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Arctic Climate Change Criminology (AC³): transgression of Arctic planetary boundaries as a white ecocide*

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ABSTRACT: The planet has finite limits, which have been determined and quantified by scientific enquiry. Consequently, it has been demonstrated that the modification and contravention of these limits can result in consequences that are irreversible. The damage to the environment caused by human activities has continued to increase over the last centuries. As a consequence of these anthropogenic pressures, six of the nine planetary boundaries have now been exceeded. Despite the efforts of some states to implement preventive measures, we are witnessing increasing levels of anthropogenic pressure in areas of particular and vital importance, such as the Arctic. International law has addressed some of these problems with sectoral or territorial mechanisms to deal with environmental damage, but these have proved ineffective. This paper addresses the construction of a monitoring and sanctioning framework from the perspective of international criminal law, with a rigorous analysis of the importance of this ecosystem to the planet. It proposes a new configuration of a crime of great ecological magnitude, namely White Ecocide, which has the potential to unleash consequences on a planetary scale.

KEYWORDS: planetary boundaries, white ecocide, Arctic, climate change, green criminology

CRIMINOLOGÍA DEL CAMBIO CLIMÁTICO EN EL ÁRTICO (AC3): LA TRANSGRESIÓN DE LOS LÍMITES PLANETARIOS DEL ÁRTICO COMO ECOCIDIO BLANCO.

RESUMEN: El planeta tiene límites finitos, que han sido determinados y cuantificados por la investigación científica. En consecuencia, se ha demostrado que lamodificación y contravención de estos límites puede tener consecuencias irreversibles. Los daños causados al medio ambiente por las actividades humanas no han dejado de aumentar en los últimos siglos. Como consecuencia de estas presiones antropogénicas, ya se han superado seis de los nueve límites planetarios. A pesar de los esfuerzos de algunos Estados por aplicar medidas preventivas, asistimos a niveles crecientes de presión antropogénica en zonas de especial y vital importancia, como el Ártico. El Derecho internacional ha abordado algunos de estos problemas con mecanismos sectoriales o territoriales para hacer frente a los daños medioambientales, pero éstos han resultado ineficaces. Este trabajo aborda la construcción de un marco de vigilancia y sanción desde la perspectiva del derecho penal internacional, con un análisis riguroso de la importancia de este ecosistema para el planeta. Propone una nueva configuración de un delito de gran magnitude ecológica, el Ecocidio Blanco, que tiene el potencial de desencadenar consecuencias a escala planetaria.

PALABRAS CLAVE: límites planetarios, ecocidio blanco, Ártico, cambio climático, criminología verde

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SUMMARY: 1. Introduction. 2. The importance of the Arctic ecosystem for the planet. 3. Boundaries crossed and new scenarios. 3.1. Climate change 3.2. Loss of biodiversity. 3.3. Biogeochemical cycles. 3.4. Ocean acidification. 4. International ecological crime: from ecocide to white ecocide. 5. Discussion.

1. Introduction

The planet is often referred to as the 'blue planet' due to its composition, which is predominantly watery (Rossi, 2014). A robust scientific correlation has been identified between the capacity to withstand the prevailing climate crisis and the ramifications of the already documented planetary boundaries (Rockström et al., 2009; Steffen et al., 2015; Morelle-Hungría, 2022a; Mendelson et al., 2023). Furthermore, scientific evidence indicates the existence of areas and territories with heightened vulnerability, such as the Arctic (Sobrido Prieto, 2017), in the context of the current planetary decline, which is manifesting as an imbalance with attendant consequences (Hansen et al., 2011).

The socio-economic system currently in place, as devised by our species, has transformed the balance that has prevailed for centuries on the planet in ways that have never before been described. The alteration of biodiversity patterns has resulted in the destabilization of ecological processes (Ellis & Ramankutty, 2008). The extent of disruption is such that science has reached a point of no return in some of the limits that are necessary to ensure human operability in a safe environment (Rockström et al., 2009). This may appear to be a contradiction, but it is simply a statement that our species has acted with unparalleled self-interest, disregarding, both actively and through inaction, the consequences of these excesses to which we have subjected a planet that was previously in equilibrium. Despite the ecocentric shifts at the legal level (Colás Turégano & Morelle-Hungría, 2020), however, it can be seen that this has not been a radical transformation. As a result, the effectiveness of these measures cannot be described as positive.

This research is concerned with the analysis of the impacts of ecological damage, whether derived from risk or from human activities that have contributed to this planetary imbalance. To achieve this objective, a bibliographic search is carried out on the planetary boundaries that have been analyzed by the scientific community, with a direct or indirect relationship with the Arctic. We focus on the nine planetary boundaries established by Rockström and his team (Rockström et al., 2009; Steffen et al., 2015; Richardson et al., 2023). In-depth analysis will be conducted on several of these boundaries, with a particular emphasis on anthropogenic activities that have a significant and direct impact on Arctic ecosystems. Secondly, through a qualitative analysis of ecological damage, a broad concept of crime is constructed based on three parameters that define ecological crime at a planetary level: the extent, severity and duration of the ecological damage generated (Morelle-Hungría, 2024; Fuentes Osorio, 2021). In this context, our contribution is based on building a discourse with a scientific argument on the ecological damage inflicted on one of the most important ecosystems on a planetary level. The Arctic is one of the territories that must have a solid system of protection that guarantees not only its conservation. We cannot ignore the fact that it is a distinctive and vital territory to guarantee planetary welfare, since, as we will see, it encompasses the interspecies balance (Lancelotti, 2019).

2. The importance of the Arctic ecosystem for the planet

The Arctic represents a distinctive and unique territory, characterized by its ability to sustain sources of equilibrium. However, this very quality makes it both vulnerable and fragile. First of all, it is necessary to identify this familiar yet unknown territory. It stretches across the far north of the Earth, encompassing the Arctic Ocean and parts of countries such as Canada, Russia, Norway, Sweden, Finland, Iceland, Denmark (Greenland) and the United States (Alaska). It can be seen that this territory encompasses a wide variety of ecosystems, which have many similarities due to their common characteristics of low temperatures and the presence of extensive ice sheets, which undergo fluctuations in their extent and influence throughout the different seasons. This makes it possible to observe species that have adapted to these extreme conditions. This has been the case for centuries. However, it is evident that some of these characteristics have been affected by the impacts of human activity. This issue will be addressed subsequently; first, it is necessary to examine these characteristics in greater depth in order to understand the importance of this ecosystem for the planet.

The albedo effect is of great importance not only for the Arctic but is essential for the balance of the planet. The reflection of solar radiation off ice is an essential event for the maintenance of planetary temperature. It is necessary to maintain these environmental conditions through the adaptation of flora and fauna as they are integral to maintaining the existing balance. Some of these species are, for example, lichens, mosses and some shrubs that provide food for other herbivorous

animal species, such as caribou. It cannot be overlooked that arctic vegetation plays a key role in maintaining the soil balance. The aim is to show that these biotic and abiotic factors are connected, directly or indirectly. It turns out that permafrost is also an important reservoir of carbon, of which organic matter represents a substantial part, making it particularly relevant to our study. The melting of Arctic soil can lead to the release of carbon into the atmosphere, which contributes to an increase in greenhouse gasses such as carbon dioxide and methane. This activity increases the danger of global warming and thus also climate change, a process that is further accelerated by human activities.

