Dead Zones: re-establishing marine biodiversity by implementing a credit trading app.

University of Warwick, 2021

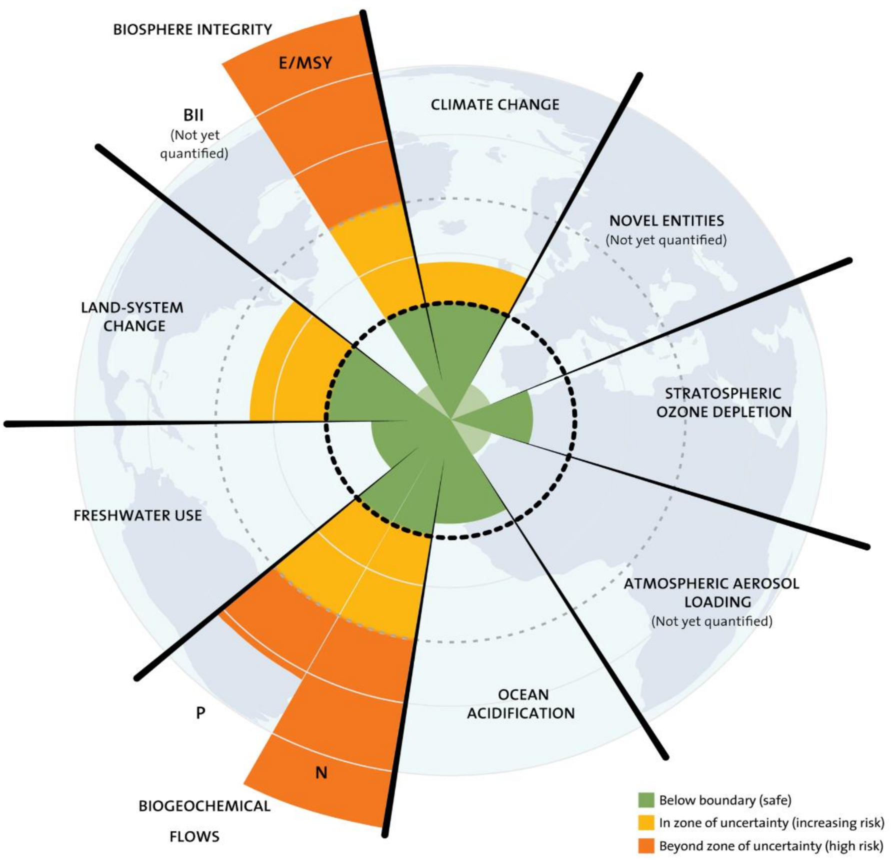
(Ganeshan et al, 2020)

Dead Zones: re-establishing marine biodiversity by implementing a credit trading app.

Executive Summary

Dead zones are anoxic areas of water that cannot sustain biodiversity. They occur naturally, but there is increasing concern that anthropogenic activities are accelerating their growth. Nitrogen and phosphorus fertilizers are primarily responsible for dead zone expansion as they cause eutrophication. Due to increased nutrient loads, there is accelerated and excessive plant growth on the surface of the ocean which blocks out vital sunlight and oxygen. Subsequent anoxic waters make aquatic survival impossible, disrupting food webs and ecosystems. To re-establish essential biodiversity, the UNEP and UN General Assembly must encourage international governments to join a global nutrient trading scheme and include nitrogen and phosphorus pollution in the SDG's. These governments will then be responsible for ensuring large polluters take part in the trading scheme using the Nutrient Trader application that will be available globally. This app allows companies to buy and sell nutrient credits earnt from reducing their nutrient loads below government quotas, therefore providing a market-based incentive to reduce nitrogen and phosphorus pollution and also a way of monitoring the actions of large nutrient polluters.

Figure 1: Planetary Boundaries Framework (Steffan et al, 2015)



The planetary boundary framework aims to define a 'safe operating space for human societies to develop and thrive' (Steffen et al, 2015). According to the Stockholm Resilience Centre, the biogeochemical flows have been 'radically changed as a result of industrial and agricultural processes' (Stockholm Resilience Centre, n.d.)

Biogeochemical flows, categorised into nitrogen (N) and phosphorus (P) flows, which are the primary cause of dead zones, are considered high-risk threats to stability of the Earth's system. (Rockström et al, 2009)

Foundational Science

Causes and effects of dead zones

Dead zones are areas of anoxic waters where marine life cannot survive. Whilst dead zones often occur naturally, scientists are concerned with rapid anthropogenic-induced expansion (Diaz, 2001; Jackson et al, 2001).

