Climate regulating ocean plants and animals are being destroyed by toxic chemicals and plastics, accelerating our path towards ocean pH 7.95 in 25 years which will devastate humanity.

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GOES
GLOBAL OCEANIC ENVIRONMENTAL SURVEY

The Global Oceanic Environmental Survey Team (GOES) aims to create an informed movement to help make governments, industry, and communities aware of an insidious, unseen crisis affecting the keystone of climate regulation – the destruction of the tiny ocean plants and animals which form the basis of the planet's largest ecosystem. Those planktonic plants and animals which are less than 1 mm in length make up 60% of all marine life. We've lost 50% of marine life in 70 years and the loss continues at a rate of 1% year on year. This means that carbon dioxide that is dissolved into the oceans is not being utilised for photosynthesis. This dissolved carbon dioxide forms carbonic acid, and as the level increases, we see pH decline. The GOES team have direct industry experience to demonstrate that at pH 7.95 the ocean ecosystem tips over. We are already seeing the start of a trophic cascade collapse. In reviewing peer-reviewed data, it becomes clear that this tipping point is forecast to occur in approximately 25 years – at which time pH is projected to be 7.95. A basic understanding of biology and chemistry leads to a conclusion that ocean toxic chemicals (including ones we use in our homes), combined with plastic pollution over the last 70 years, is the reason for this destruction. We know the chemicals that inhibit or destroy marine life, and this means it is possible for us to act, innovate, change policy and behaviours. Without action, ongoing destruction of planktonic life will continue to impact negatively on climate change, as the oceans sequester less carbon in the abyss. The GOES team present here data from peer-reviewed reports, coupled with the team's direct industry experience of working in the world's most extensive closed marine systems and of witnessing irreversible drops in pH which have triggered ecosystem collapse. Ocean acidification is often referred to as the Evil Twin of climate change, evil because the consequences will be far more serious. We have 10 years to stop oceanic pollution, because in 25 years it will be too late.

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Abstract

Marine plants and animals should be thriving in ocean waters because of the current high concentrations of carbon dioxide and nutrients along with slightly elevated temperatures - but they are not. We have lost 50% of all marine life over the last 70 years; this decline is continuing today at a rate of 1% year on year. The GOES team has used its collective professional and academic experience to undertake analysis of peer- reviewed and published data to explore the reasons for this decline and its implications for climate and humanity. In our view, this loss of marine life is directly related to the presence of toxic chemicals and plastic which started to appear with the 'chemical revolution' in the1950's.

There is no doubt that tiny ocean planktonic plants and animals are key to regulating our climate, but this keystone of the planet's largest ecosystem seems to be ignored as one of the tools to address climate change. Every second breath we take comes from marine photosynthesis, a process which also uses 60-90% of our carbon dioxide. Now that we have lost 50% of a key climate regulator, surely it is time to stop, take a fresh look at ocean chemistry and biodiversity and ask ourselves some fundamental questions: Why have we lost this level of marine life? Why is the decline continuing? What does this mean for our climate and humanity?

Of particular concern from a climate change perspective is the level of carbonic acid in the oceans. This carbonic acid is created when atmospheric carbon dioxide dissolves into the surface seawater. In the 1940's, ocean pH was 8.2, but in 2020, pH had dropped to 8.04, indicating that the oceans are becoming more acidic. If there are not enough plants to use up carbon, the unused carbonic acid moves the pH downwards. Reports from respected institutes around the globe flag an acceleration of the ocean acidification process. This decline will result in the loss of more marine plants and animals, especially those that have carbonate shells and body structures (aragonite) based. These same reports forecast that in 25 years (by 2045), pH will drop to 7.95, and estimate that with this, 80% to 90% of all remaining marine life will be lost. The GOES team's opinion is that this is a tipping point: a planetary boundary which must not be exceeded if humanity is to survive. No ecosystem can survive a 90% loss; the result is a trophic cascade collapse. We will lose all the corals, whales, seals, birds, fish and food supply for 2 billion people – an outcome worse than climate change.

Let's be clear: If by some miracle the world achieves net zero by 2045, evidence from the Intergovernmental Panel on Climate Change (IPCC) BIOACID report [1] **demonstrates that this reduction will not be enough to stop a drop in ocean pH to 7.95. If the level of marine life (both plant and animal) is reduced, then the oceans' ability to lockout carbon into the abyss is depleted. It is clear to the GOES team that if we only pursue carbon mitigation strategies and don't do more to regenerate plant and animal life in oceans, we will reach a tipping point: a planetary boundary from which there will be no return, because all life on Earth depends upon the largest ecosystem on the planet. Humanity will suffer terribly from global warming, but it must be understood that the oceans are already showing signs of instability today at pH 8.04, (the start of the tipping point) and in 25 years when the pH has dropped to pH 7.95 represents the end point, the point of no return.**

Introduction

In this short 'think piece', which is based on the GOES Team's 4 decades of academic and professional experience (unique knowledge of closed loop marine systems, water, and colloidal chemistry), the above-described demise is explained by bringing new, and possibly key, pieces and solutions to the climate mitigation jigsaw. Recommendations in 7 areas are also suggested, to provide some focus for action. If acted on, these would go a long way towards reducing the toxic pollutant loading on the ocean and kickstarting regeneration. Sectors for early attention include; industrial and municipal wastewater, green chemistry, regenerative agriculture, plastics, petrochemical atmospheric pollution, and ecosystem regeneration. If we can act and gain momentum in the next 5 to 10 years, we may be able to avoid a trophic cascade collapse of the marine ecosystem and our life support system.

Why dissolving shell should ring alarm bells

Carbonate-based plankton and marine life are at the root of the food chain and the life support system for the planet. They cannot be removed without catastrophic repercussions; we will lose the ability to stop climate change, with no possibility of reversal, unless we take remedial action to stop pollution from plastic and toxic chemicals, thereby allowing nature to regenerate.

The oceans have, to date, taken-up around 30% of all anthropogenically produced carbon dioxide and, as stated above, ocean pH has dropped. It is now clear that this drop in pH has started to cause some instability for the 50% of marine plants and animals which are carbonate-based; for example, corals [3]. This view is supported by L.Q. Jiang 2021 [2], and by the Ocean Acidification model presented by Doney in 2009 [3] . This model predicted that aragonite-based plants and animals in the already less alkaline Southern Ocean, which remove 40% of the anthropogenic carbon, would start to show signs of stress by 2020, and the same would occur in all the oceans by 2050 [4]. With increasing ocean acidification, saturation levels of aragonite will continue to decrease, making it difficult for juveniles of plants and animals to form their shells and body structures. If we stop and think about the implications of this for the vast, cold expanse of the Antarctic Ocean, it is quite overwhelming. This is the most productive ocean; it plays the most critical role in climate regulation because, being cold, it absorbs more carbon dioxide. It is already affected by acidification - the magnitude of the threat of aragonite dissolution of plant and animal life should surely be filling us all with enough horror to take action.