It is beyond dispute that the principal threat to the Arctic is climate change. One of the consequences of rising global temperatures, which can be defined as global warming, is an increase in polar and permafrost melt. These consequences extend beyond the local species in the area, with global climatic ramifications. Furthermore, the exploitation of natural resources, including oil, gas and minerals, in conjunction with increased maritime traffic, represents an additional threat. The Arctic ecosystem plays a pivotal role in maintaining the planet's climate and ecological equilibrium. The conservation of the Arctic ecosystem is of vital importance, not only for the survival of the species that depend on it, but also for the maintenance of global climate stability.

The great white cap of the planetary north is of great interest and even essential not only for the planet's climate but also for its biodiversity. We cannot ignore the fact that this region is home to many ecosystems that are crucial to maintaining planetary balance. Moreover, it has been shown that Arctic ecosystems are among the most vulnerable in the world, due to their adaptation to extreme conditions and their sensitivity to climate change. It is therefore necessary to briefly discuss some of the ecosystems that make up the Arctic.

- Tundra is one of the most important terrestrial ecosystems in the Arctic region. It is a biome identified by the absence of tree vegetation. The most common species are mosses, lichens and low-growing shrubs. It is characteristically adapted to extreme cold and even to permafrost which is frozen throughout the year, an exception being observed on the surface in summer (Bliss & Matveyeva, 1992). This ecosystem also provides habitat for a variety of animal species such as caribou (Rangifer tarandus) and the arctic fox (Vulpes lagopus), which depend on this ecosystem for their survival (Chapin et al., 1992).

- The taiga, or boreal forest, is an ecosystem that can be considered of great interest, bordering the tundra to the south and extending northwards. This ecosystem is dominated by conifers such as pine and spruce, and is crucial for species such as the brown bear (Ursus arctos) and the moose (Alces alces) (Payette & Delwaide, 2003). Despite the fact that taiga is densest in subarctic areas, its edges in the Arctic are subject to climatic changes that affect its extent and biodiversity.

- Ice in the Arctic is essential, as we have indicated, for planetary maintenance. It turns out that the sea ice in this region functions as a reflector of solar radiation. This role directly influences the global temperature of the planet (Serreze and Barry, 2011). Arctic sea ice can be considered a true ecosystem, as it happens to be the main habitat of several iconic species, such as the polar bear (Ursus maritimus). This species depends on the ice for subsistence, for example to feed on other species such as seals and walruses (Odobenus rosmarus), and these species also employ this habitat by using the ice to rest between feeding sessions (Derocher and Stirling, 1995).

- The Arctic Ocean and its coastal areas are nutrient-rich marine ecosystems that support a great diversity of marine life, including whales, narwhals (Monodon monoceros) and seals (Tynan & DeMaster, 1997). The productivity of these ecosystems is dependent on the seasonal formation of sea ice, which affects food chains from phytoplankton to large predators (Moore & Huntington, 2008).

- Glaciers are one of the fundamental pillars of the structure of the Arctic region as they support the ice. They are also an important freshwater reservoir and play a key role in regulating sea level (Rignot et al., 2011). Global warming has directly affected glaciers and their melting causes a rise in sea level and the consequent release of carbon stored in permafrost and sea ice (Schuur et al., 2015). At certain times of the year, such as in summer, this melting creates new habitats such as rivers and lakes. It turns out that these freshwater bodies are of great ecological importance, as they are considered a new habitat that serves as a food source for arctic and other migratory species that depend on this area for breeding (Wrona et al., 2006).

Global warming causes sea ice to melt, resulting in an alteration of reflectivity, known as albedo. This change also leads to an increase in heat absorption in the oceans and thus accelerates global warming (IPCC, 2023). As we can see, this is cyclical and the result is a decrease in the amount of solar radiation reflected and an increase in the amount absorbed by the ocean, which serves to accelerate warming in the region (Screen & Simmonds, 2010).

Another essential feature in this region is observed in the ocean, influencing ocean currents such as the thermohaline circulation[1], which plays a key role in the distribution of heat around the globe. Changes in the salinity and temperature of Arctic waters, as a result of alterations to this cycle, alter these currents and this modifies weather patterns, resulting in extreme weather events (IPCC, 2014). These modifications and alterations in both temperature and ice cover in the Arctic can also alter the jet stream. This is a fast-moving air current that influences weather patterns, especially at low latitudes (Francis and Vavrus, 2012). These alterations can lead to extreme weather events even in other regions of the world, such as harsher winters or hotter summers, due to alterations in the behavior of the jet stream.

The biodiversity of the Arctic is of significant interest with regard to the maintenance of planetary equilibrium, both in marine and terrestrial ecosystems. This biodiversity is of particular interest due to its unique adaptation to the extreme climatic conditions of this continent. Despite the social recognition of its importance, this element is also being altered as a consequence of various anthropogenic pressures. Some of the anthropogenic variables that contribute to this situation of stress include global warming and ice loss, which are placing these ecosystems at risk and could have cascading effects on global biodiversity (Post et al., 2019). The following section presents a concise overview of potential scenarios that could emerge as a consequence of significant human impact on these ecosystems.

3. **Boundaries crossed and new scenarios**

The concept of planetary boundaries, as initially proposed by Rockström et al. (2009), delineates threshold values that can be identified as critical limits that must not be exceeded in order to avert irreversible environmental changes that could compromise the stability of the Earth system. It is important to note that the Earth system is in a state of constant equilibrium, which provides the planet with a certain degree of stability. The Arctic is a territory of particular importance, especially in terms of global climate regulation. However, some of the limits identified by researchers have been exceeded at the planetary level. This is of great importance as it can alter both local biodiversity, which can change the lives of indigenous communities, and also the global climate balance (Rockström et al., 2009; Steffen et al., 2015; Richardson et al., 2023).

The concept of planetary boundaries, according to scientific studies, identifies the nine key processes or points necessary for the maintenance of planetary stability. This approach provides a framework for understanding the so-called safe operating space for humanity and does so within the broader context of planetary sustainability. These processes include, but are not limited to, climate change, biosphere integrity, biochemical fluxes of nitrogen and phosphorus, and ocean acidification. As has been demonstrated, each of these processes has a threshold defined by the scientific community (Rocström et al., 2009; Steffen et al., 2015). Should this threshold be exceeded, there is a danger – with uncertainty – of destabilizing the prevailing balance on the planet. In the context of the Arctic, anthropogenic pressures at the global level have demonstrated a direct correlation with some of these limits. For instance, global warming has precipitated the accelerated loss of sea ice, which has also resulted in the melting of permafrost and the intensification of ocean acidification. These phenomena serve as evident indicators that several of these limits are undergoing alteration and even exceeding their established thresholds, as will be elaborated upon subsequently.