The primary cause of dead zones is nitrogen and phosphorus pollution from agricultural fertilizers and industrial sewage (as suggested by Figure 2). These nutrients enter the ocean after seeping into rivers and streams (Diaz et al, 2001; Sutton et al, 2013). The nitrogen boundary is defined as 62Tg/year however anthropogenic activity produces approximately 227Tg/year (Sutton et al, 2013). Figure 3 highlights this excessive use using empirical data. This suggests that we have exceeded the planetary boundary and are now at high-risk of disrupting the system. Indeed, excessive use of nitrogen and phosphorus fertilizer causes eutrophication which leads to huge algae blooms covering the water surface and suffocating marine organisms underneath (Diaz et al, 2001).

This leads to the degradation of vital ecosystem services (Morseletto, 2018) and these are summarized in Figure 2. Anoxic waters make aquatic survival impossible, therefore reducing supporting ecosystem services as marine habitats are lost, leading to a loss of functional and genetic biodiversity. This has subsequent impacts on regulatory processes as food webs are disrupted, which causes imbalances in the marine ecosystem. Implications for provisionary services are inevitable, for example fish stocks required for commercial fishing will be greatly reduced.

Figure 2: The effects of biogeochemical flows on ecosystem services

Ecosystem Service	Impact of biogeochemical flows
Regulatory	Reductions in predators cause over-population of some species, which creates excessive competition for resources, causing a positive feedback loop.
Provisionary	Reduced fish stocks have implications for commercial fishing. (Diaz et al, 2001)
Supporting	Increased plant cover may increase rates of photosynthesis which can reduce carbon dioxide levels and therefore regulate air quality and temperature. Creation of anoxic waters by eutrophication reduces marine habitats, forcing migration. However migration may not be possible if organisms are not resilient to change, e.g. in temperature or pH.
Cultural	Negative implications for coastal populations who rely on the marine ecosystem for their livelihoods. They may have to migrate further inland to cities away from their homes.

Figure 3: Values of nitrogen and phosphorus flows (Steffen et al, 2015).

Table 1. The updated control variables and their current values, along with the proposed boundaries and zones of uncertainty, for all nine planetary boundaries. In the first column, the name for the Earth-system process used in the original PB publication (R2009, reference 1) is given for comparison.

Earth-system process	Control variable(s)	Planetary boundary (zone of uncertainty)	Current value of control variable
Biogeochemical flows: (P and N cycles) (R2009: Biogeochemical flows: (interference with P and N cycles))	*P Global*: P flow from freshwater systems into the ocean	11 Tg P yr^{-1} (11–100 Tg P yr^{-1})	~22 Tg P yr^{-1}
	P Regional: P flow from fertilizers to erodible soils	6.2 Tg yr^{-1} mined and applied to erodible (agricultural) soils (6.2-11.2 Tg yr^{-1}). Boundary is a global average but regional distribution is critical for impacts.	~14 Tg P yr^{-1}
	N Global: Industrial and intentional biological fixation of N	62 Tg N yr^{-1} (62–82 Tg N yr^{-1}). Boundary acts as a global 'valve' limiting introduction of new reactive N to Earth System, but regional distribution of fertilizer N is critical for impacts.	~150 Tg N yr^{-1}

