around $870 \pm 61 G_t$. Of this, tropical forests hold more than half. Every year, plants sequester around $4.8 G_t$ of carbon (Cantillon et al. 2025). Pan et al. (2024, p.563) estimate that "The global forest sink is equivalent to almost half of fossil-fuel emissions ($7.8 \pm 0.4 PgCy_{r-1}$) in 1990–2019."

Plants are thus the architects of the habitable Earth - not only by providing almost all the energy flowing through ecosystems and human brains, but also, as mentioned, by producing oxygen, a byproduct of photosynthesis. Between 2.45 and 2.2 billion years ago, the *Great Oxidation Event* occurred, which saw the amount of oxygen in the planet's atmosphere rise substantially as a result of the proliferation of cyanobacteria, photosynthetic microorganisms that utilized sunlight, water, and carbon dioxide to produce energy and release oxygen as a byproduct (Olson et al., 2018). This paved the way for the evolution of aerobic respiration

– the energy system used by animals, fungi, and many other organisms, including humans. Plants also play a crucial role in soil formation and maintenance, as well as in habitat provision. Vegetation is critical for soil stability and fertility and plant transpiration regulates atmospheric humidity and local rainfall patterns.

During the Cretaceous period, around 130 million years ago, *angiosperms* - flowering plants - emerged. Flowers co-evolved with pollinators, particularly insects, and this fueled an explosion of biodiversity - also described as the *Angiosperm Terrestrial Revolution*, the origin of modern biodiversity (Benton et al., 2022; Cappellari et al., 2013).

It is due to the ocean and the plants that fossil fuels, the boon and bane of human civilization, exist. Coal is the result of decomposed plant matter - mosses and ferns -that grew in forests that covered large parts of the Earth around 359-299 million years ago (the Carboniferous period), while oil and gas formed from the ancient remains of marine organisms, such as plankton and algae.[15]

And without the wood of more recent plants, humans would not be able to make optimal use of fossil fuels. As Fressoz (2024, p.96,55) "Wood was first and foremost essential to the emergence of the oil industry" and that "without abundant wood, Europe would simply have had no coal, and hence little or no steam, little or no steel, and few or no railways" given the use of wood among others to make oil barrels, derricks and for scaffolding in coal mines. For Fressoz (2024, p.102) the 20th century was the "age of wood."

Modern human civilization is deeply dependent upon plants. Agriculture, the outcome of the Neolithic Revolution, began approximately 11,700 years ago at the end of the last major ice age (Walker et al., 2009). This heralded the geological age labeled the Holocene, an interglacial geological era, characterized by a relatively stable climate. This stable climate allowed humans to develop agriculture, from which cities and, ultimately, complex, globe-

[15] See: `https://open.maricopa.edu/hazards/chapter/9-7-fossil-fuels`

spanning societies arose (Pringle, 1998; Gupta, 2004).

In the modern industrial economy, plants are essential not only for agriculture but also for the production of construction materials, fibers for textiles, rubber, paper, medicines, and fuel “Thanks to petrochemistry, wood provides the basis for some revolutionary construction materials” that include plasterboard, plywood, particleboards, and which facilitated the use of concrete, ”the most consumed man-made material in the world” (Fressoz, 2024, p.103).

Just as plants, by producing sugar and oxygen required by human brains, and help stabilize the climate make human life possible, so human life has an ultimate limit on the planet, when in the very far future plants stop photosynthesis. As explained by Graham et al. (2024, p.1):

> “*In the far future, as the Sun brightens, Earth’s surface will warm, and in response the carbonate-silicate cycle is expected to draw* CO_2 *out of the atmosphere through climate-dependent silicate weathering and carbonate burial. This will create an increasingly stressful environment for land plants, eventually driving them to extinction through* $CO2$ *starvation [...] This would also lead to the extinction of macroscopic life on land that relies on land plants.*”

The appearance and disappearance of plants bookend human life on the planet.

In the meantime, between these bookends, plants are at the center of the provision system for modern civilization, which has been called *Ecosystem Services*. For example, Bologna and Aquino (2020, p.8) list the services provided by trees to range from “carbon storage, oxygen production to soil conservation and water cycle regulation” and that “ it is highly unlikely to imagine the survival of many species, including ours, on Earth without them.”

Folke et al. (1996, p.10) list these ecosystem services as including “photosynthesis, provision of food and other renewable resources, soil generation and preservation, pollination of crops, recycling of nutrients, filtering of pollutants and waste assimilation, flood control, climate moderation, operation of the hydrological cycle, and maintenance of the gaseous composition of the atmosphere." Dirzo et al. (2022) discuss ecosystem services as consisting of provisioning services (such as food, fuels and medicines), of regulation services (including pollination and nutrient cycling), of support services (such as habitat, soil erosion control and litter decomposition), as well as cultural services (such as inspiration and education). Moreover, the structural complexity created by diverse plant communities is a key driver of overall biodiversity.

Ecosystems with a greater variety of plant forms-trees of different heights, shrubs, herbs, vines-offer a more extensive array of ecological niches (Turnbull et al., 2016). According to the biological insurance hypothesis, greater species diversity increases the likelihood that some species will possess traits necessary to continue performing essential functions, even if other species are negatively affected (Naeem and Li, 1997). Thus, the functional diversity of ecosystems is enhanced by a variety of species and ecosystems.

McCauley (2006, p.27) defines *Ecosystem Services* as the "economic benefits provided by natural ecosystems." Herein also lie the limits and dangers of the concept. As he elaborates, "the underlying assumption is that if scientists can identify ecosystem services, quantify their economic value, and ultimately bring conservation more in synchrony with market ideologies, then the decision-makers will recognize the folly of environmental destruction and work to safeguard nature" (McCauley, 2006, p.27).