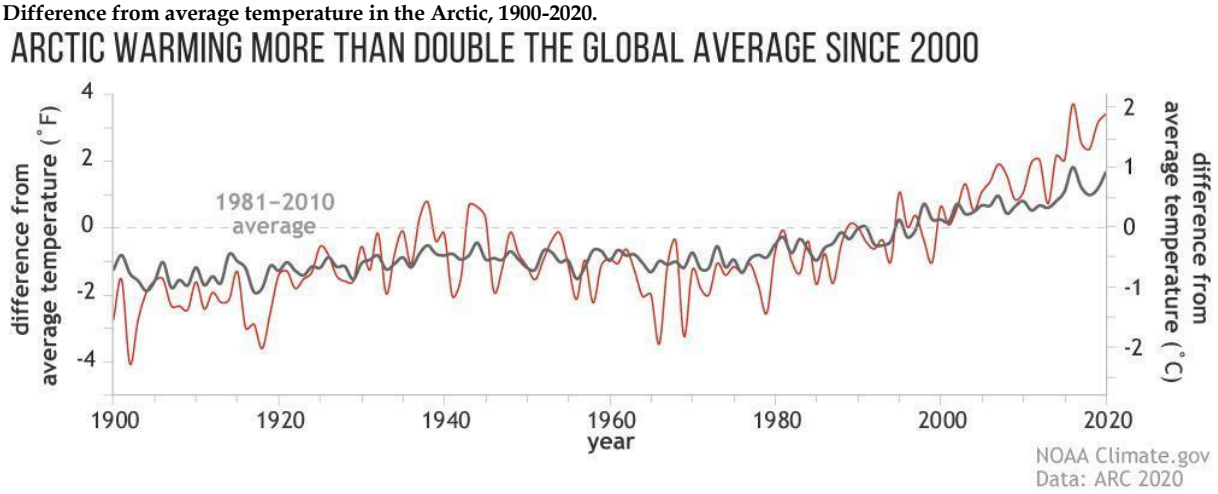
3.1. Climate change

Arctic amplification is an event in which the Arctic region records a higher temperature increase and thus a warming three times higher than the global average (Rantanen et al., 2022). In the last decades of the 20th century, Arctic temperature records revealed an alarming trend of accelerating warming (see Figure 1). As a consequence, it has been possible to observe the impact of this accelerated rate on sea ice, including

[1] The movement of ocean currents is primarily driven by differences in temperature and salinity across distinct water regions. This process is of great importance and is characterised by the sinking of cold water in the polar regions, particularly in the northern North Atlantic, where the circulation is often referred to as the Atlantic Meridional Overturning Circulation (AMOC), and in the vicinity of Antarctica. The theory of the thermohaline circulation was first proposed by Henry Stommel and Arnold Arons in 1960. Thermohaline circulation. Encyclopaedia Britannica, 9 August 2024. For further information,please refer to the Encyclopedia Britannica website:https://www.britannica.com/science/thermohaline-circulation.

seasonal variations in the retreat of this ice extent. This is due to the fact that warming is not a uniform process, neither spatially nor seasonally, and is affected by different parameters. The reduction of Arctic ice and alterations of the albedo effect have been shown to be directly correlated with global warming (Lenton et al., 2019). In addition, this phenomenon contributes to sea level rise and changes the Earth's weather patterns, leading to global climate change. New studies have found that rising mercury in the Arctic is linked to climate change (Segato et al., 2023).

Figure 1. Difference from average temperature in the Arctic, 1900-2020.



Source: NOAA available in https://www.climate.gov/media/11760

3.2. Loss of biodiversity

Climate change and increasing anthropogenic pressures have attracted the interest of several research fields. We cannot ignore the fact that the Arctic is home to a unique and particularly important biodiversity, including some species that are considered key to the state of the polar ecosystem (Post et al., 2013). The species and high biodiversity of this region are under threat, mainly due to anthropogenic alteration of Arctic ecosystems. Anthropogenic pressure has increased markedly, especially in this highly vulnerable and fragile territory. In addition, a phenomenon known as Arctic warming has been detected, which exceeds records elsewhere (AMAP, 2021). Some of the consequences of this warming have already been outlined. Sea ice melt, which has been identified as an ecosystem and habitat, especially necessary for the survival of certain species such as polar bears (Stirling and Derocher, 2012).

The exploitation of natural resources, including oil and gas, and industrial fishing are putting increasing pressure on Arctic ecosystems (CAFF, 2013). In addition, pollutants have been found to affect native species. It is important to remember that the Arctic is one of the most vulnerable regions to changes in the global climate system. The phenomenon of accelerated warming in this region, previously referred to as Arctic amplification, has resulted in a precipitous decline in sea ice, with considerable adverse effects on local biodiversity (AMAP, 2021). The loss of biodiversity in the Arctic has global implications, as previously outlined from a systemic perspective. The loss of biodiversity unique to the Arctic, such as the polar bear (Ursus maritimus), can represent a real ecological tragedy, disrupting food webs and impacting biogeochemical cycles and contributing to the instability of the Earth system (CAFF, 2013).

In addition to the above, if we take an anthropocentric view, the loss of biodiversity in the Arctic has a direct impact on the indigenous communities that depend on these natural resources for their livelihoods and affects their economies. These communities have developed ways of life, socio-economic models and systems that are closely intertwined with Arctic biodiversity. These activities are pushing Arctic ecosystems towards a tipping point beyond which recovery may be impossible or extremely difficult. We note that this limit, biodiversity, is linked to other limits, such as changes in land use or altered nitrogen and phosphorus cycles, as well as climate change, as discussed above. Anthropogenic activities also contribute to increased greenhouse gas emissions, which contribute to ocean acidification, which in turn affects marine biodiversity (Carson & Peterson, 2016). As we can see, these processes are interlinked.

3.3. Biogeochemical cycles

The vulnerability of this territory is an issue that needs to be highlighted. Especially because the effects of climate change have a more drastic impact on this region than on others. Rising temperatures cause permafrost to thaw, reducing the ice cover and expanding previously undisturbed areas (AMAP, 2021). This process emits large amounts of carbon and other gasses, such as methane, and contributes to global warming (Schuur et al., 2015). This process alters the carbon cycle, turning the Arctic from a carbon sink to a net source of emissions.

Furthermore, the nitrogen cycle has been affected by this rise in anthropogenic activity. The exploitation of natural resources, agricultural activities and the development of infrastructure have increased nitrogen deposition in soils, resulting in the eutrophication of local receiving waters and the transformation of aquatic and terrestrial species (Lamarque et al., 2013). Changes in biogeochemical cycles have a large-scale impact, affecting, in terms of system dynamics, the entire planet. In addition, alterations to the phosphorus cycle are being experienced as a consequence of changes in land use. The alteration of hydrological processes and phreatic erosion as a consequence of thawing permafrost has an impact on phosphorus by increasing phosphorus mobilization. This, in turn, contributes to eutrophication and changes in the primary productivity of aquatic ecosystems (Vitousek et al., 2013). With these alterations, trophic relationships in arctic ecosystems may be affected, posing an even greater risk.

The relationship between these biogeochemical cycles and land use change in the Arctic is directly linked. For example, the consequences described above, such as the melting of ice and the intensity of anthropogenic activities, will significantly alter the dynamics of essential nutrients such as carbon, nitrogen and phosphorus. These changes not only directly affect ecosystems and their members, but also contribute to climate change.