1259855-4 13 FEBRUARY 2015 • VOL 347 ISSUE 6223 sciencemag.org SCII

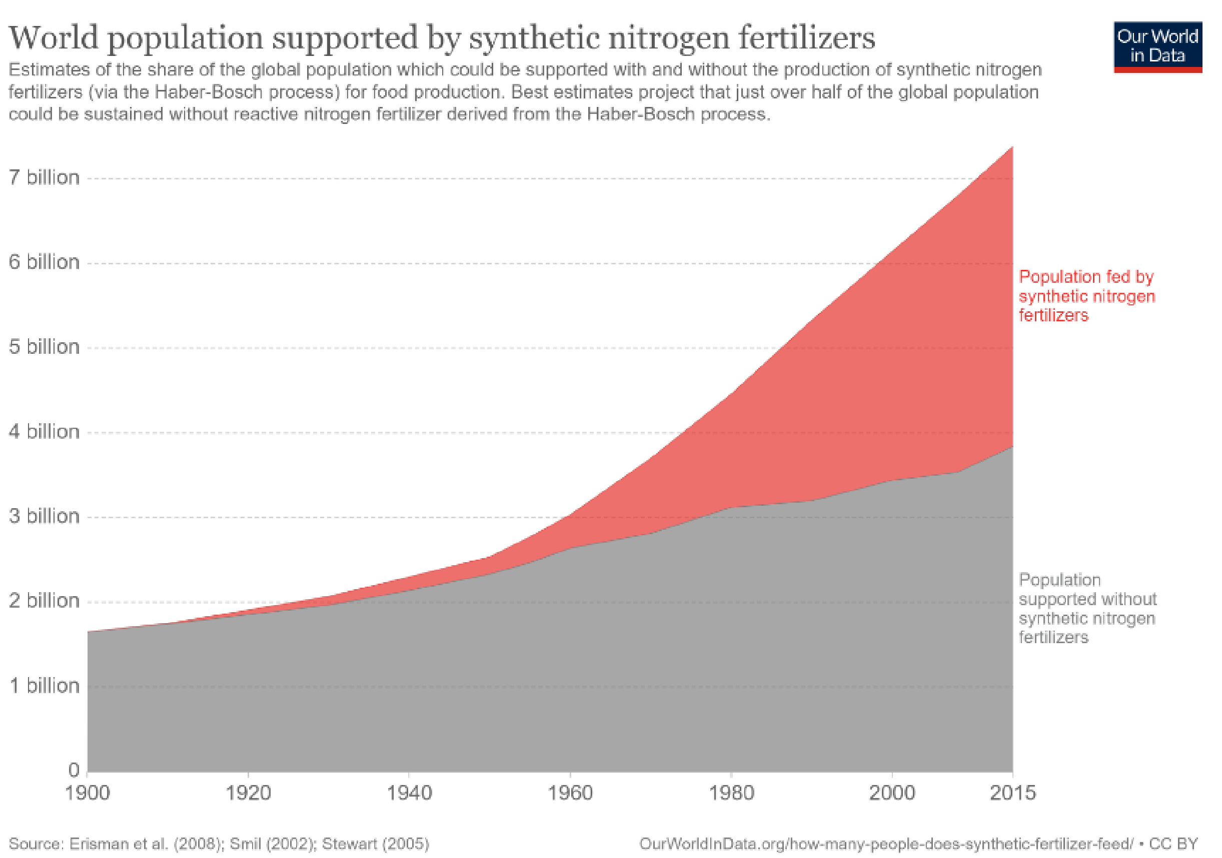
Importance to Human Development Agenda

Fertilizer contributes to food security and poverty alleviation, which are essential sustainable development goals (Morseletto, 2018). The 1900 level of agricultural activity shows extremely limited use of fertilizer and could only feed 2.4 billion people (IFA, 2002). Figure 6 shows that the use of synthetic nitrogen fertilizers soared from the 1960s onwards, which coincides with the expansion of oceanic dead zones, suggesting a positive correlation (Diaz et al, 2008). Thus, we must develop a strategy that increases global food security whilst minimising environmental impacts and the expansion of oceanic dead zones.

Figure 4: UN Sustainable Development Goals that are significantly affected by nitrogen pollution. (Morseletto, 2018)

Figure 5: Positive correlation between fertilizer use and dead zones. (World Bank, 2011)

Figure 6: World Population supported by synthetic nitrogen fertilizers. (Roser et al, 2013)