The main problem is that making "ecosystem services the foundation of our conservation strategies is to imply - intentionally or otherwise - that nature is only worth conserving when it is, or can be made, profitable" (McCauley, 2006, p.27). For example, in the late 1990s, Costanza et al. (1997) valued these ecosystem services at US$33 trillion. Dasgupta (2021, p.47) criticized this calculation as "a case of misplaced quantification" because "if the biosphere were to be destroyed, life would cease to exist. Who would then be here to receive US$33 trillion of annual benefits if humanity were to exchange its very existence for them?"

Sadly, just as humans have built a global economy that harms the oceans, that same economy is also putting increasing pressure on the plant kingdom. The rare and unlikely Earth has been turned into a less habitable world through the economic system of a single species. The following section examines this by considering how human activity is causing significant biodiversity loss.

5 Bulldozing the Rare Earth

Without the ocean and the plant kingdom, our planet would not be habitable. Planetary habitability refers to a planet's capacity to support life. Biological diversity is an indicator of a planet's ability to support life. It refers to "the range of variation or differences in living organisms and their environments" (Barbier et al., 1994, p.4). The Convention on Biological Diversity (CBD) defines biodiversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (Dasgupta, 2021, p.502). It includes diversity of genes, species and ecosystems (Girardello et al., 2019).

Measuring biodiversity is complex, reflected in the fact that there is no single agreed-upon measure of biodiversity - in fact, as Cantillon et al. (2025, p.18) lament, "The challenge is not a lack of biodiversity metrics but their sheer variety and the absence of consensus on which to use." Despite this, according to the *Catalogue of Life* (COL), around 2,3 million species have been cataloged by taxonomists, with recognition that this catalog is far from complete (Bánki et al., 2025). According to Mora et al. (2011), there are approximately 8,7 million eukaryotic species on the planet (with an error margin of roughly 1,3 million). Bar-On et al. (2018), using biomass to measure the abundance of life on Earth, report that the biomass of life on the planet is ≈ 550 gigatons of carbon (GtC). Around 80% are plants, and 15% bacteria. Humans only constitute around 0,1% of all biomass on the planet.

The fact that only around a quarter of all likely species on the planet have been cataloged, reflects according to May (2011, p.1) "humanity's narcissism" since "we know the number of books in the US Library of Congress on 1 February 2011 was 22,194,656, but cannot tell you - to within an order-of-magnitude - how many distinct species of plants and animals we share our world with."

Similarly, even though Earth's surface is 70% ocean and the ocean contains 95% of the planet's livable space, humans' ignorance and neglect of the ocean is striking. As Heffernan (2025, p.3) relates, "*one of the earliest known maps of Europe -the Carta Marina, published in 1539 - shows waters dominated by oversized, mythical beasts, among them the ziphius, a fierce-looking fish that swashbuckles its way throughout the high seas.*" Five hundred years later, we may not believe in the ziphius, but our ignorance has not been reduced very much. Only about 27% of the ocean seafloor has been mapped;[16] the total area of the deep seafloor (below 200m) that has ever been visually imaged is less than 0.001% (Bell et al., 2025).

Roughly 90% of ocean species remain undiscovered and undescribed.[17] At the current rate of discovery, it would take "several hundred years to describe the remaining 1-2 million unknown marine species" (Bouchet et al., 2023, p.1). Given our ignorance, it is not surprising that only around 3 per cent of the ocean is under protection (Steinauer-Scudder, 2025).

Human civilization, whose economic system is premised on growth in extraction and consumption and relies on fossil fuels to drive this growth, is now steering the planet towards a mass extinction event. The extent of the loss of biodiversity already occurring is such that it has been described as "bulldozing biodiversity" (Spash, 2015). Section 5.1 catalogs the current extent of this bulldozing across land, and Section 5.2 catalogs the current extent of this bulldozing across the ocean.

[16]See: `https://tinyurl.com/2r733tzk`
[17]See: `https://oceanservice.noaa.gov/facts/ocean-species.html`

5.1 Biodiversity loss on land

According to Bradshaw et al. (2021, p.3) "The IUCN estimates that some 20% of all species are in danger of extinction over the next few decades, which greatly exceeds the background rate. That we are already on the path of a sixth major extinction is now scientifically undeniable." A mass extinction occurs "when extinction rates accelerate relative to origination rates such that over 75% of species disappear within a geologically short interval- typically less than 2 million years, in some cases much less" (Barnosky et al., 2011, p.52).

McCallum (2015) reports that between 1500 and the 1980s, the extinction of vertebrate species was proceeding 24 to 85 times faster than during the so-called *Cretaceous terminal extinction* around 65 million years ago. Moreover, since 1980, "The magnitude of extinction has exploded since 1980, with losses about 71–297 times larger" than during the Cretaceous extinction.

Klebl et al. (2025) report that extinction rates are now around 1,000 times higher than natural rates. Dasgupta (2021, p.1-4) notes that around 1,000 species are becoming extinct every year. Overall, approximately 1 million of an estimated 7 to 10 million species are threatened with extinction (Bradshaw et al., 2021; Mora et al., 2011). Moreover, since 1500, 84 mammal species have become extinct, with 32 species lost since 1900 (Dasgupta, 2021). In total, over 700 documented vertebrate species have gone extinct over the past 500 years (Bradshaw et al., 2021).

According to Shaw et al. (2025), analyzing 628 species of animals, plants, and fungi across terrestrial and marine ecosystems over more than three decades (1985-2019), there has been a worldwide decline in genetic diversity, particularly among mammals and birds.

Not only are species being lost at high rates, but biomass as well (Bar-On et al., 2018). According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem

Services (IPBES), there has been an 83% reduction in wild mammal biomass and a $\approx$ 50% reduction in plant biomass relative to pre-human times (IPBES-IPCC, 2021). In some regions, such as Germany, a 76% decline in insect biomass has been reported in protected areas over the past thirty years alone (Hallmann et al., 2025). (Fallah, 2024) discusses the World Wildlife Fund's (WWF) Living Planet Report 2024, which reports a "73% decline in the average size of monitored wildlife populations in just 50 years."