3.4. Ocean acidification

Ocean acidification poses one of the greatest threats to the long-term integrity of the planet's marine ecosystems, especially in this region. This is one of the planetary boundaries that has not yet been exceeded, but recent research suggests that we are on the verge of witnessing it (Morelle-Hungría, 2022a). Acidification is a process caused by the absorption of carbon dioxide (CO_2) from the atmosphere and is related to the alteration of other planetary boundaries (Rockström et al., 2009; Morelle-Hungría, 2022a). If at the planetary level it is a threat, the situation in Arctic ecosystems is even more worrying due to the higher CO_2 absorption capacity than in other oceanic areas, which serves to accelerate the acidification process and its associated ecological impacts.

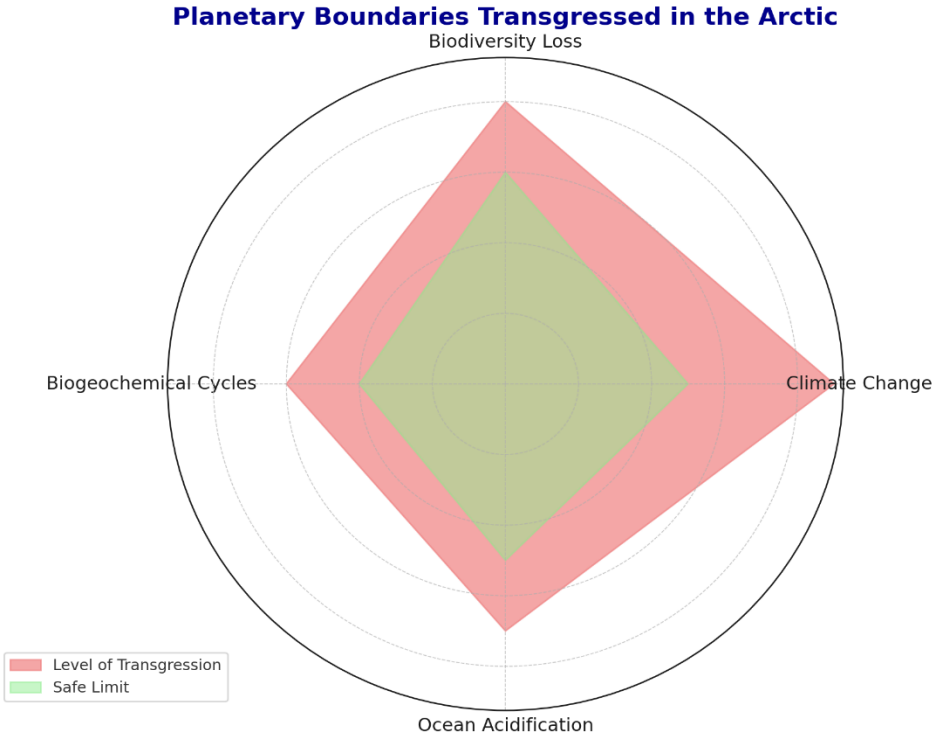
The altered CO_2 absorption is determined by the decrease in sea ice resulting in the exposure of a larger expanse of ocean to the atmosphere (AMAP, 2018). In this sense, the greater capacity of cold Arctic waters to dissolve this gas has a direct impact on this planetary boundary as it accelerates the acidification process compared to other oceans (Steinacher et al., 2009). This has an impact on certain organisms such as calcifiers, e.g. molluscs and certain types of plankton, which depend on calcium carbonate to form their shells and skeletons. Under conditions of higher acidity, the availability of carbonate is reduced, compromising the survival of these organisms and, consequently, the stability of marine food webs (Feely et al., 2009).

Morelle-Hungría (2022b) has emphasized the significance of ocean acidification as a discernible indicator of the dissolution of planetary boundaries, as evidenced by her research on Mediterranean acidification and its ecological consequences. Although the author has focused on biological systems in the Mediterranean, both the principles used and the consequences described could be applicable here. It has been shown that breaching planetary boundaries in terms of acidification not only threatens local biodiversity, but can also have large-scale and global implications, as it affects the ability of the oceans to act as carbon sinks and climate regulators.

Ocean acidification in the Arctic should therefore not be seen in isolation, but as part of a wider global crisis that is irreversibly eroding natural systems. The interaction between acidification and other stressors, such as rising water temperatures and changes in salinity, serves to exacerbate these risks, underlining the urgent need for global action to mitigate CO_2 emissions and protect vulnerable marine ecosystems (Morelle-Hungría, 2022a; AMAP, 2013).

Figure 2 shows how the four planetary boundaries have been breached in the Arctic, which is the threshold value that would trigger an international penal response.

Figure 2. Planetary boundaries transgressed in the Arctic.



Source: Adapted from Steffen et al. (2015); Rockström et al. (2009) - Own Elaboration

Source: Adapted from Steffen et al., 2015, Rockstrom et al., 2009 and Richardson et al., 2023.

4. International ecological crime: from ecocide to white ecocide

The Arctic is currently facing a critical state, which not only endangers this region but also has the potential to affect the entire planet, given the impact this could have on climate stability. Anthropogenic pressure on natural resources at a global scale has reached unprecedented levels, either because records are lacking or because they exceed available records. However, since 2009, several planetary boundaries have been crossed at the global scale, and the situation in this area is equally critical (Rockström et al., 2009). Despite the efforts of the international community, the mechanisms and legal instruments that have been set up have not been entirely effective in providing comprehensive protection[2]. It is therefore particularly important to set up a new scenario that takes into account scientific evidence in order to generate a protection framework that not only aims to conserve but also to provide a response that even includes the restoration of the damage caused or generated.

Some Arctic ecosystems act as a natural cooling mechanism on a planetary scale. This makes the Arctic region a valuable ally in the fight against global warming. However, based on the effects described above, it is clear that both the Arctic and the planet are undergoing rapid degradation due to human activities that have pushed several planetary boundaries. This degradation has implications beyond the regional level and has the potential to affect global climate stability. International mechanisms are therefore needed to address this issue. Based on a growing body of empirical evidence and supported by the proposal for a specific legal instrument on environmental crimes, the proposal aims to define and recognise the phenomenon of white ecocide as a form of ecocide that can and should be classified as an international crime.

As previously stated, planetary boundary theory identifies nine critical processes that regulate the stability of the Earth system. In the context of the Arctic, three of these boundaries have been significantly transgressed: climate change, biodiversity loss and altered biogeochemical cycles (Steffen et al., 2015;

[2] The Arctic environmental legal regime is constituted by a series of non-binding agreements, declarations of principles and policy guidelines. As previously stated in the introduction, this regime originated in 1991 with the Declaration on the Protection of the Arctic Environment and the Arctic Environmental Protection Strategy. The latter was subsequently incorporated into the work of the Arctic Council, which was established in 1996. However, the Arctic lacks a legal regime that binds states to common rules, resulting in the application of the laws of the eight countries with respect to their respective Arctic territories. (Zazzali & Rogovich, 2008).