Aragonite not only starts to become unstable in ocean surface waters at a pH of 8.04 (2020) but its solubility increases with water depth. At 200 m below the ocean surface[5], aragonite will dissolve completely at pH 8.04, and this is referred to as the "dissolution compensation depth". What this means is that the environment for these plants and animals to thrive is gradually reducing, because as the ocean surface pH drops, the dissolution compensation depth approaches the surface.

Most marine life and all plants live in the top 200 m, which is also the most sensitive to climate change and acidification. It means that when the water chemistry becomes more acidic, the ability of the plants and animals to form or maintain their calcium carbonate shell or body structures is affected [2]. Any changes to marine ecology or plant and animal populations will impact on the solubility of aragonite. The fewer the number of phytoplankton plants, the more carbon dioxide there will be in the water and the lower the pH due to the formation of carbonic acid. The process of acidification is therefore accelerating as marine plankton numbers decline.

The importance of this dissolution mechanism almost seems to have been overlooked, or its importance misunderstood, by governments and regulators. The BIOACID report [1] stated that: (i) mineral forms of calcium carbonate have started to dissolve; (ii) pH was predicted to drop to 7.98 in less than 25 years; and (iii) 30 to 50% of all molluscs, echinoderms and calcified macro-algae will be negatively affected – these are aragonite-based animals! The pteropod - snail-like and referred to as fish candy - is a key source of food for fish. While we concern ourselves with overfishing, we may not appreciate that fish stocks are going to decline rapidly due to lack of food for the fish.

These key species in the marine food chain will be among the first to disappear from the deep ocean due to the destabilising effects of acidification. The GOES team strongly believes that if dissolution of aragonite life continues at its present rate, it will lead to a cascade collapse of the wider marine ecosystem in 25 years. Figure 1 below is provided to help the reader visualise the data presented by IPCC committee and respected journals from which the GOES team have undertaken the analysis presented in this 'think piece'. We suggest that Figure 2 be read in conjunction with Figure 1.

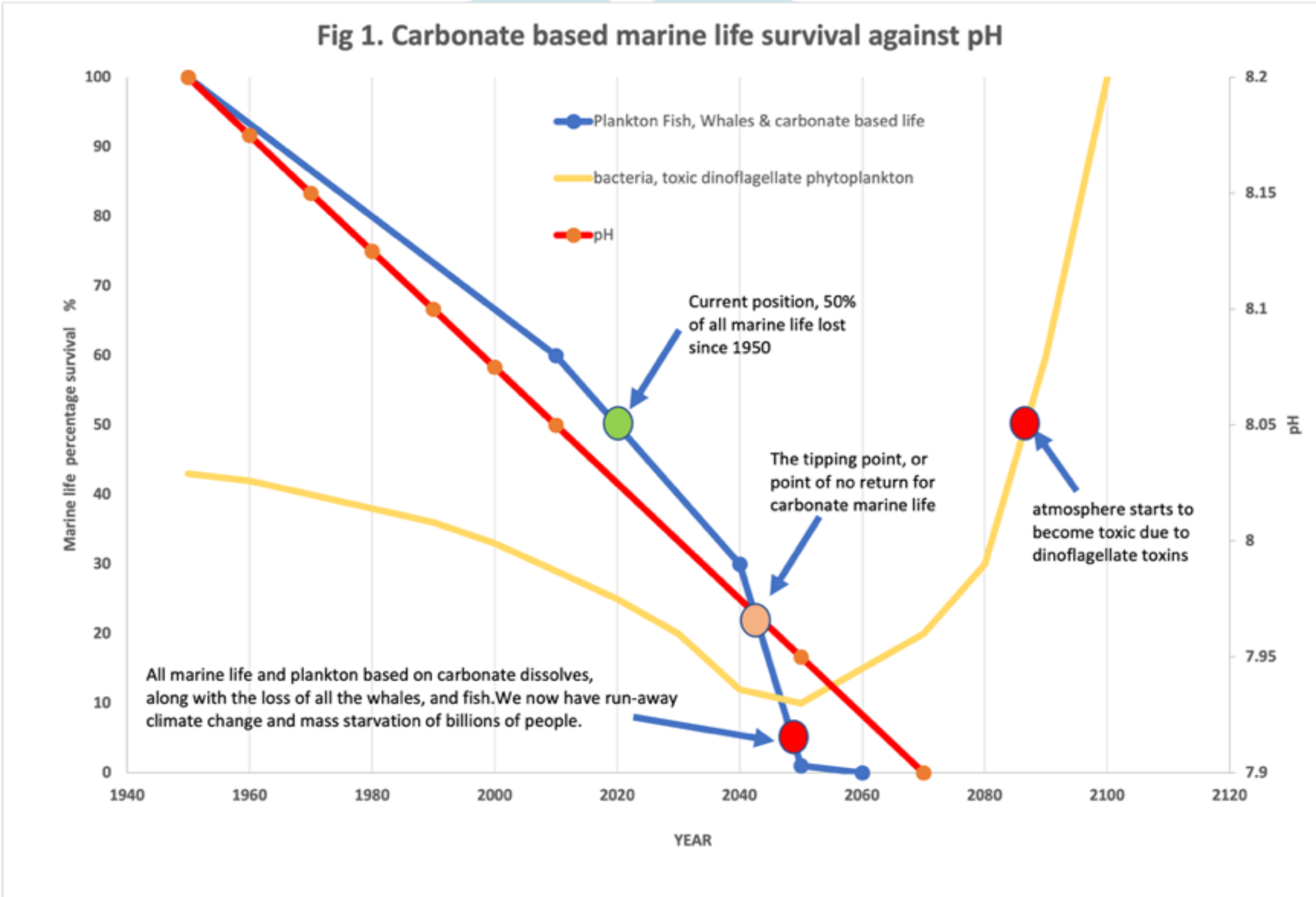

Figure 1: Carbonate-based marine life survival against pH: below is key in explaining the GOES Team's observations. It brings together pH and biodiversity loss, and informs the prediction for a pH tipping point. It should be read in conjunction with Figure 2 below.