Given that around 40% of plants are considered endangered (Bradshaw et al., 2021), the biomass loss is most starkly apparent in deforestation. Deforestation has reduced global forest cover from 60 million square kilometers to less than 40 million square kilometers (Bologna and Aquino, 2020). Between 2000 and 2012 alone, 2,3 million km^2 of forests worldwide were cut down at a rate at which all forests on Earth would be gone in 100 to 200 years (Bologna and Aquino, 2020). Montane deforestation is accelerating globally at an annual rate of 0.31%, but much faster in Africa, with rates in unprotected areas ten times faster, reaching 3% per year (Abera et al., 2024).

Predictions regarding further deforestation are given weight by evidence that in 2024 alone, a record 6,7 million hectares of tropical rainforests, containing over 50% of Earth's plants and animals, were lost - an area nearly the size of Panama (Goldman et al., 2025). Global tree cover loss has increased from 22,8 megahectares (Mha) per year in 2022 to 28, 3 Mha per year in 2023 (Ripple et al., 2024).

Two-thirds of the benefits from forests as a carbon sink have already been negated by tropical deforestation (Pan et al., 2024, p.563) . Climate models predict a decline in terrestrial plants' ability to absorb carbon as human carbon emissions rise. Moreover, despite this, in 2023, scientists were unpleasantly surprised by an "unexpected collapse of natural carbon sinks, exemplified by very high CO_2 growth rate. In this year, the terrestrial biosphere took up almost no net carbon (Sinking Carbon Sinks, 2025).

Finally, as Luckeneder et al. (2021) explain, the recent quest for green economic growth based on renewable energy sources is leading to significant increases in the consumption of critical metals and minerals[18] needed in their production, such as lithium and cobalt. The mining of these metals are having hugely negative environmental impact, "partly because the vast majority of metal and minerals mining takes place in species-rich biomes, or 20 km or less from protected territories, with around 90% of mining sites in areas with significant water scarcity (Luckeneder et al., 2021, p.12). The negative impact on biodiversity is investigated by Sonter et al. (2018, p.2) who details how mining affects biodiversity "at multiple spatial scales (site, landscape, regional and global) through direct (i.e. mineral extraction) and indirect processes (via industries supporting mining operations, and external stakeholders who gain access to biodiversity-rich areas as the result of mining)." A warning has been sounded that mining for green minerals have "an enormous spatial footprint not specifically factored into global biodiversity threat maps or conservation plans" (Sonter et al., 2020, p.2).

5.2 Biodiversity loss in the ocean

The Earth is an ocean world, as was explained in section 3. Hence, the health of the ocean system ought to concern humans. Unfortunately, the current world is built around the maximum extraction of profit from the oceans, with the nature, extent, and role of the oceans not appreciated. Farrier (2017) pictures how the North Sea, as an example, are being over-commercialized:

> "*Container ships up to 400m long pass in and out of the port cities of Rotterdam, Antwerp and Hamburg, a moving tapestry of routes that weaves and unweaves itself over the surface of the globe. Nearly 200 oil platforms and many more gas*

[18] These include aluminum, graphite, nickel, copper, zinc, lead, manganese, cobalt, and lithium(Mervine et al., 2025). Malmaeus et al. (2025, p.1) argue that "basing a green transition on such a large overuse of critical metals is not sustainable."

production plants perch in the water like giant wading seabirds. The coastline is dotted with petroleum refineries, power stations and industrial chemical plants, and forests of wind turbines have sprouted in its southern reaches. Plastic lines its shores, as well as the gullets of its fish and birdlife."

As a result, total marine populations have declined by 56% since 1970, meaning "more than half of marine life gone in 50 years" (Berman, 2025). This is mainly due to the over-exploitation of fish stocks for commercial purposes: a third of the world's estimated 2,570 marine fish stocks are already over-exploited (Robinet, 2025b). Syvitski et al. (2020, p.7) report that in 1950, "only 1% of the high seas were fished, with 0% of fishery species considered exploited, overexploited or collapsed. However, by 2006, 63% of the high seas were fished and 87% of fish species were considered exploited, overexploited, or had collapsed."

Not surprisingly, marine biomass has decreased by more than 500% since the start of whaling and industrial fishing (Bar-On et al., 2018). The industrial fishing industry is not for nothing described as "*the most destructive of all private industries*" (Monbiot, 2025). To make matters even worse from a regulatory perspective, Paolo et al. (2024, p.85) conclude, using satellite imagery and vessel GPS data, that "72–76% of the world's industrial fishing vessels are not publicly tracked." Moreover, seafloor trawling for fishing not only threatens biodiversity but also adds significant amounts of carbon to the atmosphere. Trawling the sea floor "disturbs carbon that took millennia to accumulate", according to Atwood et al. (2024), who found that up to 60% of trawling-released CO_2 ends up in the atmosphere in 7 to 9 years.

And it should be kept in mind that the incessant and growing shipping across the ocean highways is causing harmful noise pollution. "Propellers, hull vibrations, and engines generate low-frequency sounds that travel vast distances underwater. Unlike oil spills or visible trash, noise pollution leaves no trace – but its impact is no less acute" (Robinet, 2025a).

Halpern et al. (2019) investigates cumulative human impacts (CHI) on the ocean over the period 2003 to 2013, finding that CHI increased by 59% globally. The areas with the highest absolute impacts were the Black Sea, the Eastern Mediterranean Sea, the Canadian Eastern Seaboard, the southern Atlantic Ocean, and Southern/Western Australia. The state that "these regions are at high risk of ecosystem collapse; indeed, some already have (e.g., the Black Sea)" (Halpern et al., 2019, p.2). As far as climate change impacts on ocean habitability are concerned, it is profoundly altering marine chemistry and environments. The above impacts - from climate change to over-exploitation - are resulting in *ocean warming and de-oxygenation, sea-level rise, ocean acidification*, and the *destruction of coral reefs and plankton*. These damaging impacts will be briefly described.