Richardson et al., 2023). Arctic ecosystems can be used as a good system for measuring the planetary state of climate change since the Arctic amplification analysed by Serreze and Barry (2011, 2014) results in significantly higher temperature increases than those observed in other regions. The loss of sea ice directly contributes to sea level rise, changes in climate correlations, which affects biodiversity and, in turn, increases the overall global impact (Stroeve et al., 2012).. In the face of regulatory changes at the international level that increase holistic and integral visions, effective legal protection at the environmental level has not been achieved. While it is true that there are mechanisms at our disposal, we believe that their scope and application have been insufficient. In the following, we will briefly argue this assertion.

- The United Nations Convention on the Law of the Sea (UNCLOS) is a mechanism that provides a general framework for regulating activities in the oceans, including the Arctic. However, it is noted that the wording of some paragraphs is vague and can be vague with regard to Arctic-specific environmental protection. Furthermore, this instrument lacks direct enforcement mechanisms, allowing extractive activities to continue without rigorous control (Hoel, 2009).
- The Arctic Council is an intergovernmental forum that promotes cooperation between the Arctic states that have competence in the management of its member regions. It does not have the power to develop binding rules, nor does it have the capacity or resources to enforce its own recommendations. The lack of capacity and binding texts thus limits its effectiveness in protecting the Arctic environment (Young, 2012).
- The Agreement on the Prevention of Unregulated High Seas Fishing in the Central Arctic represents a promising initiative. In this regard, as it has limited effect, its focus solely on fisheries makes it inadequate to cover the threats mentioned above (Serdy, 2019).

The instruments described above are intended to protect the environment and we believe that they have been insufficient. Their effectiveness is limited. For example, the Arctic Council lacks binding mechanisms to enforce the environmental protection measures they recommend (Young, 2012). Similarly, the United Nations Convention on the Law of the Sea (UNCLOS), which establishes and incorporates a general framework for regulating some activities in the oceans, does not specifically address the unique needs of the Arctic, for example, nor does it impose effective sanctions (Hoel, 2009). It is thus imperative to establish a more robust mechanism, one that explicitly acknowledges the gravity of exceeding planetary boundaries and the necessity of international criminal prosecution in cases where such limits are transgressed. The Arctic, with its inherent vulnerability, serves as a case in point.

Despite the fact that a number of different proposals to recognise ecocide as an international crime have been put forward and defended over the last decades, none of them has been consolidated at the international level to become an effective instrument. Furthermore, none of the proposals has been consolidated at the international level to be implemented as an effective instrument. Of the proposals put forward, there are three that have generated the greatest consensus or debate, both in terms of their scope and in terms of the proposed definition of crime. For Higgins (2015) Ecocide is defined as,

> The extensive destruction, damage to or loss of ecosystem(s) of a given territory, whether by human agency or by other causes, to such an extent that peaceful enjoyment by the inhabitants of that territory has been severely diminished. (pp. 62-63).

We concur with Higgins (2015) on the destructive capacity of a territory's impact on ecosystems. However, we take a different stance on the peaceful enjoyment of inhabitants. We believe that the damaging capacity of the alteration caused by this conduct results in consequences of such intensity that peaceful enjoyment cannot be measured over a certain period of time. Furthermore, including this conduct in the Rome Statute would be ineffective as it would only apply to natural persons, not legal persons or states. Additionally, modifying this treaty would be challenging (Fernández Hernández, 2024).

We are convinced that Neyret's (2017) proposal is more accurate. This is not because of the definition itself, but because it takes a more rigorous look at the existing variables. This approach ensures that the response fully accounts for the complexity of the damage generated, contemplating a range of possibilities. The configuration of a double track, an International Criminal Court in environmental matters and an International Convention against Ecocide would undoubtedly be a great achievement and would significantly improve effectiveness if States made it a priority to tackle this conduct. We are convinced that the proposal made by Neyret (2017) in article 2 establishes that intentional conduct committed as a generalized or systematic action that affects planetary security can be conceived as ecocide. This proposal also incorporates numerous situations that undoubtedly give rise to this situation. For example, conduct that, when committed intentionally, represents an attack on planetary security. Furthermore, it explicitly addresses

an attack on planetary security, including substantial, permanent, and serious damage to the quality of the air, soil, water, animals, or plants, as well as the disruption of ecological functions. While there are many areas where we agree, there are also points of disagreement. One such point is the inaction of governments despite their knowledge of the serious consequences of ignoring scientific evidence. This issue is a major problem because, as Serra-Palao (2020) points out, it is necessary to change a whole economic model implemented at a global level in order to deal with this situation.

The proposal put forth by Stop Ecocide (2021) is to incorporate a new crime into the Rome Statute. To this end, the definition of ecocide is proposed to be "any unlawful or arbitrary act perpetrated in the knowledge that there is a substantial likelihood of causing serious, widespread or lasting damage to the environment". It is acknowledged that there are points of connection with previous proposals where there is agreement. However, reservations remain regarding both the substantive and procedural aspects of this proposal. The incorporation of this offense would be of little practical effect, and as we have previously observed, it would serve more as a symbolic gesture (Morelle-Hungría, 2021). There is a pressing need for the development of robust and effective defense mechanisms. As with Higgins' proposal (2015), amending the Rome Statute presents certain variables that could hinder its effectiveness. One such variable is the delimitation of the active subjects to natural persons, as the majority doctrine has pointed out (Neyret, 2017; Mwanza, 2018). It would be prudent to consider the implications of the aforementioned proposals as Serra-Palao (2019), Morelle-Hungría (2021), and Fernández Hernández (2024) in light of the fact that the Statute does not explicitly address the role of legal persons or the responsibility of states. Cuerda Arnau (2023), has indicated that the European Commission itself estimates that three quarters of environmental crimes are perpetrated by legal persons or companies.

Interestingly, in September 2024, member states of the International Criminal Court (ICC) formally submitted the crime of ecocide for consideration. This marked a key milestone in global efforts to recognise large-scale environmental destruction as a crime under international law. The proposal submitted was led by the island nations of Vanuatu, Fiji and Samoa, and defines ecocide as an 'unlawful or arbitrary act committed in the knowledge that there is a substantial likelihood of causing serious, widespread or lasting damage to the environment'. This definition, developed in 2021 by an Independent Expert Panel convened by the Stop Ecocide Foundation, has since gained significant legal and political support.

The ICC has been the only international tribunal with the authority to prosecute individuals in leadership positions for crimes such as genocide, crimes against humanity, war crimes, and the crime of aggression. If the proposed amendment to the Rome Statute is adopted, recognizing ecocide as an international crime, individuals responsible for severe environmental damage—such as massive oil spills, the destruction of river ecosystems, or large-scale deforestation—could face criminal prosecution. (Stop Ecocide, 2024).

