Ocean Acidification Induced Global Decline of Phytoplankton: International development aid needed

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This proposal is for the United Nations Environment Programme (UNEP), who encourage cooperation across all nations to help sustainably manage the global environmental agenda. As the leading environmental figurehead for the UN, the UNEP has the influence and expertise to encourage the Organisation for Economic Co-operation and Development's (OECD) participating countries to provide financial aid to developing countries to reduce carbon emissions, thus providing global environmental benefits.

Executive Summary

Ocean acidification is resulting in the decline of marine life due to an increase in seawater acidity, leading to the dissolution of calcium in organisms' shells. The disruption of the food web's cycling of nutrients is also a consequence of the altered seawater chemistry, leading to decreased productivity of phytoplankton which provides negative repercussions on global ocean functioning as phytoplankton indirectly support all marine life and ecosystem processes. This is because they are a primary source in marine food webs and dissolve oxygen, which affects water quality. Phytoplankton also produce atmospheric oxygen; however, this oxygen production is negatively affected by the global warming induced rise of water temperatures. The larger the phytoplankton density decline, the less oxygen can be released into the atmosphere, and less carbon dioxide (CO_2) is able to be absorbed into the oceans and sequestered when phytoplankton die and sink, (see figure 1). The UNEP promotes partnerships across nations to work together to improve global sustainability. Despite this, small-state governments attempt to not pay the necessary economic measures to reduce their greenhouse gas emissions. If the vagueness of the Paris pledge and review allows for poorer countries to not adhere to the climate adjustment measures, the UNEP could attempt to persuade the OECD countries to finance emission reductions in developing countries; incentivised by explaining the global benefits in their next meeting held in 2 years' time. Until then, research into Carbon Capture and Storage (CCS) would prove beneficial as an effective mitigation strategy against the current rate of climate change.

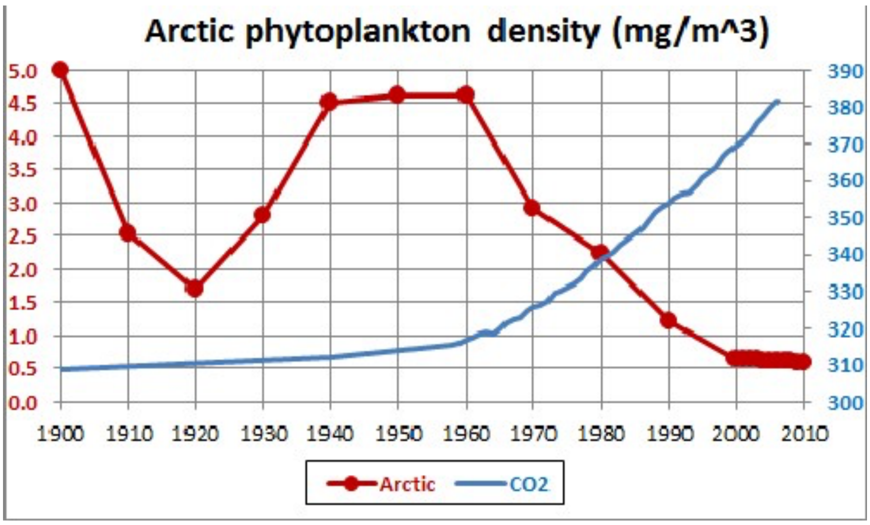

Figure 1: Line graph showing the negative correlation between 1960 and 2010 Arctic phytoplankton density and atmospheric carbon-dioxide concentration (ppmv) (Roper, 2016).

Foundational Science: Discussion and Analysis

Ocean acidification is one of the nine planetary boundaries, identified by Rockström et al. (2009) as 'posing a challenge to marine biodiversity' (p. 10). Many marine species are sensitive to the altered chemical composition of seawater and are directly affected by carbon emissions since 'the atmospheric removal process includes both dissolution of Co_2 into seawater, and the uptake of carbon by marine organisms', (Rockström et al., 2009:10). Ocean acidification is a result of anthropogenic Co_2 emissions forming carbonic acid and lowering the pH of surface water- 'carbonic acid is a part of a biphasic system consisting of water and carbon dioxide' (Novikov et al., 2020:1136). This results in the decline of marine life- 'changes in marine phytoplankton using satellite remote sensing (1979–86 and 1997–present) have… reported global decreases' (Boyce et al., 2010:591). The decline in phytoplankton density results in lower food supplies for apex predators, meaning phytoplankton 'directly or indirectly feed every animal in the ocean' (Minogue, 2010). Since marine phytoplankton 'have been declining by about 1% of the global average per year', this means that 'if the trend continues, it could decimate ocean food chains and accelerate global warming' (Minogue, 2010).