The Red Line maps data from peer-reviewed papers to provide a historical pH profile from the 1940's to the present day (references [6] [8] [1] [8] [9][10][11][4][12][13][14]). IPCC data has then been applied to provide a projected pH profile. We have used the IPCC's Representative Control Pathway (RCP)8.5 or "business as usual" model for the burning of fossil fuels). These data suggest that we will reach an ocean acidification pH tipping point [15][16], beyond which it will not be possible to recover most carbonate-based life forms by 2045. The IPCC states that at pH 7.98, half of all remaining carbonate-based marine life will be negatively impacted, a pH of 7.95 will have more serious consequences.

The Blue Line maps a drop of around 40% of marine plankton from the 1950s to 2010 [6][17]. NASA reported a decline of 1% year on year from 1998 to 2012 [7]. The extrapolation forward from 2020 is based on the BIOACID report and *the simple fact that calcium carbonate minerals will start to dissolve. Plankton and carbonate-based marine life cannot adapt to dissolving. The projected end point is more than 80% loss of all marine life and a tipping point at pH 7.95.*

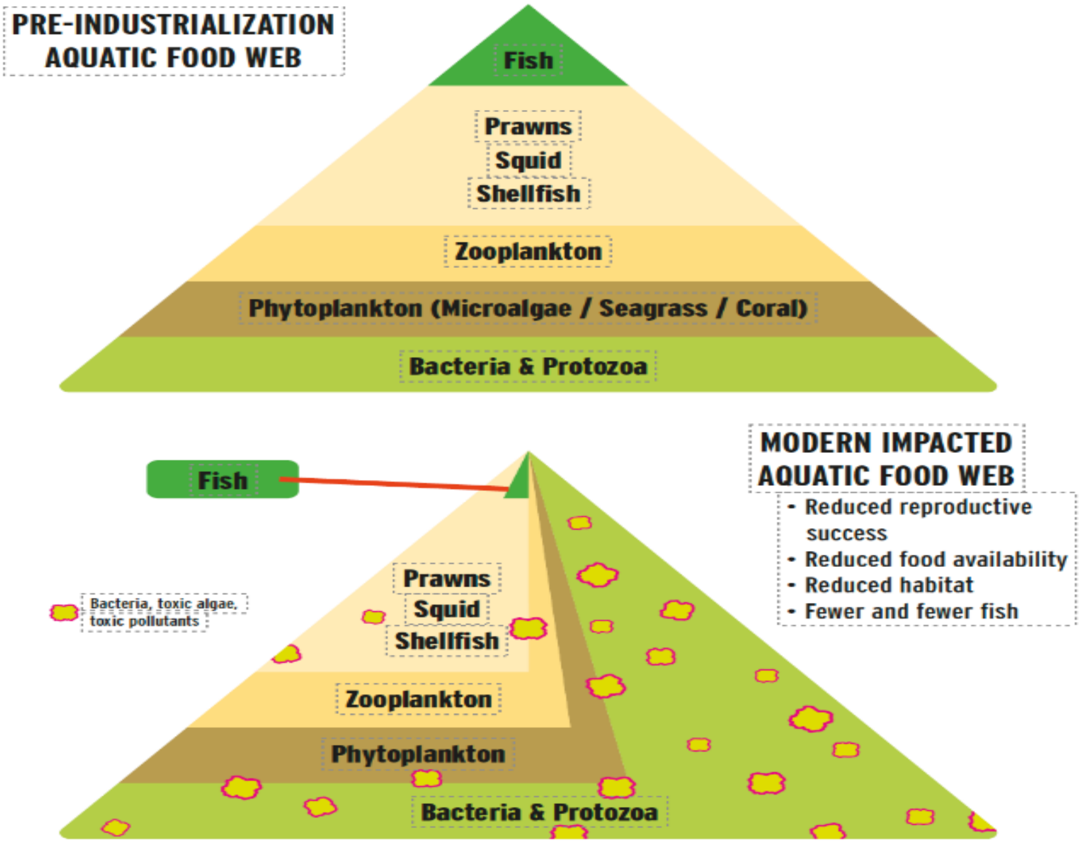

Figure 2: Landos et al. - Aquatic Pollutants in Oceans and Fisheries, This IPEN Report, funded by the Swedish and German Governments, illustrates the outcomes of chemical pollution on ocean ecosystems.

The Yellow Line is our prediction for the increased growth of bacteria and dinoflagellates, based on (i) the IPEN (2021) report, funded by the German and Swedish Governments (see Figure 2) and (ii) A European Commission report, which states we will see a 40% decline of the marine environment [18]. The paper also reports an increase in bacteria and protozoa which we are now witnessing in the Marmaris Sea [19][20][21].

When there are changes in ocean chemistry, the conditions may favour a new set of species - there will be winners and losers - and this happens right across the animal and plant kingdoms. More acid conditions will favour organisms like cyanobacteria, protozoa, and toxic dinoflagellate algae[22]. They will replace carbonate and silica-based plankton, resulting in not only a toxic ocean environment, but potentially a toxic atmosphere[23][24][25][26][27].

Diatoms, one of the most abundant varieties of planktonic plant, travel in the air streams and are spread around the world. They are found in the cells of most animals, including humans. Archaeologists use them to learn more about the bones they uncover during digs. Toxic planktonic plants, like dinoflagellates, do this too, but their numbers will increase, and unlike diatoms their presence will have a negative impact on the air we breathe, and on the quality of fresh water. There will be no escape from ocean acidification, even hundreds of miles from the sea. The change in plankton species distribution is already being observed and monitored. [28]

A different lens on "high-nitrate, low-chlorophyll zones" (dead zones) now cover 30% of the oceans and are spreading

Along with a 50% decline in marine plants and animals, huge areas covering 30% of the world's ocean surface [29] are described as being "high-nitrate, low-chlorophyll" (HNLC) zones. These HNLC zones, equivalent to 70% of the area of dry land, are devoid of marine life and are effectively dead zones. The Southern Ocean is the largest HNLC region in the global ocean. The difference between these HNLC and coastal dead zones is that the latter are the result of excessive, rapid plant growth caused by high nutrient load, HNLC have a high nutrient load but no plant growth.

The GOES team have applied their own expertise from closed loop marine aquaculture systems and colloidal chemistry to consider why these dead zones have occurred. Their experience from the very largest, closed loop systems points to another mechanism. We believe that the combination of lower pH and redox potential changes in ocean chemistry have impacted both the metabolism of marine plankton and their ability to stay stationary or swim through water.