Global warming leads to warmer oceans. In fact, a recent headline revealed that "*The Ocean Surface Is Warming Over 400% Faster Than in The 1980s*" (Koumoundouros, 2025). The global mean sea surface temperature (GMSST) is accelerating, driven by an upward trend in Earth's energy imbalance - increasing by $0.54 \pm 0.07K$ for each GJm^{-2} of accumulated energy (Merchant et al., 2025).

Global warming leads to a loss in marine oxygen levels - warm water retains less oxygen (Dasgupta, 2021, p.108). It is estimated that the ocean will lose more than 10% of its oxygen, even if global warming is halted immediately (Oschlies, 2021). This is already causing many marine species to migrate towards the poles, in what has been described as "the largest known migration of life in Earth's history" (Berman, 2025). Berman (2025) warns that this is "*not redistribution of marine life but a cascading collapse. As species flee lower latitudes, the ecosystems they leave behind deteriorate. Northern waters may not offer enough nutrients and habitats for legacy species and newcomers to survive.*"

Another impact of global warming will be to cause sea-level rise (SLR). According to estimates by Van de Wal et al. (2022) , with global warming of $+2°C$, SLR will be up to 0.9 m in 2100, and 2.5 m in 2300. Global mean sea level (GMSL) increased by around 20 cm between 1901 and 2018, with the rate of change accelerating from $\approx 1.4mm$ year between 1901 and 1990 to $\approx 3.7mm$ a year between 2006 and 2018, and to 4.5mm per year in 2023 (Stokes et al., 2015). By 2024 average the global sea level was at a "record high" (Ripple et al., 2024, p.816).

Sea-level rise is caused by the melting of Greenland and Antarctic ice, which adds fresh water to the North Atlantic. The added danger this poses is the reduction of the AMOC. The danger is that "this isn't merely a local or temporary issue. AMOC regulates the planet much like an HVAC system regulates your home. If it breaks, conditions become unlivable: colder European winters, altered monsoons, and accelerated sea-level rise are among the major anticipated outcomes" (Berman, 2025).

Global warming also leads to ocean acidification (OA). OA refers to the long-term change in marine carbonate chemistry resulting from the ocean's absorption of CO_2, which increases ocean acidity (Findlay et al., 2025). Czerski (2023, p.367) explains how this will inhibit the formation of calcium carbonate, "ocean life's most useful solid construction material [...] the stuff that the shells of oysters, snails and limpets are made of, as well as the solid architecture of coral reefs." The danger to coral reefs is significant.

According to the IPBES-IPCC (2021), half of coral reef areas have already been lost. Recent studies warn that more than 70 percent of the Atlantic Ocean's coral reefs will "begin dying by 2040 even under optimistic climate warming scenarios" and that "if the planet exceeds 2 degrees Celsius of warming above preindustrial temperatures by the end of the century, 99 percent of corals in the region would meet this fate" (Mulkey, 2025; Perry et al., 2025). Extreme concern about the loss of coral reefs is justified because coral reefs are the "rainforests of the sea" containing much biodiversity and providing support to approximately a third of all ocean species (Readfearn, 2025).

In addition to higher ocean temperatures destroying coral reefs, it will, if it continues at current rates, make the ocean largely uninhabitable for *Prochlorococcus*, the most abundant photosynthesizing organism in the ocean, which contributes 5% of global photosynthesis (Ribalet et al., 2025).

In addition to ocean warming and deoxygenation, ocean acidification, coral reef destruction and plankton loss, the ocean is also facing unprecedented damage from human-generated pollution and sheer physical destruction. Around 80% of pollution of the ocean starts due to human activity on land - for instance, from "untreated municipal wastewater, industrial water, landfill sites, illegally dumped waste, agricultural run-off including herbicides and pesticides, deforestation, habitat destruction" (Dryden and Duncan, 2022, p.3422). Massive amounts of polychlorinated biphenyls (PCBs) have been dispersed throughout almost every part of the ocean (Jamieson et al., 2017) - even in the bodies of amphipods 10 kilometers deep (Bradley, 2025).

A particular challenge is plastic pollution. According to The Lancet[19] "*the world is in a plastics crisis.*" Landrigan et al. (2025) describe how the planet is already burdened with 8000 Mt of plastic waste. Plastics, of which 98% is made from fossil carbon, have grown significantly in terms of production, from 2 Mt in 1950 to 475 Mt in 2022, and are expected to increase to 1200 Mt by 2060 (Landrigan et al., 2025). Containing more than 16,000 chemicals, plastic pollution on land already causes health-related economic losses exceeding US$ 15 trillion annually (Landrigan et al., 2025).

Plastic breaks down into micro- and nanoplastics, which absorb toxins and accumulate in animal bodies, persisting for hundreds or thousands of years (Bradley, 2025). The ocean is covered by a surface microlayer (SML) which consists of a complex mixture of proteins, carbohydrates and lipids (Dryden and Duncan, 2022). It is where much of the microplastic in the ocean ends up, which decreases lipid concentrations in the SML, in turn leading to more water vapour, a greenhouse gas, and negatively impacting plankton biodiversity (Dryden

[19] See: `https://tinyurl.com/3tu4k8tf`

and Duncan, 2022).