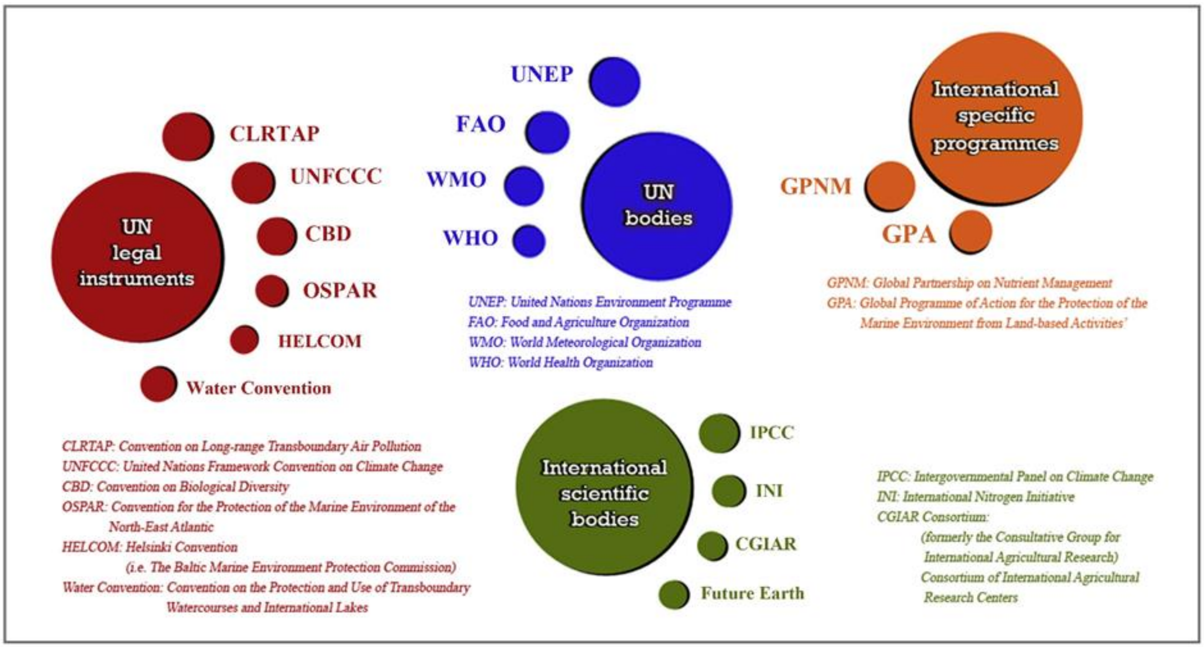


Assessment of Existing Governance

Nitrogen and phosphorus pollution and the Sustainable Development Goals

Although nitrogen and phosphorus pollution and the subsequent expansion of oceanic dead zones is an extremely important environmental problem, one which we have already exceeded the established planetary boundary, it is not directly mentioned in the UN's Sustainable Development Goals (Morseletto et al, 2017; Oenema et al, 2011) As depicted in Figure 7, there are a number of UN bodies with treaties on this environmental issue, including the UNEP and the FAO, however there is no unifying framework at the supranational level to coordinate the vital international action that is needed (Oenema et al, 2011). Sutton, (2020) argues that a new goal to 'halve nitrogen waste' by 2030 would save US$100 billion every year, offering alongside the environmental benefits an economic incentive too.

Figure 7: examples of current governance, (Morseletto, 2017)



Nutrient trading: Chesapeake Bay

This particular region is prone to nutrient pollution and subsequent large algae blooms which has caused dead zones throughout the bay. The proposed Chesapeake Clean Water and Ecosystem Restoration Act 2009 considers nutrient trading an effective approach to reducing the dead zone (Jones et al, 2010). So far, Maryland, Pennsylvania, West Virginia and Virginia have introduced nutrient trading programmes, allowing credits to be exchanged across state boundaries and nine major river basins (Jones et al, 2010).

In a nutrient trading market, sources that have reduced their nutrient pollution below target levels can sell their surplus pollution in the form of 'nutrient credits' to other sources (Jones et al, 2010; Branosky et al, 2011) As highlighted in Figure 8, there are many advantages to this approach, for example this is a cost-effective strategy that could create revenue opportunities for farmers and business that implement efficient reduction policies (Jones et al, 2010).

Nutrient trading: Gulf of Mexico

The World Resources Institute has developed a hypothetical case study approach to assess the economic feasibility of using nutrient trading. 'It could serve as a cost-effective way to shrink the Gulf's dead zone' (Perez, 2013). Nutrient reduction schemes save farmers money in the form of reduced fertiliser bills, generating additional profit (Perez, 2013). However, some disadvantages of this scheme are analysed in Figure 8.

Figure 8: Pros and Cons of using nutrient trading schemes

Pros

Sources who reduce their nutrient pollution levels and therefore their impact on oceanic dead zone expansion, for example by limiting their fertilizer consumption, can sell credits for profit, providing an economic incentive. This provides a source of revenue to farmers and businesses (Jones et al, 2010)

Sources that face expensive reduction policies can purchase nutrient credits instead of costly technological upgrades.