In aquaculture proxies where clay was used to successfully drop zeta potential and increase water surface tension, marine larvae found that the water could support them to stay stationery and to move through the water.

With reduced surface tension, we suggest that planktonic plants and animals aren't supported, and simply 'drop out' of the water column and fall into the abyss. The addition of ferric ($Fe3+$) does the opposite – it drops zeta potential and increases surface tension, thereby keeping planktonic life in suspension. In this scenario, the ferric is changing the water structure rather than being a limiting nutrient. Building on this idea, the GOES team suggest that changes in ocean chemistry might be a reason for the timing of the migration of zooplankton at night from a depth of between 200 and 400 m up to the ocean surface waters where they feed on phytoplankton. At the end of the day, photosynthesis activity means that oxygen levels are at their highest, zeta potential is low and surface tension is high; this provides the support zooplankton require to propel themselves to the surface. Just before daybreak, oxygen levels are at their lowest, zeta potential is at its highest and surface tension drops; this means it is easier for zooplankton to sink back down to levels of 200 to 400 m.

This aquaculture sector proxy suggests that HNLC zones could be explained in terms of zeta potential rather than a lack of certain trace nutrients. This change in chemistry could also mean that climate regulating, planktonic life could simply have been lost because they have dropped to the abyss and have not been able to return to the surface.

The GOES team have been particularly interested in the use of satellite imagery to map microplastic contamination/concentration in the ocean surface waters [30]. Smooth water occurs when the zeta potential charge is high and surface tension low. The GOES team therefore do not think that microplastic is the cause of smooth water. Rather, the team consider that a high concentration of phytoplankton releasing omega 3 and other oils contribute to smooth waters.

Microplastics are toxic and can inhibit the growth of plankton [8], and this too may have caused and is now helping the spread of HNLC zones. The GOES team have suggested that the satellite imagery may be an observation of a decline in zooplankton, meaning that phytoplankton are not being eaten. While they would have initially flourished, without the zooplankton, nutrients would not be recycled back to the surface. With key elements like ferric depleted, it would be reasonable to suggest that the presence of toxic microplastics may be playing a more heightened role not only in in the formation and spread of HNLC zones, but also in climate change and acidification.

Suggesting further research might seem useful at this point, but it would be tantamount to genocide to continue to document ocean decline, when we need to action a precautionary approach, this may represent a significant research opportunity for academic institutes at the forefront of ocean acidification research.

Modelling limitations and what we expect to occur in our oceans

Few ocean acidification predictions or models take into account major decline in biodiversity and/or productivity, yet there is no doubt that it is critically important[31]. The GOES team are especially concerned that none of the climate models consider: (i) zooplankton migration and their mixing of the water column[32]. (These tiny animals are under 1 mm in length, and their mass is estimated to equate to 17 million jumbo jets); or (ii) changes in zeta potential/surface tension which will have a profound impact on the acidification process - there are very few references to this [33][34][35][36] .

It is well documented that the Allee effect, or an 80-90% drop in biodiversity or populations of plants and/or animal communities, spells danger of their total collapse.[37] The consequences of a widespread collapse in plankton numbers would be catastrophic. The ocean's capacity to remove dissolved carbon dioxide would be severely diminished, and this would lead to an acceleration in the ocean acidification process.

Figure 2, from the IPEN report[13] supports Figure 1 from GOES. Alarm bells and sirens should now be rung by every government and regulator around the world. While reducing carbon emissions to net zero by 2045 will buy us some time, it is not going to prevent the loss of most marine life. Even if, by some miracle, the world achieved net zero by 2030 instead of 2045, atmospheric carbon dioxide concentrations will still pass 500ppm and oceanic pH will still drop below pH 7.95 – a tipping point. The only upside here is that it might buy us time to wake up and address chemical and plastic pollution by giving us an extra 5 to 10 years to address the problem.

If carbon emissions continue on a business-as-usual trajectory and the world becomes net zero for carbon by 2045, we will still have twice as much plastic pollution as we have in 2021 in the air, soil, and water, coupled with thousands of tonnes of toxic chemicals at even higher concentrations. It never ceases to surprise most people that wastewater discharged from our homes, offices, factories, and farms remains highly toxic to our water courses, and the 'forever' chemicals we use every day in our homes and offices don't break down – ever. More disturbing is that it all eventually ends up in the oceans, and despite the billions of dollars spent over the decades on water and sanitation infrastructure around the world, 80% of the world's wastewater still isn't treated [38].

We must take our opportunity now – we can and must address chemical pollution

We may meet the current targets for climate mitigation with regard to carbon dioxide, but we will have sacrificed Earth and any future for humanity in the process unless we address chemical and plastic pollution.

Oxygen levels are dropping faster than can be accounted for by the burning of fossil fuels alone [39][40] due to anthropogenic reasons [41][42] . The only explanation for this is that we are losing oxygen-producing plants from the ocean and on land, at the rate reported by NASA [43]. This loss of marine life is not sustainable. It is part of what is described as the 6th Mass Extinction and is happening hundreds or thousands of times faster than the "normal" or "background" rates that have prevailed over the last tens of millions of years [44].

Figure 3 shows carbon, plastic and toxic chemical pathways. With 2.5 giga tonnes of carbon locked out in the abyss every year and 0.6 giga tonnes locked out by plants on land, this illustration demonstrates the importance of the ocean's role in the carbon cycle. It is well known that all marine life is inter-dependent: if you kill the fish, sharks, and whales, then the plankton at the base of the food chain and life support system for the planet will also be impacted. Humanity has already killed more than 90% of all the top predators - the big fish, sharks, and whales in the world's oceans; it is naive of us not to consider the implications of what is happening to our marine ecosystem and how it relates to climate change and mitigation.