As if ocean warming and deoxygenation, sea-level rise, ocean acidification, coral reef and plankton destruction, and pollution are not enough damage, humans have recently discovered that the sea floor can be mined - primarily to obtain critical minerals needed to fuel humans' insatiable energy appetite. The problem is, as Bradley (2025) put it, that we have minimal "understanding of the ecology of the deep ocean" and that "the noise and sediment thrown up by deep-sea mining can spread across large areas, and that "regions disturbed in 1989 hadn't recovered when researchers returned nearly three decades later." The potential to destroy species that have not even been discovered yet is significant. Unfortunately, the International Seabed Authority (ISA), created under UNCLOS to manage the seabed as "common heritage of humankind," has prioritized commercial mining regulations and relies on data provided by the commercial miners themselves (Reid, 2025).

The combination of pollution and climate change is also leading to the darkening of the ocean, meaning that the extent to which light can penetrate the water is decreasing over time. This has adverse impacts on ocean biological diversity, as many species depend on light (Davies and Smyth, 2025).

One has to agree with Berman (2025)'s assessment that "The ocean covers nearly three-quarters of Earth. It should be front and center in every conversation about climate, biodiversity, and survival. It has been saving us for a long time. But it can't do it forever." Indeed, Dasgupta (2021, p.108)provides an even starker warning, asking, "*What would happen to the biosphere if life in the oceans were to be extinguished?*" His answer is clear, that "*the changes would be so enormous that life on land itself ceases for the vast majority of organismal lineages. Perhaps not total annihilation over time, but a mass extinction that has not occurred since life began.*"

In light of this section and the previous, it is clear why Gowdy (1997, p.2) insists that, "for many biologists, the total value of biodiversity is essentially infinite; it is essential to the sustainability of life on Earth." Dirzo et al. (2022, p.4) concur, stating that despite efforts by economists to put a value on biodiversity and ecosystem services, "the fundamental value of ecosystems is essentially incalculable." And Murphy et al. (2021, p.3) provide a thought experiment of the terraforming of Mars to indicate the extent to which current economics far underestimates the economic value of ecosystem services when relating that:

> "*Images of a barren Mars from Perseverance remind us of what it would cost, monetarily, for humans to build such a system from scratch (i.e., starting with a sterile planet)— assuming we had the intellectual standing and wherewithal to do so. The figure might well run into the quadrillions or quintillions of dollars, if not unimaginably more. Just how much value did humanity inherit in Earth's abundant provision? Presumably, the amount absolutely dwarfs today's trillion-dollar economic scales. Yet society continues to place essentially zero economic value on this foundation despite the fact that it took billions of years to produce.*"

Essentially, as this thought experiment implies, the problem is not assigning a quantifiable value to biodiversity and ecosystem services - indeed, economists should be relying on scientific metrics to convey the existential risks posed by biodiversity and ecosystem service losses - but rather in vastly underestimating them.

6 From Sustainability to Planetary Habitability

> "*Like the foolish person who jumps from the top of the Empire State Building without a parachute, we exclaim, 'So far so good!' as we pass the twelfth floor on the way down* (Barbier et al., 1994, p.4)

Section 5 of this paper sounded a warning that the very basis of life on the planet, the oceans and the plant kingdom, are under immense pressure. In section 6.1 below, it is explained why this is essentially the result of the ever-growing impacts of human civilization. The question is, what can realistically be done? This paper, alas, does not pretend to have a satisfactory answer to this question. There are at least three reasons why a satisfactory answer cannot be given in this paper - or perhaps ever.

First, as Ligotti (2018, p.112) described the conundrum, "Because of evolution we got made. We did not bring ourselves out of the primeval ooze. And everything we have done as a species has been a consequence of being made. No matter what we do, it will be what we were made to do." Human sapiens have evolved, in line with the maximum power principle, with a propensity to maximize energy use in ways that lead to planetary dominance and ecological destruction, rather than self-limitation (Odum and Odum, 1976) - see more in section 6.1. Second, as Rees (2023, p.15) warns, "the human brain and associated cognitive processes are functionally obsolete to deal with the human eco-crisis. H. sapiens tends to respond to problems in simplistic, reductionist, mechanical ways. Simplistic diagnoses lead to simplistic remedies."

And third, the ecological crisis, as summarized in section 5 of this paper, is a collective action problem - moreover as Scott Barret states[20] "the most vexing collective action problem in human history." As an example how this collective action problem frustrates any effort to address ecological overshoot and specifically climate action, Blake and Gilman (2024) spells out that:

> "*The UNFCCC, which remains the primary global body tasked with curbing climate change, doesn't respond to the atmosphere, nor to the planet it envelops. Like the WHO, it responds instead, and only, to its member states. The member states, meanwhile, respond to their human citizens (at least, ideally). No part*

[20]See https://www.scottbarrett.org/climate-change/

> *of this chain of authority is concerned with the planet's climate as a whole. In this, the UNFCCC is no different than any of the other institutions of global governance. The international system is built upon the foundation of the sovereign nation-state. The UN and its many parts and agencies – from UNICEF to the Universal Postal Union – answer not to humanity nor the world, but the nations that united to join it.*"

Thus, while a satisfactory answer to the question of how to deal with the bulldozing of biodiversity on land and sea cannot be given in this paper, sections 6.2 and 6.3 will argue that a necessary (although not sufficient) answer will somehow include that the field of economics move beyond sustainability as a framing concept towards planetary habitability. This structural critique, supported by the cosmic context of the Rare Earth and the biological primacy of the Ocean and Plant Worlds, is the novel contribution of this paper.