Phytoplankton's ability to photosynthesize is enabled through their habitation in the euphotic zone of the ocean, as 'light can penetrate, allowing photosynthesis to take place' (Department of Energy and Climate Change, 2013:1). Here they can 'release dissolved organic carbon (DOC) into the ocean' (Käse & Geuer, 2018:58), producing oxygen through the assimilation of Co_2. The Co_2 is then sequestered when the phytoplankton die and sink to the bottom of the ocean (see figure 2); since 'they take up carbon dioxide from the atmosphere and bind the carbon in their cells, which then… become part of sinking particles' (Käse & Geuer, 2018:57). This means the carbon can no longer be released into the atmosphere but does contribute to ocean warming- 'the ocean takes up about 93% of the global warming heat entering Earth's climate system' (Johnson & Lyman, 2020: 757). This has negative repercussions for atmospheric oxygen production as 'the net oxygen production by phytoplankton is known to depend on the water temperature and hence can be disrupted by warming' (Sekerci & Petrovskii, 2018:1), evidencing how anthropogenic carbon emissions indirectly results in lower levels of oxygen being released into the atmosphere. Oxygen produced during the day by phytoplankton is a significant contributor to overall

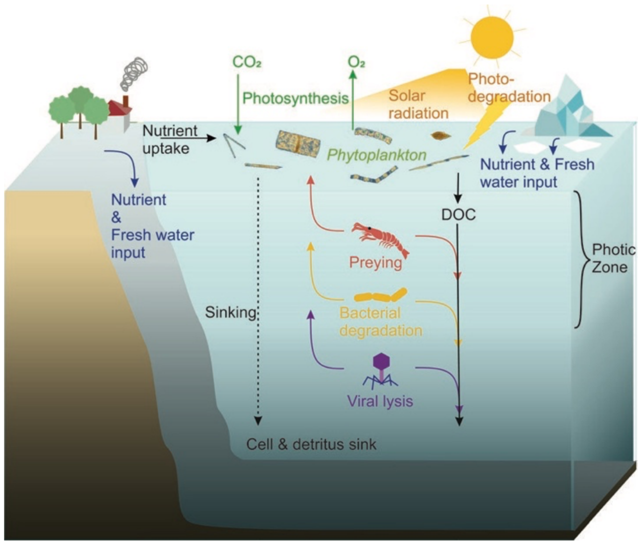

Figure 2: Carbon stored in phytoplankton is sequestered when phytoplankton die and sink to the bottom of the ocean (Käse and Geuer, 2018:58).

atmospheric oxygen levels, which has been the case since the beginning of humanity as ‘phytoplankton provided the original source of oxygen for our planet, without which our very existence would not have been possible’ (Falkowski et al., 2003: 99). Anthropogenic ocean acidification also affects phytoplankton through the lowered pH of seawater breaking down their shells, resulting in ‘up to 76% thinner shells than their historic counterparts’ (Fox et al., 2020:1). Phytoplankton are imperative to the production of atmospheric oxygen and functioning of marine ecosystems, since they are the ‘basis of the marine food chain’ (Sekerci & Petrovskii, 2015: 2326). Therefore, their longevity is essential.