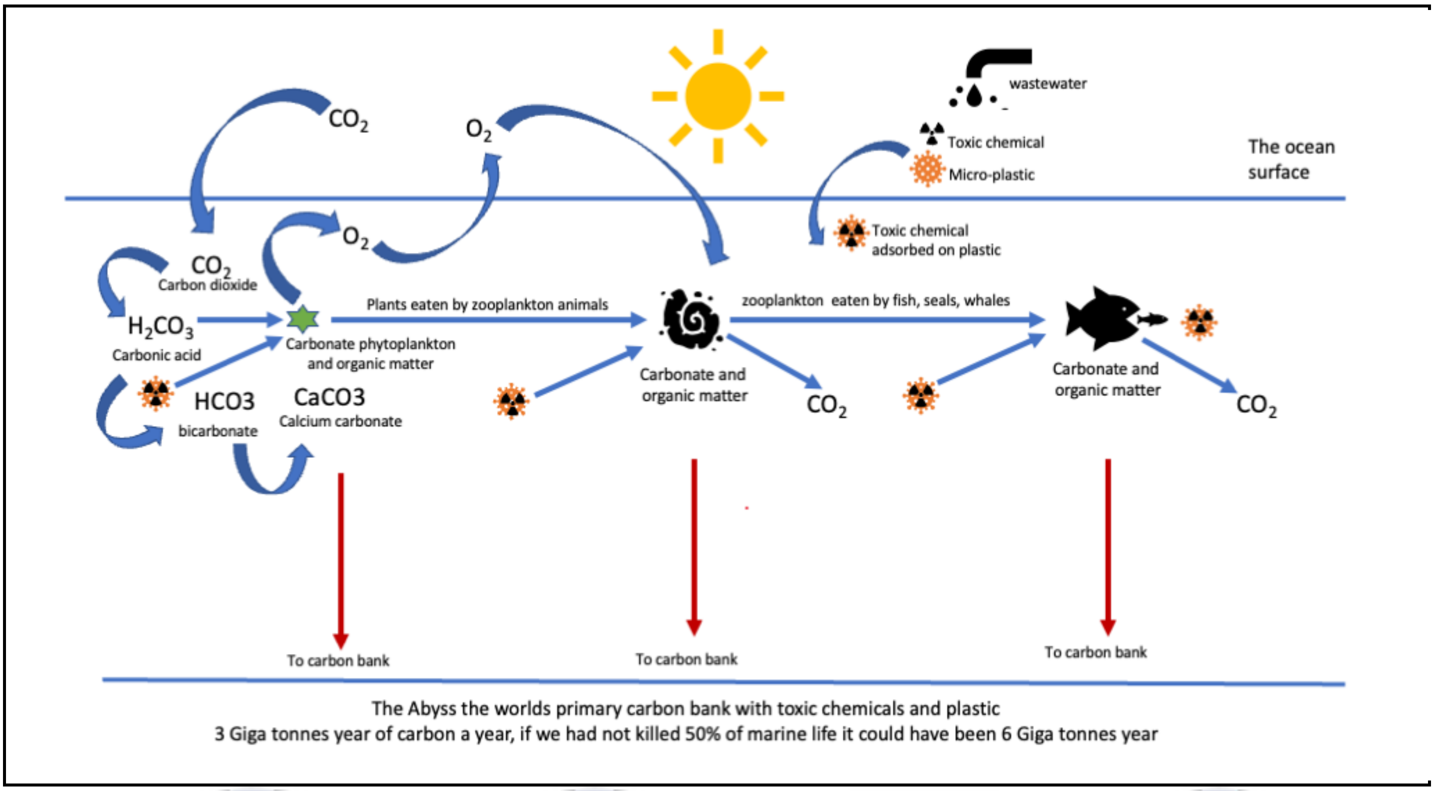

Figure 3: Carbon and oxygen pathways and the toxic cycle of plastic and chemicals

The world's environmental regulators, water industry professionals and governments seem to consider that the 'solution to pollution is dilution'. This to the GOES team seems completely irresponsible, because many of the modern-day toxic chemicals and substances discharged into our rivers and the oceans do not breakdown; they are persistent and will never disappear. The most toxic are lipophilic (or fat- loving); they bioaccumulate and can make their way from the bottom of the food chain and onto our tables.

Microplastics act like tiny sponges to concentrate toxic chemicals, which are then eaten by plankton [45][46][47]. Even though the chemicals are at an extremely low concentration in the water, they become concentrated on particles and can have a huge impact on marine life. For example, oxybenzone (a photo-active chemical added to sunscreens and cosmetics, but banned by the island state of Hawaii) was found to be toxic and to inhibit the growth and reproduction of coral reefs at a staggeringly low level of 62 parts per trillion [48][49].

The 2017 Lancet Commission on Pollution and Health Chemical report highlighted the growing global problem, with over 140,000 new chemicals and pesticides developed since 1950. 5000 of these chemicals were found to be present across the global environment, yet fewer than 7,500 had ever been tested for toxicity. It is only in a few high-income countries, and in the last decade, that mandatory pre-market evaluation of new chemicals has come into force. Chemicals and pesticides that were never tested for toxicity are known to have caused, and still be causing, disease, death, and environmental degradation. Examples many will have heard about include lead, asbestos, dichlorodiphenyltrichloroethane (DDT) and polychlorinated biphenyls (PCBs). Synthetic chemicals that have had minimal toxicity testing include neurotoxicants, endocrine disruptors, herbicides, insecticides, pharmaceutical cocktails, and nanomaterials. The evidence is now emerging that these pollutants cause harm not only to human health, but also to ocean health.

Many of these chemicals behave like oil, and do not want to dissolve in water but instead float on the surface or form an emulsion. They can become concentrated many thousands or millions of times on particles, including microplastic, because of their 'sticky', oil-like properties. In turn, the plastic particles get coated with a toxic cocktail, which, if eaten by plankton (or, if smaller than 20 nm, absorbed directly into plankton) represent a double negative for marine life. Figure 5 illustrates this and highlights that the worst and most dangerous place we can dump toxic chemicals is in our rivers, seas and oceans, because we can't remove them, and they will continue to elicit a toxic response for tens or hundreds of years. There is no safe concentration for toxic forever chemicals. We must work to an objective of achieving zero discharge, or we ultimately kill off our own life support system. Taking just one chemical group, the extremely toxic PCBs, we know that concentration is the same on particles in the highly polluted North Sea as it is in the Antarctic or Southern Ocean. While the concentrations of PCBs and particles are 7 times lower in the Southern Ocean, the concentration of the chemicals that end up on the particles eaten by the zooplankton is the same as the North Sea.[50][47].

The end point for carbon, plastic and toxic chemicals is the ocean bed. Even the deepest part of the Oceans, at the bottom of the Mariana trench, PCB concentrations are 50 times higher than the most polluted rivers in China [51] . Thankfully, deep sea mining is getting a thumbs down from the international community, and long may this be the case, given that mining could release toxic chemicals stored on the seabed and distribute them over an even wider area.