6.1 Roots of Unsustainability

Human society was not always bulldozing the Rare Earth to the extreme extent cataloged in section 5 of this paper - although, even in deep history, our ancestors seem to have driven some species - such as the megafauna - to extinction. Andermann et al. (2020) discuss how human hunting and land use have caused various mammalian species' extinctions even 126,000 years until before the modern industrial age, noting that "Human population density as a single predictor explains the mammalian extinction patterns with 96.0% accuracy." Apart from this, as Rees (2020, p.4) points out, "for 99.9% of human history our species functioned within thermodynamically 'healthy' limits. " The discovery and use of fossil fuels as a source of energy changed all of this. As described by Kasting (2010, pp.567-569):

> "*Starting about 150 years ago, we discovered the great energy potential locked in fossil fuels. Access to external energy augments our average power by twenty*

to a hundred times compared to animal metabolism [...] This energy gives us the capabilities of superheroes. We can fly higher and faster than a bird, easily access building rooftops, punch through walls, excavate mountains, stop speeding bullets, send fire and destruction long distances, and communicate instantaneously with others all over the world [..] [fossil fuels] has permitted a ferocious growth in population, particularly since the dawn of the industrial age, when our energy use so greatly expanded. Extinction of 97% of human beings living on Earth today would reduce us only to the number of people on Earth at the dawn of the scientific revolution some 500 years ago."

Fossil fuel energy has endowed humans with "superpowers" (Jancovici and Blain, 2024), which have propelled real gross world production to increase by a factor of 100 since 1800 (Rees, 2023). Considering production of goods using materials sourced from the Earth, by 2020 "human-made mass has reached about 1.1 teratonnes, exceeding overall global biomass" (Elhacham et al., 2020).

Moreover, as far as population growth is concerned, fossil fuel energy is essential for food production - around 40% of the protein in human diets depends on synthetic nitrogen fertilizers produced using fossil fuels - and has thus also facilitated the exponential increase in the human population in recent centuries (Raudsepp-Hearne et al., 2010). By 2025, the human population exceeded 8,2 billion people, up from 1 billion as recently as 1810 (Rees, 2023). Around half of the world's population is alive due to synthetic nitrogen, as "by 2000, nitrogen fertilizers were responsible for feeding 44% of the world's population" (Erisman et al., 2008, p.636). According to Fowler and Hobbs (2003, p.2579), the human species are not "ecological normal' since "all but nine out of the 31 tests showed humans to be outside the 99% confidence limits for variation among the other species."

Using energy to boost the human population and producing more and more goods and services with abundant and cheap fossil fuel energy not only causes ecological overshoot, but as a symptom of such ecological overshoot, climate change, due to the effects of fossil fuel use, causes emissions of CO_2, a greenhouse gas (Bradshaw et al., 2021). Each year, humans generate around 41,6 gigatonnes of CO_2 emissions and 120 million tonnes of methane (Visioni and Gruener, 2025). Total annual solar radiation from the sun, known as Total Solar Irradiance (TSI) is 1360.8 Wm^2 - which means a global average of $340.2 \pm 0.12 Wm^2$ (Kren et al., 2017). CO_2 acts as a "blanket," reducing the amount of solar energy radiated back into space. As the imbalance persists, energy accumulates on the planet (especially in the ocean), leading to warming (Kren et al., 2017). The Earth's current energy imbalance is estimated at $+1W/m^2$ (Hansen et al., 2025).

Hence, it is no surprise that by 2025, global warming was already $1,3°C$ above pre-industrial levels (Borowiak et al., 2025). What is a surprise however is that the energy imbalance is rising much faster than scientists had expected - by 2023, it was already twice as high as the IPCC expected (Mauritsen et al., 2025). According to Hansen et al. (2025, p.1) "Global warming has accelerated since 2010 by more than 50% over the 1970-2010 warming rate of $0.18°C$ per decade [...] Earth is now warmer than at any time in the Holocene, the past 11,700 years of relatively stable climate in which civilization developed, and it is at least as warm as during the extreme warm Eemian interglacial period 120,000 years ago."

It would be a mistake to consider an average global warming of $1,3°C$ as not much. The problem is that it brings the world closer to a *tipping point*, after which global warming becomes self-reinforcing (Lenton et al., 2008, 2019). Once the tipping point has been reached, even if humans stopped emitting carbon, the planet will continue to warm. Estimates by Snyder (2016, p.226) suggest that "stabilization at today's greenhouse gas levels may already commit Earth to an eventual total warming of 5 degrees Celsius. " Even if the tipping point is avoided, say by keeping global warming below $2°C$ warming by achieving net zero carbon emissions, even fifty years after the planet will still be warmer, with achieving net zero likely only reducing global warming by $0.19°C$ after fifty years (Borowiak et al., 2025).

The continued use of fossil fuels and the resulting increase in CO_2 emissions are therefore at the source of the unsustainability of the global economy. If it continues and all fossil fuels are exploited, it will release at least 5 trillion tons more carbon, resulting in atmospheric CO_2 levels skyrocketing from their current 425 ppm to around 2,000 ppm (Tokarska et al., 2016). This could cause an increase in average global temperature of between $4°C$ and $10°C$ with carbon levels comparable to those that triggered the Permian-Triassic extinction event 252 million years ago. This does not even consider the damage caused by plastic pollution, which is produced by 98% of which comes from fossil fuels.

As Naudé (2023, p.21) discusses, despite this clearly existential danger, "existential risk is not a narrative or term that has been widely adopted or further developed by the climate change research community. Neither the concept of existential risks nor the term 'existential' was used in the IPCC 5th Assessment Report (AR5), nor in the IPCC Special Reports of the 6th Assessment Cycle" (Huggel et al., 2022, p.4). And climate catastrophe remains "relatively under-studied and poorly understood" (Kemp et al., 2022, p.1).

A further mistake would be to diagnose the problem solely as the use of fossil fuels and assume that it can be solved by transitioning to renewable, cleaner forms of energy that will not lead to further CO_2 emissions. This would be a mistake, since global warming is but a part of the overall problem: the bulldozing of biodiversity. While switching to renewable energy in time will avert the impacts of global warming on the plant kingdom and the ocean, the continued use and growth of energy will not necessarily be accompanied by reduced impacts. "*If every jackass on the planet has access to cheap and abundant energy, what do you think they'll do with it?*" (Murphy, 2022).