Assessment of Existing Governance

As part of the United Nations Paris Climate Agreement (2015), a pledge and review system was established to reduce greenhouse gas emissions and officially break away from the ‘unsuccessful Kyoto regime’ (Keohane & Oppenheimer, 2016:142). Progressing beyond the Kyoto protocol was essential for reducing the rate of climate change as countries with high carbon emissions, as shown in figure 3, broke away from the 1994 Kyoto agreement; with Canada withdrawing in 2011 and America refusing to ratify. The need to impose a new agreement was important as ‘Kyoto… imposed politically unsustainable burdens on wealthy democracies while avoiding putting any constraints on countries that were becoming major sources of emissions’ (Keohane & Oppenheimer, 2016:146). Whilst ‘the Kyoto Protocol imposed no limits on emissions for developing countries’ (Victor, 2011:29), the vagueness of the Paris pledge and review provisions made it possible for developing countries to continue to not reduce carbon emissions. Unlike the Kyoto protocol, the Paris Pledge and Review was agreed by all nations, yet many governments of developing countries used ‘the vagueness of the Paris Agreement, and the discretion that it permits, to limit the scope or intensity of their proposed actions’ (Keohane &

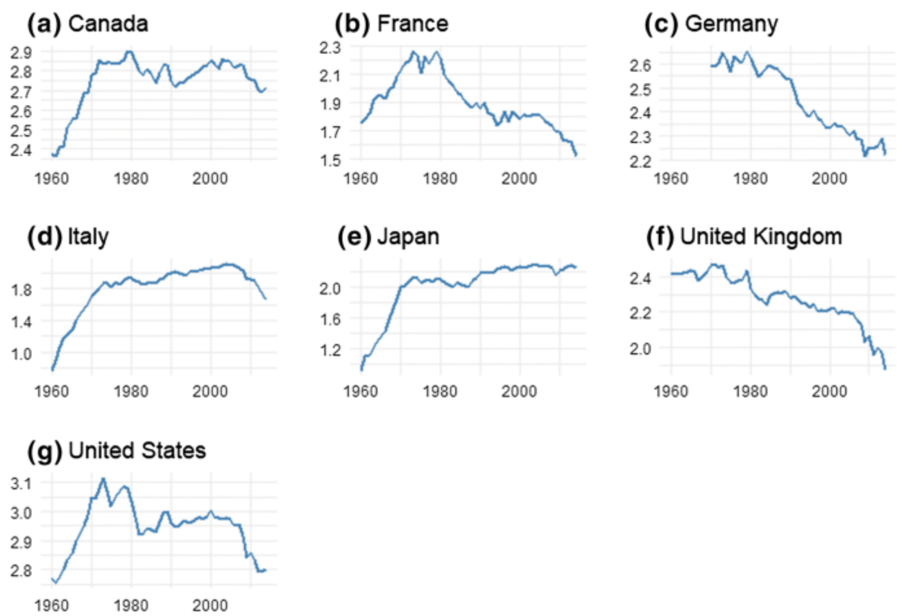

Figure 3: Line graph evidencing the Co2 emissions for the G-7 countries between 1960-2015, measured by Co2 emissions per capita (Balcilar et al., 2019:8106).

Oppenheimer, 2016:142). The Montreal Protocol, established in 1987, was more successful and 'highly effective' (Victor, 2011:89), at reducing ozone depletion.

Image 1: SDG'S supported through the Montreal Protocol (UNEP, 2021).

In 1991 the Multilateral Fund was established under article 10 of the Montreal protocol, and 'supplied over $2.5 billion to initiatives that support the phase-out of ozone-depleting chemicals in developing nations' (Tieszen, 2010: ii). The Multilateral Fund is funded by non-Article 5 countries (developed countries), with its initiatives devised by the: World bank, UNEP, and UN developmental programme (UNDP). This has allowed many developing countries to 'have exceeded the reduction targets for phasing out ODS' (Ozone Depleting Substances), 'with the support of the Multilateral Fund' (UNEP, 2021). The Montreal Protocol also contributes to the progression of other sustainable development goals (SDG's), as shown in image 1. The Montreal Protocol is still an existing set of policies revised every year, with the latest amended being the sixth in the thirteenth edition of the Montreal Protocol handbook (2019). This allows for the current state of ozone depletion to be counteracted with up-to-date science and funding. However, the Montreal Protocol's primary goal is to phase out the use of harmful ODS, which are man-made chemical substances such as 'methyl bromide and HCFCs' (Hydrochlorofluorocarbon) (Ziegler, 2012:142). Whilst this reduces anthropogenic global warming's effect on ocean acidification, more targeted policies that are climate change specific are needed to reduce the decline of phytoplankton density rather than specifically ozone depletion. The success of the multilateral fund suggests that richer nations supporting its poorer partners to reach global goals could be a 'model for future mechanisms to address climate change' (Tieszen, 2010: ii).