Vanuatu formally submitted the proposed amendment to the ICC Assembly Working Group on Amendments. This support from Small Island Developing States (SIDS), including Fiji and Samoa, addresses the pressing need for environmental justice, especially for some of the nations highly vulnerable to climate change. The state was also the first country to advocate for international recognition of ecocide at the ICC in 2019. In recent months, significant progress has been made in advancing legislation against ecocide at both national and regional levels. In 2024, Belgium became the first country to criminalize ecocide in its national legislation, while the European Union introduced a 'qualified' ecocide-like offense in its new Environmental Crime Directive. In addition, countries such as Peru, Brazil, Scotland, Italy, and Mexico are moving forward with legislative initiatives to address ecocide. Globally, support for the criminalization of ecocide continues to grow, as demonstrated by the Global Commons Survey 2024, which found that 72% of respondents from the world's wealthiest countries endorsed the establishment of ecocide as an international crime. (Stop Ecocide, 2024).

Our proposal defines white ecocide as any act or omission, intentional or negligent, that causes or contributes significantly to the destruction or serious degradation of Arctic ecosystems that crosses any planetary boundary and has a significant impact on planetary stability. It is clear that there is no need for a specific offense in the Arctic; it is a subset of ecocide which, due to its unique characteristics, entails a set of specific consequences. In any case, the crossing of a planetary boundary would trigger a criminal response. It can also be considered an aggravated form of the crime if the safe space zone is exceeded and the point of no return is reached. We must be prepared to face obstacles, but we cannot allow this type of conduct to go unpunished. It is a crime against humanity with global impact. It is true that the scope of international criminal law has been questioned. Fernández Hernández (2024) argues that criminal sanctions do not necessarily have to be more effective, which is an incorrect assumption. The doctrine has been arguing that in matters of environmental protection, both control and sanctions at the administrative level are more effective than penal sanctions (Fuentes Osorio,

2021; Morelle-Hungría, 2024). However, it is necessary to establish quantitative values that serve as limits in order to delimit criminal offenses and thus activate a response based on rational criteria that will lead to greater effectiveness. It is therefore essential for our proposal to articulate that criminal activation at the international level is mandatory when a planetary boundary is crossed or transgressed.

Furthermore, in order to achieve real effectiveness in this area, it is necessary to establish a specialized international court or tribunal that focuses on ecological justice, given the magnitude and complexity of environmental crimes that transcend national borders. In this sense, some authors (Sands, Peel and Aguilar, 2012; Speth, 2004) have defended and argued for the creation of an international court for environmental crimes. In this context, it has been pointed out that the existing International Criminal Court would not be effective in dealing with such a wide range of environmental conduct. Similarly, we support Neyret's (2017) proposal that the Ecocide Convention should be endowed with a specialized court or tribunal. This would be a significant achievement on a global scale.

It is recommended that this court be empowered to investigate large-scale environmental crimes, including the proposed crime of ecocide, within its remit. It is imperative that this court is granted independence, along with the full capacity to impose criminal sanctions, including on the states and companies responsible. As a specific object of protection, the concept of planetary boundaries would be incorporated as a fundamental principle of the court's jurisprudence. Although some have argued that the planetary boundaries framework is lacking in legitimacy, we concur with Serra-Palao (2024) that 'The process of translating this theoretical framework of science into concrete policy goals, which necessarily requires public participation in the deliberative processes of democratic societies, has been criticized for lacking democratic legitimacy' (Biermann & Kim, 2020). Furthermore, collaboration with scientific organizations would enhance the effectiveness of this measure by ensuring that decisions are based on empirical evidence. Such a judicial body is necessary and imperative as the creation of such a specialized international court sends a clear and unequivocal message to the international community about the seriousness with which environmental crime is regarded.

5. Discussion

It is of the utmost importance that the construction of effective legal mechanisms incorporates scientific evidence in regulatory proposals. This entails establishing empirical law, particularly in the context of environmental protection. It is thus imperative to construct a regulatory and protection framework with an empirical basis and a global scope. It is imperative that the direct and indirect connections between the various natural systems are not ignored. As has been demonstrated, climate regulation can be indirectly affected by a causal relationship, as a result of crossing one of the planetary boundaries. It is therefore evident that international criminal law should not be oblivious to this variable, and that instruments of global scope should be configured, in order to ensure the viability of the aforementioned scientific evidence, it is necessary to integrate quantitative elements into public policies.

The response that must be articulated at the international level is so complex, given the ecological damage they can cause on a global scale, that we must articulate science-based instruments. The planetary limits mark a new horizon for the construction of legal instruments that we must take advantage of. To this end, it is essential to develop an effective instrument through international criminal law. The elaboration of an International Convention against Ecocide in this proposal is based on a clear scientific component, since the limits mark the turning point for activating the most forceful response. This is illustrated by the case mentioned above, which would trigger a criminal response at the international level. The definition of a conceptual framework for white ecocide, with the Arctic region as an example of a territory vital to maintaining planetary stability, requires an international response. But this is not enough; specialized environmental courts are needed, which is why the creation of an International Criminal Court, with a mandate to investigate and prosecute ecocide crimes, would be helpful and of particular interest, including because some conduct could have legal ramifications for companies, organizations and even states. This is of paramount importance in light of the potential scenarios that can be envisaged today. The creation of such an instrument will make it possible to include the so-called white ecocide among the crimes to be prosecuted as ecocide. This is why we propose this need, where the crossing of a planetary boundary implies a threshold that triggers an international criminal response.

Should the criminal response to the transgression of a planetary boundary be implemented, the case under analysis reveals a potential scenario that could prove catastrophic, given the consequences of overstepping such values. It is evident that six of the nine planetary limits have been exceeded. Consequently, we propose that, in light of the transgression of three limits in the current case, potential global consequences have been provoked. In accordance with the precautionary principle, it is imperative to take action, as we are confronted with a genuine threat of white ecocide,

which could result in irreversible planetary alteration and destabilization.

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References

AMAP (2013). Arctic Ocean Acidification 2013: An Overview. Arctic Monitoring and Assessment Programme (AMAP).

AMAP (2018). AMAP Assessment 2018: Arctic Ocean Acidification. Arctic Monitoring and Assessment Programme (AMAP).

AMAP, 2021. Arctic Climate Change Update 2021: Key Trends and Impacts. Summary for Policy-makers. Arctic Monitoring and Assessment Programme (AMAP), Tromsø, Norway. 16 pp

Biermann, F., & Kim, R. E. (Eds.). (2020). *Architectures of earth system governance: Institutional complexity and structural transformation*. Cambridge University Press.

Bliss, L. C., & Matveyeva, N. V. (1992). Circumpolar Arctic Vegetation. Arctic Ecosystems in a Changing Climate, 59–89. https://doi.org/10.1016/b978-0-12-168250-7.50010-9

Carson, M. & Peterson, G. (eds). (2016). Arctic Resilience Report. Arctic Council, Stockholm Environment Institute and Stockholm Resilience Centre, Stockholm. http://www.arctic-council.org/arr.

Chapin, F. S., Jefferies, R. L., Reynolds, J. F., Shaver, G. R., & Svoboda, J. (1992). Arctic Plant Physiological Ecology in an Ecosystem Context. Arctic Ecosystems in a Changing Climate, 441–451. https://doi.org/10.1016/b978-0-12-168250-7.50027-4

Colás Turégano, A. & Morelle-Hungría, E. (2021). El Derecho ambiental frente a los delitos ecológicos: la eficacia y eficiencia penal a debate. *Revista electrónica de ciencia penal y criminología*, *23*.