There is, however, also a paradox in the use of energy, which can cause ecological overshoot, in that highly advanced scientific and technological achievements (e.g., NASA exoplanet catalogs, climate models, deep ocean imaging, molecular biology of abiogenesis) have also allowed humans to build a coherent argument about planetary habitability and possible collapse. These diagnostic tools - and this very paper that is a result of it - are themselves products of the complex, energy-intensive civilization that has caused ecological overshoot.

6.2 Beyond Sustainability

Given the human predicament of having fossil-fuel-based superpowers that allow humans to overshoot the planet's carrying capacity and wreak havoc on the plant kingdom and the ocean, the world's response has been to frame everything in terms of "sustainability." A sustainable economy would be one that, in the dominant viewpoint, is a "net zero" carbon emitter. In the discipline and practice of economics, and related fields such as entrepreneurship, business and management, the approach to sustainability is therefore largely based on climate action, which means that sustainability in these areas boils down to a quest to continue economic growth and business as much as usual, without causing climate change and pollution.

This in turn necessitates a focus on decarbonisation, which in turn requires a shift to non-carbon forms of energy sources such as renewables and nuclear. To reduce pollution, the economy and business models should, according to this approach, be as circular as possible - i.e. recycle as much materials as possible. Within this approach to sustainability, setting a high and universal carbon price is seen as the *Holy Grail* - to encourage efficient resource use and incentivize innovation. To complement the stick that is carbon prices, governments are also called on to intervene by providing carrots in the form of subsidies for decarbonisation. Thus, the essence of the current mainstream approach to tackle climate change is decarbonisation, recycling, price incentives and clean energy subsidies.

However, in light of the bulldozing of the ocean and forests as cataloged, Spratt and Dunlop

(2021, p.4) warn that the essence of the mainstream approach means "giving up on protecting major Earth systems and ecologies" and that striving only for decarbonisation (net zero) "will not save the world's coral reefs."

Moreover, the notion of sustainability, as it has been pursued since the 1980s, has been to maintain economic growth despite the increased pressure of human consumption and production on the oceans and forests. In fact, the notion of "sustainable development" was coined in 1983 by the Brundtland Commission, in response to the Limits to Growth Report (Meadows et al., 1972), as a program to fast-track economic growth.

As Spash (2020) reminds us, the definition of sustainable development offered by the Brundtland Commission was that sustainable development is development that "seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future. Far from requiring the cessation of economic growth it recognizes that the problems of poverty and underdevelopment cannot be solved unless we have *a new era of growth* in which developing countries play a large role and reap large benefits."

Thus, the notion of sustainability has lost meaning and serves today primarily to ensure a "*new era of growth*." Spash (2020, p.1124) describes how "financiers, bankers and super-rich entrepreneurs are rebranded as planetary saviours in our time of crisis" and how:

> "*the role of Nature has become exclusively that of value provision in the global economy. The aim has been to convert environmental problems into a narrow, mainstream economic and financial discourse that supports market governance. Ideally Nature can be bought and sold to boost corporate profits. If nothing else, Nature protection cannot be allowed to stand in the way of business interests and economic growth* (Spash, 2015, p.550).

Moreover, economists have had remarkably little to say about biodiversity, and often when it does, it frames biodiversity as a substitutable resource - or even worse. For example, Clark (1973, p.950) basing his analysis on a typical neoclassical economic model concludes that "depending on certain easily stated biological and economic conditions, extermination of the entire population may appear as the most attractive policy."

Adrienne Buller, in her book "*The Value of a Whale*" discusses as a typical example of the mainstream economics approach to sustainability the International Monetary Fund's (IMFs) calculation that the value of a great whale is *US$2 million*, rightly pointing out that "many might recoil at the idea of attaching a dollar value to a sentient life form" (Buller, 2022, p.3). Similarly, a World Bank study estimated that ecosystem collapse would reduce global GDP by a relatively small 2,3% annually by 2030 (see Johnson et al. (2021)). And according to Kapnick (2022) biodiversity loss could cause economic damages between US$ 4 trillion and US$20 trillion annually - between 4% and 23% of global GDP.

Of course, one could argue that it is ridiculous to think that the vast bulk of GDP would be left unscathed in the event of ecosystem collapse and the biodiversity loss that leads to a mass extinction event. That the IMF, World Bank and other economists can come to the conclusions and valuations of biodiversity as mentioned, reflects the dominance in modern economics of the early 19th century economics view, attributed to French economist Say, that nature and natural resources are unlimited, and thus essentially disconnected from the economy (Jancovici and Blain, 2024).

In this regard Buller (2022) makes the point that what is at the deepest level wrong with the economics of sustainability is that "*rather than appraise our economy from the perspective of supporting life - recognizing the ways in which our economic institutions and systems currently drive social and ecological crisis - instead we appraise life, and any action taken to protect it, in economic terms*" (Buller, 2022, p.10).

It is no wonder then that "stopping biodiversity loss is nowhere close to the top of any country's priorities, trailing far behind other concerns such as employment, healthcare, economic growth, or currency stability" (Bradshaw et al., 2021, p.4). Giglio et al. (2023) state that biodiversity risk is even by economists' standards and approaches, poorly priced.

Economics as social science has also embedded into policy making and politics the belief that ever increasing consumption and production is desirable. This is, as Boulding (1966, p.9) pointed out, a rather strange idea because the less consumption we need to maintain a given state, the better off we are. "If we had clothes that did not wear out, houses that did not depreciate, and even if we could maintain our bodily condition without eating, we would clearly be much better off."

In any case, the failure of the concept of sustainability to prevent the bulldozing of biodiversity on the Rare Earth is apparent from the failures of 30 UN COP meetings, the ongoing destruction of nature, and the rise in global warming. Indeed, as far as the most visible and most debated sustainability goal, the one of limiting climate change, is concerned, "Wall Street has determined the temperature goal is effectively dead" (Hiar, 2025).