Trees are great, but plankton are even better

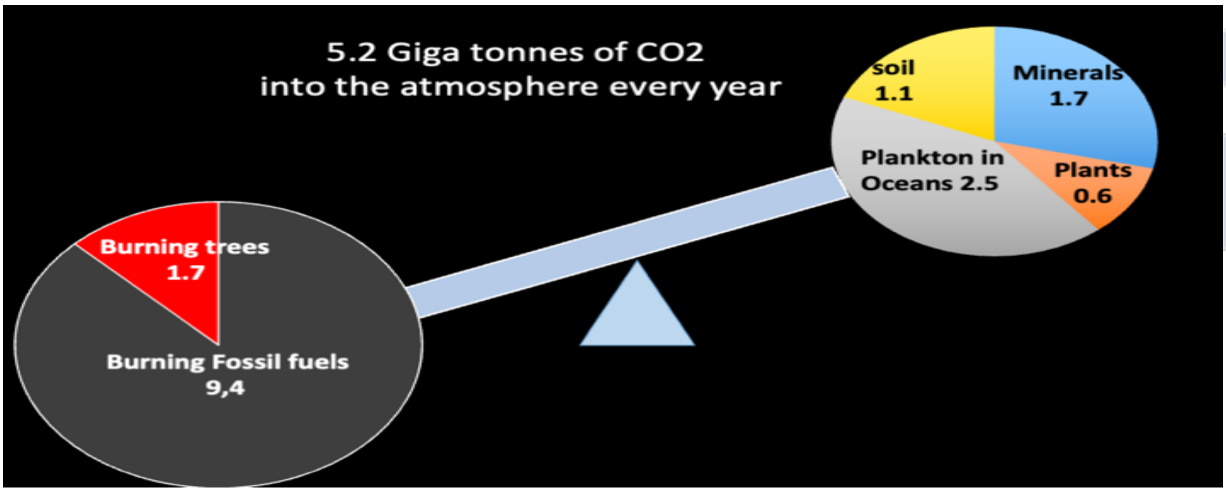

Figure 4: The Global Carbon Budget Data 2020, IPCC [52] with the addition of silicate mineral carbon sequestration and volcanic activity

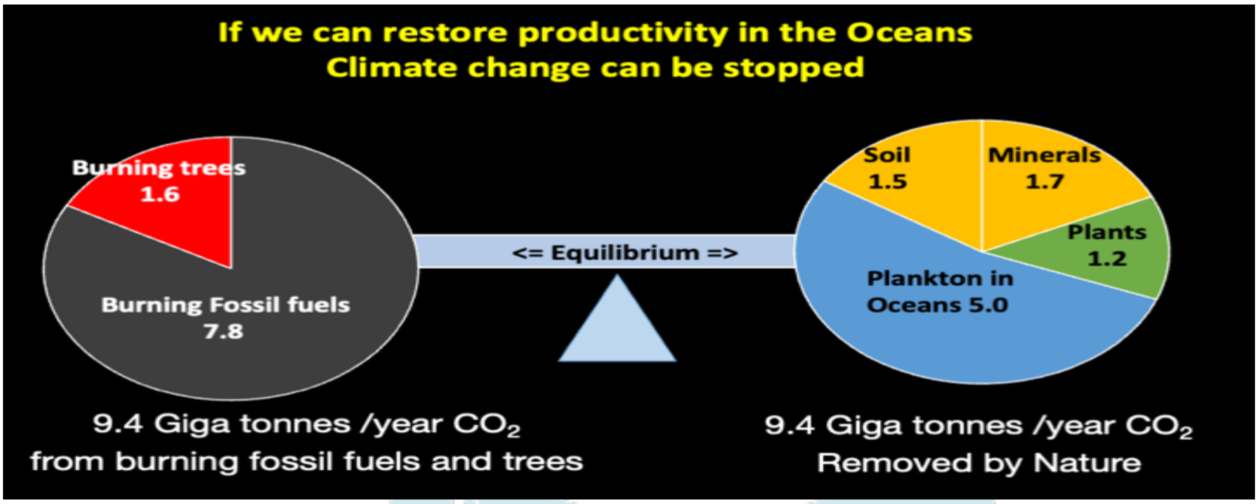

Figure 5: GOES Team's illustration of the outcome of restoring marine productivity (photosynthesis).

It is a myth that the Amazon Rainforest is the 'lungs of the earth', but most people are convinced that trees and grass remove most of our carbon dioxide and that planting lots of trees is one of the most important things we can do to mitigate climate change. The thing is, it takes 60 years for terrestrial plants and animals to double their mass, because trees take decades to grow. Compare this to the oceans, where 60% of all marine life is under 1 mm in size. Most of these tiny plants and animals reproduce and double their mass in hours or a few days [53]. This means that by helping nature regenerate and recover in the oceans, could be our best hope to win the fight against acidification and climate change. This is illustrated by the GOES team in Figure 5 :

The World Carbon Budget represents 11.1 giga tonnes of carbon emitted from the burning of fossil fuels every year. During springtime, deciduous trees and grasses remove 1200 giga tonnes of carbon, and in autumn, trees lose their leaves and grass dies back. When all the plant material is decomposed, 1200 giga tonnes of carbon are released back into the atmosphere. The net result is that zero carbon is removed by mature forests and other land plants. This doesn't mean to say that trees and land plants aren't important, new plantations will sequester and store carbon, and the soil biome will also store carbon. Trees and plants also help to clean the atmosphere, remove particles and produce dimethyl sulphide which aids in cloud formation.

Marshlands, wetlands, and mangrove swamps are critically important ecosystems that store huge amounts of carbon, yet they are being destroyed. Bacteria, fungi, insects and other organisms living in the soil also store carbon, but chemicals such as plastic, herbicides and pesticides are destroying this biome. The amount of carbon released by man from the burning of fossil fuels is less than 1% of the total carbon exchanged by nature on land. Nature removes 50% of this carbon, so it represents just 0.5% of the total carbon flux within ecosystems. The GOES team considers that nature in a healthy state should have the capacity to deal with excess carbon. If nature isn't coping it is a clear indication that it is under considerable stress.

It cannot be overstated that locking away carbon in the deep oceans is critically important if we are to address both acidification and climate change. If marine life, and in particular plankton numbers, could be restored to the pre-chemical revolution of the 1950's, then the increase in dead marine life falling to the abyss (below 3000 m) would mean that twice as much carbon would be locked out of the system.[54]. Instead, we have HNLC (dead) zones, which now cover 30% of the deep oceans and they are expanding, this should be cause for concern, and hitting the headlines, because all life on earth depends upon the oceans. The implications of which are not hundreds of years into the future, but over the next 20 to 40 years.