Governance Recommendations

Since 'the world's oceans are a major sink for atmospheric carbon dioxide' (Basu & Mackey, 2018:1), reduction of anthropogenic carbon emissions is essential to prevent further decline of phytoplankton density. To achieve reduced carbon emissions, global partnership encouraged by the UNEP is essential as OECD countries providing financial developmental aid to their poorer UN partners will increase the likelihood of achieving globally beneficial environmental targets- 'effective action against climate change will depend on the inclination both of OECD countries and newly industrializing countries to take costly actions, which for the OECD countries will include financial transfers to their poorer partners' (Keohane, 2016:142). Since the Montreal Protocol was a UN treaty ratified by every country, this shows that

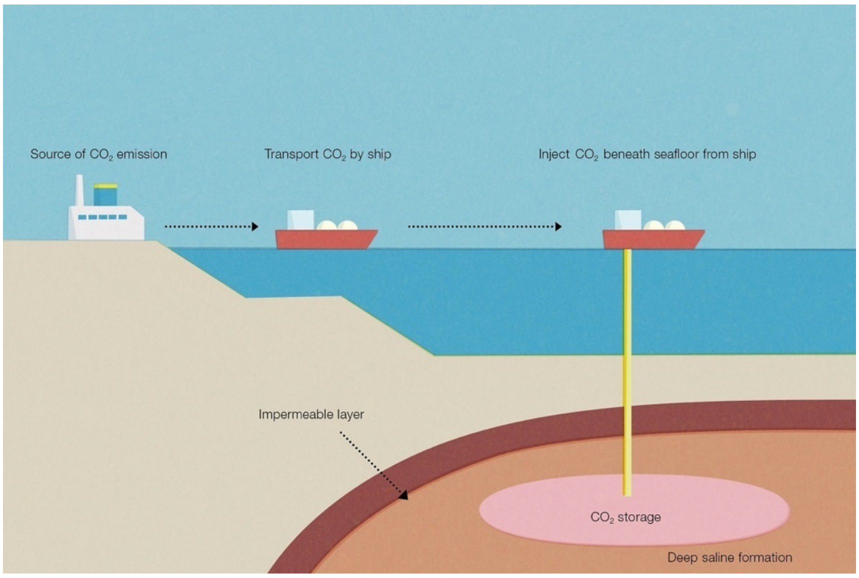

Image 2: The process of carbon capture and storage (University of Tokyo, 2019)

worldwide cooperation of OECD's supporting developing countries is possible. Global cooperation through financial developmental aid and carbon capture and storage (CCS) technological advancements are needed for global net zero to be reached by 2050, with a limit of 1.5•C warming according to the Intergovernmental Panel on Climate Change's (IPCC) revised estimates (2018). Since 'transactional movements and organizations can play an important role in mobilizing support within countries for costly climate change action' (Keohane & Oppenheimer, 2016:150), The UNEP could encourage financial transfers to developing countries by reducing hyper normalization through explaining how current smaller financial transactions could prevent larger future economic investment in expensive technology developing and discovery of alternative energy forms. When it is almost too late, more expensive subsidies funding renewable energy programmes would need to be implemented- 'without real change in the way nations plan, govern and commit resources, disaster relief will likely be inadequate, insurance funds will probably fail' (Clark, 2013). Control measures must be established to define what constitutes as a developing country, this could be done through operationalising a set GDP per capita and countries below the figure would be entitled to loans from developed countries. The figure could be determined through the help of advisors of the IPCC and finalised at the next United Nations Environmental Assembly (UNEA), when the financial aid initiative would commence upon agreement amongst the UN. The next UNEA will be held in 2022, until then, research and funding into CCS would prove beneficial. By transporting liquified Co2 to beneath an impermeable layer in the sea (see image 2), the carbon is unable resurface and enter the atmosphere or seawater. For CCS to be a successful carbon emissions mitigation strategy, 'its current implementation must be scaled up nearly by a hundredfold to become an effective tool that helps meet mitigation targets' (Omar et al., 2021:1). OECD countries must mutually fund initiatives installing this in global bodies of water deemed necessary by professional researchers in this field, hired by the UNEP. By implementing these measures- increased financial developmental aid and installation of mass CCS- the current rate of carbon emissions, of which '98.5% of the pre-industrial CO_2 is in the ocean' (Marinov & Sarmiento, 2004:251), would decrease. Through reducing the acidulation of seawater through reduced Co2 emissions, phytoplankton density would increase, resulting in the continuous release of oxygen into the atmosphere.