Comiso, J. C., & Hall, D. K. (2014). Climate trends in the Arctic as observed from space. *Wiley Interdisciplinary Reviews: Climate Change*, *5*(3), 389-409.

Cuerda Arnau, M. L. (2023). La justicia penal nacional frente al ecocidio: David contra Goliat (veinte años desde la catástrofe del Prestige). En Marullo, M. C., Sales Pallares, L. y Zamora Cabot, F.J. (dirs.). Empresas transnacionales, derechos humanos y cadenas de valor: nuevos desafíos. A Coruña. Pp. 167-191.

Derocher, A. E., & Stirling, I. (1995). Temporal variation in reproduction and body mass of polar bears in western Hudson Bay. Canadian Journal of Zoology, 73(9), 1657–1665. https://doi.org/10.1139/z95-197

Ellis, E. C., & Ramankutty, N. (2008). Putting people in the map: anthropogenic biomes of the world. *Frontiers in Ecology and the Environment*, *6*(8), 439-447.

Feely, R., Doney, S., & Cooley, S. (2009). Ocean Acidification: Present Conditions and Future Changes in a High-CO2 World. Oceanography, 22(4), 36–47. https://doi.org/10.5670/oceanog.2009.95

Francis, J. A., & Vavrus, S. J. (2012). Evidence linking Arctic amplification to extreme weather in mid-latitudes. Geophysical Research Letters, 39(6). Portico. https://doi.org/10.1029/2012gl051000

Fuentes-Osorio, J. L. (2021). *Delitos contra el medio ambiente*. Ad-Hoc.

Gruber, N., & Galloway, J. N. (2008). An Earth-system perspective of the global nitrogen cycle. Nature, 451(7176), 293–296. https://doi.org/10.1038/nature06592

Hansen, J., Sato, M., Kharecha, P., & von Schuckmann, K. (2011). Earth's energy imbalance and implications. Atmospheric Chemistry and Physics, 11(24), 13421–13449. https://doi.org/10.5194/acp-11-13421-2011

Higgins, P., Short, D., & South, N. (2013). Protecting the planet: A proposal for a law of ecocide. *Crime, Law and Social Change,* 59(3), 251-266. https://doi.org/10.1007/s10611-013-9413-6

Higgins, P. (2015). Eradicating Ecocide: Laws and governance to prevent the destruction of our planet (2ª ed.). Londres: Shepheard-Walwyn (Publishers)

Hoel, A. H. (2009). Do We Need a New Legal Regime for the Arctic Ocean? The International Journal of Marine and Coastal Law, 24(2), 443–456. https://doi.org/10.1163/157180809x421770

Intergovernmental Panel on Climate Change (Ed.). (2014). Climate Change 2013 – The Physical Science Basis. Cambridge University Press. https://doi.org/10.1017/cbo9781107415324

Intergovernmental Panel on Climate Change (IPCC). (2023). Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press. https://doi.org/10.1017/9781009157896

Lamarque, J.-F., Kyle, G. P., Meinshausen, M., Riahi, K., Smith, S. J., van Vuuren, D. P., Conley, A. J., & Vitt, F. (2011). Global and regional evolution of short-lived radiatively-active gasses and aerosols in the Representative Concentration Pathways. Climatic Change, 109(1–2), 191–212. https://doi.org/10.1007/s10584-011-0155-0

Lancelotti, C. (2019). Las humanidades y la promoción del bienestar planetario. *La maleta de Portbou. 2019;(37): 37-42*.

Lenton, T. M., Rockström, J., Gaffney, O., Rahmstorf, S., Richardson, K., Steffen, W., & Schellnhuber, H. J. (2019). Climate tipping points — too risky to bet against. Nature, 575(7784), 592–595. https://doi.org/10.1038/d41586-019-03595-0

Moore, S. E., & Huntington, H. P. (2008). ARCTIC MARINE MAMMALS AND CLIMATE CHANGE: IMPACTS AND RESILIENCE. Ecological Applications, 18(sp2), S157–S165. https://doi.org/10.1890/06-0571.1

Morelle-Hungría, E. (2020). Ecocriminología, la necesaria visión ecosistémica en el siglo XXI. *REC: Revista Electrónica de Criminología*, (3), 2.

Morelle-Hungría, E. (2021). La visión del" Ecocidio" desde la perspectiva de la Criminología verde y el derecho animal: nota acerca de la propuesta de inclusión de un nuevo precepto entre los que tipifican determinadas conductas humanas como crimen internacional. *Revista General de Derecho Animal y Estudios Interdisciplinares de Bienestar Animal: Journal of Animal Law & Interdisciplinary Animal Welfare Studies*, (8), 9.

Morelle-Hungría, E. (2022a). La acidificación del Mediterráneo y sus efectos sobre la Posidonia oceánica: una aproximación al daño ecológico desde los límites planetarios. REC: Revista Electrónica de Criminología, 5.

Morelle-Hungría, E. (2022b). Introducción a los límites planetarios desde la ecocriminología: análisis de la seguridad integral frente al cambio climático. Boletín Criminológico, (28). Recuperado de https://revistas.uma.es/index.php/boletin-criminologico/article/view/16054

Morelle-Hungría, E. (2024). El ecosistema como bien jurídico protegido en el artículo 325 del Código Penal: propuesta de una nueva configuración ecocéntrica integral del delito ecológico. *Revista electrónica de ciencia penal y criminología*, (26), 10.

NASA. (2020). The Climate Events of 2020 Show How Excess Heat is Expressed on Earth. https://www.nasa.gov/earth-and-climate/the-climate-events-of-2020-show-how-excess-heat-is-expressed-on-earth/#:~:text=The%20situation%20in%20the%20Arctic,is%20 warming%20three%20 times%20 faster.

Neyret, L. (2017). From Ecocrimes to Ecocide. Protecting the Environment Through Criminal Law. Cambridge: C-EENRG Reports 2017-2, Cambridge Centre for Environment, Energy and Natural Resource Governance, University of Cambridge. Disponible En: https://www.ceenrg.landecon.cam.ac.uk/report-files/report-002/view

Payette, S., & Delwaide, A. (2003). Shift of Conifer Boreal Forest to Lichen?Heath Parkland Caused by Successive Stand Disturbances. Ecosystems, 6(6), 540–550. https://doi.org/10.1007/s10021-002-0182-9

Post, E., Alley, R. B., Christensen, T. R., Macias-Fauria, M., Forbes, B. C., Gooseff, M. N., Iler, A., Kerby, J. T., Laidre, K. L., Mann, M. E., Olofsson, J., Stroeve, J. C., Ulmer, F., Virginia, R. A., & Wang, M. (2019). The polar regions in a 2°C warmer world. Science Advances, 5(12). https://doi.org/10.1126/sciadv.aaw9883

Post, E., Bhatt, U. S., Bitz, C. M., Brodie, J. F., Fulton, T. L., Hebblewhite, M., Kerby, J., Kutz, S. J., Stirling, I., & Walker, D. A. (2013). Ecological Consequences of Sea-Ice Decline. Science, 341(6145), 519–524. https://doi.org/10.1126/science.1235225