We propose that if we had not lost 50% of marine plant life over the last 70 years due to toxic chemical and plastic pollution, and had we looked after nature in our oceans, we would not now be experiencing climate change. Indeed a recent international report [55] entitled "Estimating global biomass and biogeochemical cycling of marine fish with and without fishing" states that **"**biogeochemical impact of fisheries has been comparable to that of anthropogenic climate change" - and this does not include the anthropogenic impact of toxic chemicals and plastic on primary productivity which will be many times the scale of the fishing industry.

Moving Forward

The GOES team conclude that, as a matter of urgency, we must act at every level of society to address chemical and plastic pollution and move to a true circular economy where waste and toxicity are designed out. The wider aquatic environment must be prioritised if we are to recover and regenerate ocean ecosystems and maintain our way of life. The following prioritised recommendations are provided for illustration. However, they only scratch the surface of the transition required to have real impact. Any legislation, policy, framework, convention, or industry guidance must ensure that zero discharge or zero environmental impact is built in as standard. Not only must we stop doing harm to nature, but we must now actively regenerate and support nature.

As well as fully educating and disclosing the dangers to human and environmental health of chemical products and the plastics we use in our homes, the following 7 key areas are examples of how we can move towards zero discharge and zero impact behaviour across all economies and societies.

Recommendations

1. Industrial and municipal wastewater

a) Only 20% of the world's wastewater is treated, with a tiny percentage returned in a better condition than when it was abstracted [56]. Governments and regulators need to bring forward infrastructure plans and initiate 'polluter pays' regulation to fund effective systems and innovation to achieve zero discharge or zero impact of the water to the receiving environment.
b) In the UK, less than 10% of municipal water treatment systems are fitted with tertiary treatment to remove plastic or toxic chemicals, and only some of these systems are effective. For example, in England billions of tonnes of untreated wastewater and storm water are discharged into the sea every year [57].
c) The water industry report microplastic removal rates of 98%, but even if 1% are discharged into the aquatic environment, it still represents trillions of particles. Recently published data reported that there are now 21 million tonnes of microplastics in the Atlantic Ocean, and up to 7 particles in every litre of water[58]. 1 in 3 fish are reported to contain plastic [59].
d) Plastic ends up in sludge from municipal wastewater, which is then used as fertiliser on agricultural land or placed in landfill sites. This sludge also contains pharmaceutical and toxic chemical residues, which will, along with microplastics, make their way into streams and rivers after precipitation events. In effect there is no water treatment, just dispersed disposal.
e) Molecular plastic (acrylate) is used as a sewage sludge thickener and end up on land or is not disposed of properly; similar products are used as soil conditioners. We now have an unquantified risk from molecular plastic. These chemicals are carcinogenic to human and marine life.
f) Stormwater run-off from roads is not treated. Vehicle tyres are one of the main sources of microplastic and toxic chemicals.

We must fully embrace a circular economy approach for water: We need a global shift to invest in effective management of industrial water and wastewater treatment, so that either water is discharged in as good or better condition than drinking water, or there is full recycling, or zero discharge of water polluted with chemicals and plastics. Pyrolysis or biochar may be a better solution for the sludge management. Water treatment should move to extended diffused aeration with endogenous respiration coupled with aquaponics. This will provide simple technology at 1/20th of the cost of current water treatment systems yet provides 100% recycled water.

2. Green Chemistry

a) We recommend the development of alternative, benign or safer chemical solutions for everything from cosmetics to cleaning products, and from building materials to transportation. There will be winners and losers, but it is the ocean ecosystem and humanity that we need to have as the winners. Some sectors may need to review their business models - for example, harder wearing plant-based tyre formulae are already available but have not been brought to market [60][61].

b) Chemicals toxic to nature are also toxic to humans, so why do we continue to manufacture toxic cosmetics? We need alternatives for photo-active chemicals (like oxybenzone) used in cosmetics, as they are not only toxic to nature, but they are carcinogenic and endocrine disrupting to humans. GOES calculates those 70,000 tonnes of oxybenzone would kill all life in the oceans, yet cosmetics containing up to 20,000 tonnes and plastic containing 1,500,000 tonnes are sold every year. This is just one chemical, there are thousands of chemicals that are just as toxic, innovation is required to develop alternatives. For sunblock, we recommend products composed of zinc oxide and non-nano-particle titanium dioxide, which work effectively and are safe for the environment.

c) The concentrations of PCBs and heavy metals in whales are now up to 100 times higher than the toxic threshold that allows them to breed. ('Lulu the orca' as a harrowing example) [62][63][64]. Even if by some miracle there was an invention that sucked carbon out of the atmosphere, the continued presence of toxic chemicals would result in a world devoid of nature. There must be tighter control to ensure these chemicals cannot escape into the environment. We simply cannot survive without nature.

d) Every living human now contains PFOS (plastic found in non-stick cookware) which is carcinogenic, yet industry continues to make and sell these products; we don't need them, and there are safe options.

e) We consume around 5g (a credit card) of plastic every week[65], along with phthalates and endocrine disrupters which have reduced human fertility by 60% [66]. Most western males will be infertile by 2050.

f) We recommend the acceleration of green chemistry and manufacturing solutions for textiles that do not emit micro-fibres.

We must stop the discharge of all hydrophobic, lipophilic toxic chemicals, and toxic-for-ever chemicals and plastic particles, into the air, water, and soil - and transition to using chemicals that are zero impact to the environment. Up to 95% of cancer is caused by exposure to toxic chemicals and plastic, and neurological disorders and auto-immune diseases are also linked to environmental pollution [67].

3. Regenerative agriculture

a) We have already wiped out more than 50% of all insects in our soil and 75% of all flying insects, and they are being killed off at a rate of 5% year on year[68]. In 20 years, agriculture will collapse, and many trees and land plants will disappear because there are no pollinators.

b) Agriculture and all living plants depend upon a healthy soil biome of bacteria, fungi and insects living in the soil. The soil biome is the digestive system for all terrestrial plant life, yet it has been systematically destroyed by herbicides and pesticides. By 2045 the soil biome will no longer be effective.

c) Green chemistry MUST now be applied to design out toxicity and develop a range of nature-safe chemical products that do not contain persistent toxic pollutants. Organic farming and regenerative agriculture must become the norm.