List of Cited References

Balcilar, M., Ozdemir, Z. A., Tunçsiper, B., Ozdemir, H. & Shahbaz, M. (2019) On the nexus among carbon dioxide emissions, energy consumption and economic growth in G-7 countries: New insights from the historical decomposition approach. *Environment, Development and Sustainability* 22: 8097-8134. Available from: https://doi.org/10.1007/s10668-019-00563-6 (Accessed 26 April 2021).

Basu, S. & Mackey, K. R. M. (2018) Phytoplankton as Key Mediators of the Biological Carbon Pump: Their Responses to a Changing Climate. *Sustainability* 10 (3): 18. Available from: http://dx.doi.org/10.3390/su10030869 (Accessed 28 April 2021).

Boyce, D., Lewis, M. & Worm, B. (2010) Global phytoplankton decline over the past century. *Nature* 466: 591–596. Available from: https://doi.org/10.1038/nature09268 (Accessed 26 April 2021).

Clark, W. (2013) *Climate change: The next challenge for national security*. Available from: https://www.aljazeera.com/opinions/2013/6/25/climate-change-the-next-challenge-for-national-security (Accessed 28 April 2021).

Department of Energy and Climate Change. (2013) *Plankton*. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/504522/OESEA3_A1a1_Plankton.pdf (Accessed 27 April 2021).

Falkowski, P. G., Laws, E. A., Barber, R. T. & Murray, J. W. (2003) *Phytoplankton and Their Role in Primary, New, and Export Production*. [online] Berlin: Springer. Available from: http://dx.doi.org/10.1007/978-3-642-55844-3_5 (Accessed 29 April 2021).

Fox, L., Stukins, S., Hill, T. & Miller, G. (2020) Quantifying the Effect of Anthropogenic Climate Change on Calcifying Plankton. *Scientific Reports* 10 (1620): 9. Available from: https://doi.org/10.1038/s41598-020-58501-w (Accessed 28 April 2021).

Intergovernmental Panel on Climate Change. (2018) *Summary for Policymakers on Global Warming of 1.5• C approved by governments*. Available from: https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments/ (Accessed 28 April 2021).

Johnson, G. C. & Lyman, J. M. (2020) Warming trends increasingly dominate global ocean. *Nature Climate Change* 10 (8): 757-761. Available from: https://www.nature.com/articles/s41558-020-0822-0 (Accessed 27 April 2021).

Käse, L. & Geuer, J. K. (2018) Phytoplankton Responses to Marine Climate Change- An Introduction. *YOUMARES 8 – Oceans Across Boundaries: Learning from each other* 7: 55-71. Available from: https://doi.org/10.1007/978-3-319-93284-2_5 (Accessed 27 April 2021).

Keohane, R. O. & Oppenheimer, M. (2016) Paris: Beyond the Climate Dead End through Pledge and Review? *Cogitatio Press* 4 (3): 142-151. Available from: https://www.researchgate.net/publication/308755848_Paris_Beyond_the_Climate_Dead_End_through_Pledge_and_Review (Accessed 28 April 2021).

Marinov, I. & Sarmiento, J. L. (2004) *The Role of The Oceans in The Global Carbon Cycle: An Overview*. [online] Dordrecht: Springer. Available from: https://doi.org/10.1007/978-1-4020-2087-2_8 (Accessed 27 April 2021).