Rantanen, M., Karpechko, A. Yu., Lipponen, A., Nordling, K., Hyvärinen, O., Ruosteenoja, K., Vihma, T., & Laaksonen, A. (2022). The Arctic has warmed nearly four times faster than the globe since 1979. Communications Earth & Environment, 3(1). https://doi.org/10.1038/s43247-022-00498-3

Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S. E., Donges, J. F., Drüke, M., Fetzer, I., Bala, G., von Bloh, W., Feulner, G., Fiedler, S., Gerten, D., Gleeson, T., Hofmann, M., Huiskamp, W., Kummu, M., Mohan, C., Nogués-Bravo, D., … Rockström, J. (2023). Earth beyond six of nine planetary boundaries. Science Advances, 9(37). https://doi.org/10.1126/sciadv.adh2458

Rignot, E., Velicogna, I., van den Broeke, M. R., Monaghan, A., & Lenaerts, J. T. M. (2011). Acceleration of the contribution of the Greenland and Antarctic ice sheets to sea level rise.

Geophysical Research Letters, 38(5), n/a-n/a. https://doi.org/10.1029/2011gl046583

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., de Wit, C. A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., … Foley, J. (2009). Planetary Boundaries: Exploring the Safe Operating Space for Humanity. *Ecology and Society*, *14*(2). http://www.jstor.org/stable/26268316

Rossi, S. *El planeta azul: un universo en extinción*. Debate, 2011.

Sands, P., Peel, J., Aguilar, A. F., & MacKenzie, R. (2012). Principles of International Environmental Law. https://doi.org/10.1017/cbo9781139019842

Schuur, E. A. G., McGuire, A. D., Schädel, C., Grosse, G., Harden, J. W., Hayes, D. J., Hugelius, G., Koven, C. D., Kuhry, P., Lawrence, D. M., Natali, S. M., Olefeldt, D., Romanovsky, V. E., Schaefer, K., Turetsky, M. R., Treat, C. C., & Vonk, J. E. (2015). Climate change and the permafrost carbon feedback. Nature, 520(7546), 171–179. https://doi.org/10.1038/nature14338

Screen, J. A., & Simmonds, I. (2010). The central role of diminishing sea ice in recent Arctic temperature amplification. Nature, 464(7293), 1334–1337. https://doi.org/10.1038/nature09051

Segato, D., Saiz-Lopez, A., Mahajan, A. S., Wang, F., Corella, J. P., Cuevas, C. A., Erhardt, T., Jensen, C. M., Zeppenfeld, C., Kjær, H. A., Turetta, C., Cairns, W. R. L., Barbante, C., & Spolaor, A. (2023). Arctic mercury flux increased through the Last Glacial Termination with a warming climate. Nature Geoscience. https://doi.org/10.1038/s41561-023-01172-9

Serdy, A. (2019). The Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean: An Overview. Ocean Yearbook Online, 33(1), 401-417. https://doi.org/10.1163/9789004395633_016

Serra-Palao, P. (2019). Ecocidio: La odisea de un concepto con aspiraciones jurídicas. *Revista Catalana de Dret Ambiental*, *10*(2).

Serra-Palao, P. (2020). Cómo hacer frente a la impunidad ambiental: hacia una convención internacional contra el ecocidio". En Actualidad Jurídica Ambiental, núm. 100. Pp. 1-31.

Serra-Palao, P. (2024). Límites planetarios. En B. A. Camargo, R. G. Castillo-Villar, & L. E. Portales Derbez (Coords.), Enciclopedia de Sostenibilidad, Ética y Responsabilidad Social Empresarial en América Latina (pp. 559-565). Tirant lo Blanch.

Serreze, M. C., & Barry, R. G. (2011). Processes and impacts of Arctic amplification: A research synthesis. Global and Planetary Change, 77(1-2), 85-96. https://doi.org/10.1016/j.gloplacha.2011.03.004

Serreze, M. C., & Barry, R. G. (2014). *The Arctic climate system*. Cambridge University Press.

Sobrido-Prieto, M. *Espacios polares y cambio climático: desafíos jurídico-internacionales*. Tirant lo Blanch, 2017.

Speth, J. G. (2004). *Red Sky at Morning: America and the Crisis of the Global Environment*. Yale University Press.

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C. A., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. Science, 347(6223). https://doi.org/10.1126/science.1259855

Steinacher, M., Joos, F., Frölicher, T. L., Plattner, G.-K., & Doney, S. C. (2009). Imminent ocean acidification in the Arctic projected with the NCAR global coupled carbon cycle-climate model. Biogeosciences, 6(4), 515–533. https://doi.org/10.5194/bg-6-515-2009

Stirling, I., & Derocher, A. E. (2012). Effects of climate warming on polar bears: a review of the evidence. Global Change Biology, 18(9), 2694–2706. Portico. https://doi.org/10.1111/j.1365-2486.2012.02753.x

Stop Ecocide. (2024). *Mass destruction of nature reaches International Criminal Court (ICC) as Pacific Island states propose recognition of ecocide as international crime*. Stop Ecocide International. https://www.stopecocide.earth/2024/mass-destruction-of-nature-reaches-international-criminal-court-icc-as-pacific-island-states-propose-recognition-of-ecocide-as-international-crime

Stroeve, J. C., Serreze, M. C., Holland, M. M., Kay, J. E., Malanik, J., & Barrett, A. P. (2011). The Arctic's rapidly shrinking sea ice cover: a research synthesis. Climatic Change, 110(3–4), 1005–1027. https://doi.org/10.1007/s10584-011-0101-1

Thackeray, C. W., & Hall, A. (2019). An emergent constraint on future Arctic sea-ice albedo feedback. Nature Climate Change, 9(12), 972–978. https://doi.org/10.1038/s41558-019-0619-1

Tynan, C. T., & DeMaster, D. P. (1997). Observations and Predictions of Arctic Climatic Change: Potential Effects on Marine Mammals. ARCTIC, 50(4). https://doi.org/10.14430/arctic1113

Vitousek, P. M., Menge, D. N. L., Reed, S. C., & Cleveland, C. C. (2013). Biological nitrogen fixation: rates, patterns and ecological controls in terrestrial ecosystems. Philosophical Transactions of the Royal Society B: Biological Sciences, 368(1621), 20130119. https://doi.org/10.1098/rstb.2013.0119

Wrona, F. J., Prowse, T. D., Reist, J. D., Hobbie, J. E., Lévesque, L. M. J., & Vincent, W. F. (2006). Climate Change Effects on Aquatic Biota, Ecosystem Structure and Function. AMBIO: A Journal of the Human Environment, 35(7), 359–369. https://doi.org/10.1579/0044-7447(2006)35[359:cceoab]2.0.co;2

Young, O. R. (2012). Arctic Tipping Points: Governance in Turbulent Times. AMBIO, 41(1), 75–84. https://doi.org/10.1007/s13280-011-0227-4

Zazzali, J. C., & Rogovich, I. (2008). El Círculo Polar Ártico en tiempos del cambio climático. *Revista de Derecho Administrativo*, (6), 65-73.