These solutions could reduce the amount of nitrogen-phosphorus run-off into rivers, therefore reducing eutrophication and formation of dead zones, thus restoring marine biodiversity and ecosystem services.

Cons

Many of these schemes are hypothetical and have not yet been implemented therefore their long-term effectiveness remains unknown.

Costly monitoring and measuring investments could reduce economic incentives.

Sources of nutrient pollution can purchase large amounts of nutrient credits and continue polluting, therefore having no positive impact on the environment.

These schemes are not legally binding so can continue polluting without legal action.

Corporate Finance Institute (2021)

US Environmental Protection Agency (UNEPA)

1. Animal feeding operations

The confinement of livestock in small areas allows for efficient feeding and maintenance; however it releases huge amounts of animal waste which contains harmful bacteria and nutrients (UNEP, 2005). These harmful bacteria contaminate drinking water and nutrients are washed into streams and rivers, causing eutrophication. The UNEP (2005) suggests that farmers can limit discharges by storing wastewater and run-off in appropriate water management systems. This could be effective in decreasing the amount of nutrients seeping into rivers however it could require costly investments.

2. Livestock grazing

Overgrazing causes soil erosion and destroys floodplain vegetation. (UNEP, 2005) Supporting ecosystem services such as habitat provision and regulation of the water cycle are disrupted. 'Vegetation Buffer Strips' (VBS) reduce nutrient run-off from seeping into rivers and streams, therefore providing a natural barrier to eutrophication, reducing the need for costly technological investments (Honghai et al, 2011). However, VBS takes up potential cropland, reducing the incentive to invest (Honghai et al, 2011). The UNEP (2005) also suggests reducing grazing intensity, keeping livestock away from streams and rivers and investing in revegetation.

(Clay, 2016)

Governance recommendations

Nutrient Trader Application

In order to facilitate nutrient trading, this document proposes the creation of a new, innovative credit-trading application called the Nutrient Trader app.

How it works

The UNEP should ensure that national governments set monthly nitrogen/phosphorus pollution quotas to point-source polluters, farmers and public/private industries. This information is displayed on their app profiles with usage data shown, to allow for efficient monitoring.

Sources who reduce their monthly pollution below quota targets earn credits; 10kg of nitrogen or phosphorus saved = 1 credit, which they can then sell on the app in exchange for money. Those who exceeded theirs or want to exceed it next month must buy credits. These transactions are all facilitated by the app, which is efficient, secure and easy for governments to monitor.

Example

The average amount of nitrogen applied per hectare of farmed land[2] from fertilizers from manufactured and organic fertilizers was 110 kg/ha and 9kg/ha respectively. (Department of Environmental and Food Affairs, 2020) If a farmer uses precision farming techniques to reduce nitrogen pollution by 20%, they earn 22 credits/ha. If they have 100 hectares, that's 2200 credits. On the app, they will be rewarded by the government with 2200 credits which they can sell to another farm, who perhaps can't yet afford precision farming techniques. If one credit = 10kg of nitrogen, this farm can now produce an additional 220kg of nitrogen above their original quota.

Figure 9: The Nutrient Trader app

[Figure 10: Companies can use the app to sell and buy credits](#)

[Figure 11: The company profile facilitates trade and monitoring](#)

App designer: Proto.io https://proto.io/

General rules

- **Only nitrogen or phosphorus can be traded for comparable credits (nitrogen for nitrogen.)**
- **Nutrients are measured in kilograms/year. One credit = 10 kilograms of nitrogen or phosphorus.**
- **Credits only last one year – the total number of credits earnt resets after this duration.**

Potential future developments

Building on the recommendations of the UNEP, this application could be useful in encouraging sources to follow their advice. Sources who want to reduce their pollution but do not possess the financial capital for costly upgrades can apply for government investment via the app. This addresses the disadvantage outlined in Figure 8 which suggests that companies can simply purchase credits and continue polluting. Instead, they can apply for government investment through the app and begin earning credits which will contribute to their profit and growth. This encourages small businesses to get involved, thus making it more accessible to a wider range of sources. Indeed, this rests on government willingness and capability to invest in their environment, however it is hoped that with pressure from the UNEP and the integration of nitrogen-phosphorus pollution into the SDGs, worldwide governments will be persuaded to take action.

(Morrison, 2019)

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