Minogue, K. (2010) Critical Ocean Organisms Are Disappearing. *AAAS*. Available from: https://www.sciencemag.org/news/2010/07/critical-ocean-organisms-are-disappearing (Accessed 28 April 2021).

Novikov, I. V., Pigaleva, M. A., Levin, E. E. *et al.* (2020) The mechanism of stabilization of silver nanoparticles by chitosan in carbonic acid solutions. *Colloid & Polymer Science* 298: 1135–1148. Available from: https://doi.org/10.1007/s00396-020-04683-8 (Accessed 27 April 2021).

Omar, A. M., García-Ibáñez, M. I., Schaap, A., Oleynik, A., Esposito, M., Jeansson, E., Loucaides, S., Thomas, H. & Alendal, G. (2021) Detection and Quantification of CO2 seepage in seawater using the stoichiometric Cseep method: Results from a recent subsea CO2 release experiment in the North Sea. *International Journal of Greenhouse Gas Control* 108 (103310): 1-17. Available from: https://doi.org/10.1016/j.ijggc.2021.103310 (Accessed 27 April 2021).

Rockström, J. et al. (2009). Planetary Boundaries: Exploring the Safe Operating Space for Humanity. Ecology and Society, 14 (2): 32. Available from: http://www.ecologyandsociety.org/vol14/iss2/art32/ (Accessed 28 April 2021).

Roper, L. D. (2016) *World Peak Fishing*. [online] Available from: http://www.roperld.com/science/peakfish.htm (Accessed 26 April 2021).

Sekerci, Y. & Petrovskii, S. (2015) Mathematical Modelling of Plankton-Oxygen Dynamics Under Climate Change. *Bull Math Biol* 77: 2325–2353. Available from: https://doi.org/10.1007/s11538-015-0126-0 (Accessed 26 April 2021).

Sekerci, Y. & Petrovskii, S. (2018) Global Warming Can Lead to Depletion of Oxygen by Disrupting Phytoplankton Photosynthesis: A mathematical modelling approach. *Geosciences* 8: 21. Available from: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwi-yZyL46bwAhU5RBUIHaSAA2sQFjABegQIAxAD&url=https%3A%2F%2Fwww.mdpi.com%2F2076-3263%2F8%2F6%2F201%2Fpdf&usg=AOvVaw3XLMZWx2UgQiYtqsHGrKj4 (Accessed 28 April 2021).

Tieszen, B. (2010) *The Montreal Protocol's Multilateral Fund: An environmental and economic success.* Available from: https://core.ac.uk/download/pdf/5167921.pdf (Accessed 27 April 2021).

United Nations. (1987) *Montreal Protocol on Substances that Deplete the Ozone Layer*.

Available from: https://treaties.un.org/doc/publication/unts/volume%201522/volume-1522-i-26369-english.pdf (Accessed 28 April 2021).

United Nations. (2015) *Paris Agreement*. Available from: https://unfccc.int/sites/default/files/english_paris_agreement.pdf (Accessed 26 April 2021).

United Nations Environment Programme. (2019). *Handbook for the Montreal Protocol on Substances that Deplete the Ozone Layer: Thirteenth edition*. [online] Available from: https://ozone.unep.org/sites/default/files/2019-07/MP_Handbook_2019.pdf (Accessed 29 April 2021).

United Nations Environment Programme. (2021) *About Montreal Protocol*. Available from: https://www.unep.org/ozonaction/who-we-are/about-montreal-protocol (Accessed 27 April 2021).

University of Tokyo. (2019) *Japan's unique subsea geological Co2 storage technology*. Available from: https://www.u-tokyo.ac.jp/focus/en/features/fsi025.html (Accessed 28 April 2021).

Victor, D. G. (2011) *Global warming gridlock.* [online] New York: Cambridge University Press. Available from: http://assets.cambridge.org/97805218/65012/frontmatter/9780521865012_frontmatter.pdf (Accessed 27 April 2021).

Ziegler, O. (2013) *Ozone-depleting substances*. [online] Wiesbaden: Springer. Available from: https://doi.org/10.1007/978-3-658-00054-7_5 (Accessed 29 April 2021).