We must ban the use of all toxic-for-ever herbicides, pesticides, fungicides and molluscicides. It should become an ecocide offence to sell or use these chemicals.

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4. Plastic - loss of biodiversity and human disease

a) The uncontrolled dumping and discharge of plastic back into the environment must stop.

b) Not only is plastic directly toxic, but it also acts as a selective incubator for bacterium such as vibrio (causes cholera) and mycobacterium (causes tuberculosis) [69][70].

c) Many of the chemical components of plastic are horribly toxic hormone disrupters as well as being bio-accumulative and cancerogenic; oxybenzone UV screens, DBT, lead and antioxidants are just some examples.

d) Some plastic such as polyethylene and polypropylene can now be recycled economically by being transmuted into low sulphur fuels.

e) Plastic will adsorb and concentrate other chemicals, especially lipophilic chemicals, and amplify their concentration many thousands or millions of times. The older the microplastic, the larger the surface area and the more toxic the plastic becomes. Aged microplastic is up to 80 times more toxic than new plastic.

We recommend green chemistry, non-toxic plastic substitutes, and 100% plastic reuse

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5. Petrochemicals and Carbon

We are not going to be able to stop climate change, and it will continue to happen. However, if the ocean ecosystems crash, then climate change will spiral out of control and the other consequences of acidification will also be catastrophic. By reducing carbon emissions and achieving net zero by 2030 we would reduce the carbon dioxide dissolution into the oceans, and this could give us an extra 5 to 10 years to eliminate pollution and regenerate marine life. Unfortunately the world is unlikely to achieve Net Zero for carbon until 2050, which will be too late to prevent ocean acidification and collapse of the planets life support system, with the loss of all sea birds, seals, whales and fish and the food supply for over 2 billion people.

We must continue to reduce carbon dioxide emissions, but unless we also address pollution and ocean acidification, all our efforts in achieving carbon to net zero will be in vain.

Carbon reduction should continue, but the primary focus MUST now be to try and save the oceans, because if the oceans fail then its game over for humanity.

6. Atmospheric pollution

a) Levels of dust and aerosol in the atmosphere have increased immensely over the last 70 years[71]. Dust has slowed climate change, but at a cost to public health, with increased respiratory disease-causing millions of mortalities every year. All of nature is being poisoned by pathogenic organisms and toxic chemicals on the particles. The solar shielding effect of dust not only reduces plant photosynthesis but reduces the performance of solar cells. Reducing dust particles entering the atmosphere is a priority; some of the most toxic sources are vehicle tyres, coal power stations and diesel engines.

b) Vehicle tyres use toxic chemicals, and green chemistry needs to be applied to make the components non-toxic; as previously mentioned, there are already tyre products that are much safer[72][61].

c) When tyres wear, they release microplastics onto the roads and into the atmosphere. Arctic snow and ice now contain up to 10,000 particles of toxic plastic per litre[73][74][75]. The implications to Arctic ecosystems are catastrophic, and the implications to humanity are dire.

d) The black tyre compound coupled with carbon from diesel exhaust is making the snow black in the Arctic. Dark coloured snow melts quicker and this is a major reason (20%) for melting of the polar regions [76].

Stop all toxic particle emissions, especially from vehicle tyres. New formulation standards are required to minimise tyre dust and reduce toxicity. Extraction technology is under development, but opportunity exists to innovate and solve the problem using green chemistry.

7. Ecosystem regeneration, pandemics, and nature as the solution for climate change

a) Switching to the use of organic herbicides and pesticides globally, or practising regenerative agriculture, would result in several giga tonnes more carbon sequestered by the soil biome every year.

b) Around the globe we are seeing more trees being planted and this is a good thing, even though it takes 400 trees to offset the carbon from one person. The average carbon budget of a person in a developed country is 8000 kg/year. Alongside tree planting, we need a recognition that it is the restoration of marshlands, peat bogs and wetlands, and protection of mangrove swamps, that will give us the best land-based carbon stores.

c) In our coastal waters, we must act to stop trawling as a means of fishing: it damages highly efficient carbon storing ecosystems of seagrass, coral reefs, and marine seabed communities. Fish traps are a much more sustainable fishing strategy, but according to IPEN [13] the decline in the fishing industry is now being caused by chemical toxicity. On the current trajectory, chemical toxicity will also lead to a decline in the productivity of fish farming.

d) Displacing nature, cutting down forests, factory farming, using toxic chemicals, and not treating nature with respect all promote zoonotic diseases. They provide the conditions where viruses can jump species and then genetically mutate into forms that can infect humans. Covid-19 is number 7 in the series of coronavirus disease outbreaks, and there are going to be more outbreaks unless there is a focus on regenerating nature [77].

The survival of humanity depends upon nature, yet we have systematically destroyed more than 50% of all life on land and in the oceans over the last 70 years. Marine life is now dying at a rate of 1% year on year. We have reached a major planetary boundary and are balanced on the edge of the abyss.

Conclusion

Ocean acidification or pH decline is caused by carbon dioxide dissolving into the oceans, and there being insufficient plankton available to reduce carbon concentration by photosynthesis. Plankton levels have dropped by more than 50% over the last 70 years, and we conclude that this is due to both chemical and plastic pollution. Becoming carbon neutral will not stop the pH from dropping to 7.95. This pH level, coupled with microplastic and toxic chemical stressors on marine life, will trigger a trophic cascade collapse of the entire marine ecosystem.

Humanity is balancing on the edge of extinction, and we cannot see any possibility of human society surviving beyond the next 50 years unless action is taken over the next 10 years to stop toxic chemical and plastic pollution. Invisible nature is what really matters: bacteria, fungi, and plankton are the life support system for the planet, and within the next 25 years they will be gone unless radical change takes place.

In addition to reducing our pollution outputs, we do agree that we also need to reduce carbon emissions as much as possible, because this will slow down the acidification process and buy us some extra time to eliminate chemical and plastic pollution.

We can choose to place NATURE first and eliminate all plastic and toxic chemicals discharged into the environment everywhere, and this must be completed over the next 10 years. We must change our way of life and regenerate our natural world and life support system in the oceans and on land. We need clean water, and we need clean air - free from dust, toxic chemicals, and pathogens. We must stop disrespecting our planet and try to heal the damage inflicted by humanity since the chemical revolution of the 1950's.

If we can do all this, and become carbon neutral or negative, then there is a chance humanity can survive the next 50 years.

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