6.3 Towards Planetary Habitability

A more useful concept than sustainability is that of planetary habitability. Planetary habitability refers to a planet's capacity to support life. As discussed in section 5, biological diversity is an indicator of a planet's ability to support life. Therefore, it is a broader concept than the hackneyed notion of sustainability, with sustainability understood as a subset of habitability.

Planetary habitability, as a perspective for understanding humanity's role in an ocean- and plant-based world, is concerned with sustaining complex, multicellular life in general and identifying the conditions required for that life to be sustainable, rather than prioritizing humans alone. It improves on the sustainability concept in that "While the concept of sustainability treats nature both as distinct from humans and as existing for humans' responsibly managed instrumental use, the concept of habitability understands humans as embedded in and reliant on the more-than-human natural world" (Blake and Gilman, 2024).

Verne et al. (2025, p.2) call for a planetary turn in science, a turn away "from the global - as a political, capitalist, technocratic system that grasps the planet as a surface fundamentally determined by humans - toward the planetary, a shift intended to resist the totalizing, anthropocentric concept of globalization." They make the case that such a planetary focus will call into question "the usual separation between humans and the environment." Moreover, referring to the work of Chakrabarty (2021), Verne et al. (2025, p.9) describe the difference between sustainability and planetary habitability as framing the human predicament:

> "*The idea of sustainability puts human concerns first. The key term in planetary thinking that one could contrapose to the idea of sustainability in global thought is habitability. Habitability does not reference humans. Its central concern is life—complex, multicellular life, in general—and what makes that, not humans alone, sustainable. What, ask ESS [Earth System Science] specialists, makes a planet friendly to complex life for hundreds of millions of years)? [...] Humans are not central to the problem of habitability, but habitability is central to human existence. Habitability cannot be deduced from climate models and put the socio-economic forces that are actively making this planet uninhabitable front and center.*"

A planetary habitability perspective thus requires humans to eventually move beyond the very narrow, human-centric perspective of sustainability. As physicist Tom Murphy[21] has written , "The problem is thinking we're the pinnacle of evolution: that we're better than the

[21] See: `https://dothemath.ucsd.edu/2024/08/mm-12-human-supremacy/`

rest; somehow transcendent so that we are not mere animals. Ironically, it is in distancing ourselves from animals that we become monsters." It may be difficult, but not impossible: Webb (2025) argues that our human-centric beliefs "reflects a cultural worldview, one largely shaped and codified by dominant Western traditions [...] we need a new relationship with the living world, and a different story about who we are within it." In such a story, the ocean and the forests- the plant kingdom - will feature centrally.

The human-centered perspective on sustainability could be replaced by a biocentric holism, consistent with the notion of planetary habitability. Klebl et al. (2025, pp.2-3) explain the differences between anthropocentrism, biocentric individualism, and biocentric holism. The anthropocentric view, as illustrated in this paper, holds that biodiversity is at most an ecosystem service. Biocentric individualism is the view that "humans and animals have an inherent value independent from their utility to humans, with some theories also including other living beings." And biocentric holism argues that "the entities deserving of moral concern are not just individual species or cultural elements but the 'wholes' – that is, ecosystems or cultural landscapes." In this view, there is a moral value in biodiversity itself - in the deeply interrelated nature of all life on the planet, from the oceans to the forests - which, after all, shares a single common ancestor in the depths of time.

This latter view is also in line with emerging Earth Systems Science (ESS) (and Complexity Science), which is "grounded in a new scientific understanding of life and planets as a complex whole - a system of systems" which means that " any new theory of political economy that doesn't have the word 'planetary' in its intent has already lost the thread" (Frank, 2024).

7 Concluding Remarks

> "*The Earth will be fine in the long run. The prospects are, however, less clear for Homo Sapiens*" - (Frank and Sullivan, 2014, p.40).

This paper presented an ode to the oceans and forests - and all plants - as it celebrates the foundational, existential, and fragile nature of the planet's natural systems, and lamented the catastrophe brought upon them by humanity, calling for profound moral and economic shifts to save them from human self-destruction. In this respect, the field of economics should start with the remarkable fact that planet Earth is a *rare* Earth that is a habitable and inhabited planet, where the emergence of complex life was only barely possible, and that is fundamentally an *Ocean World* and a *Plant World*.

Despite the majesty and importance of the ocean and the plant kingdom, humans are still remarkably ignorant about their importance. Traditionally, the field of economics assumed that the ocean and plants are only valuable if they can provide a monetary product or service, moreover that the services and products provided by the ocean and plants are infinite, that they can easily be substituted for by capital formation and technology, and there to serve the consumption and production needs of humans, of which it is assumed that the more is the better. As such, a global economy has emerged that is now bulldozing biodiversity in the ocean and on land. This paper cataloged, however not exhaustively, this destruction.

The catastrophic losses in biodiversity at sea and on land, as documented in this paper, demonstrate that the current political and economic response, framed by the narrow, human-centric concept of sustainable development, has failed to protect major Earth systems. Therefore, this paper calls for a fundamental planetary turn in perspective, moving beyond sustainability towards the biocentric concept of Planetary Habitability.

Planetary habitability, as a perspective for understanding humanity's role in an ocean- and plant-based world, is concerned with sustaining complex, multicellular life in general and identifying the conditions required for that life to be sustainable, rather than prioritizing humans.

This conclusion, that a shift from sustainability to planetary habitability is needed, is akin to realizing that fixing a slow leak in a spaceship (sustainability) is insufficient when the ship's entire life support system is collapsing due to a fundamental design flaw (anthropocentrism); instead, the focus must immediately shift to ensuring the entire ship can support life (habitability), regardless of immediate human convenience.

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