Ecological Law in the Anthropocene

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ABSTRACT

The chapter examines how the Anthropocene's advent has affected the ability of humans to stop their activities from having negative ecological effects by applying legal controls to them. It finds that attempts to prevent actions from harming ecosystems through regulation have always been hampered by significant difficulties with predicting how ecosystems may react to disturbance. The Anthropocene elevation of human influence to the Earth system level exacerbates this situation by adding further layers of complexity and non-linearity to an already challenging position. This does not mean that relevant knowledge for ecological regulation is lacking. Section 2.1 identifies types of warning signs of growing vulnerability to disturbance that ecosystems have always given. The chapter calls for the adoption of laws for ecosystem protection under which duties are triggered automatically by warning signs. Adopting such a legal outlook would militate for international collaboration on reducing factors eroding ecosystem resilience, and, where possible, on restoring this property. A common response by States is needed in view of prevalent warning signs that all ecosystems are vulnerable to deterioration in their life-supporting capacity. Law's principal role under such a collaboration would be to facilitate urgent transition in the global economy and in ways of living away from an ecologically unsustainable present.

1. Introduction

Consideration is currently being given to formal definition of the Anthropocene as a unit within the Geological Time Scale in view of extensive human alteration of the Earth (International Committee on Stratigraphy). 'Anthropocene' is also used in several academic disciplines as a noun or adjective to signify that humans have become a force of change at the planetary scale (Castree 2014, Lövbrand 2015). This chapter adds to literature in legal scholarship using this second broader meaning (Kim and Bosselmann 2013, Kotzé 2014, Kotzé and French 2018). It does so by looking at what the extension of anthropogenic influence to the Earth and its sub-systems means for ecological law.

The chapter considers this question by exploring whether, and, if so, how the Anthropocene's advent has affected the ability of humans to prevent their activities from having negative ecological effects by applying legal controls to them. Section 2 argues that key aspects of the relationship between humans and ecosystems with regard to regulation have not changed. First, significant gaps remain in knowledge and understanding of ecosystem functionality, of how activities affect ecosystems, of how vulnerable they are to undergoing change, and of whether they are resilient enough to withstand future challenges. The gaps may be narrowed by scientific progress, but cannot be filled due to the complexity, non-linearity and dynamism of ecosystems and of the Earth System and socio-economic systems with which they interact. They prevent effective ecological regulation by reliance on knowledge and prediction of the extent to which human activities are already exposing and may in the future expose ecosystems to risk of change in their existing structures and functions.

Second, humans may not know how an ecosystem will respond to disturbance but do have knowledge from a number of sources which may indicate that an ecosystem is at risk of collapse. The relevant bodies of knowledge offer rare patches of solid ground in a sea of uncertainty. Policy-makers concerned with preserving ecosystems should therefore respond to them, and particularly as further 'warnings' indicating growing risk may not be forthcoming before the failure of affected ecosystems becomes inevitable.

Third, there is a requirement to move away from regulatory approaches which depend on accurate prediction of ecological effects and knowledge of the vulnerability of affected ecosystems to make finely balanced judgments on whether an activity is likely to be tolerable. They are not effective as a first-line response to anthropogenic ecological problems as they do not recognise the gap in knowledge and understanding at the heart of the human/ecosystem relationship. However, this is the approach which much current law aimed at ecosystem preservation employs. An alternative regulatory approach is proposed. It replaces reliance on the prediction of outcomes with laws which privilege and require a response to actual knowledge indicating that ecosystems may have become exposed to risk of collapse (see Section 2.1). Such warning signs trigger duties to bolster the resilience of the ecosystem concerned including by reducing anthropogenic pressures and taking restorative steps. Action should be taken as a matter of urgency in view both of the catastrophic consequences which an ecosystem's collapse has for species dependent on its functioning even if risks of this happening are small, and of an inability to discount, due to non-linearity, that the risk of failure of an ecosystem for which a warning sign has been given could already be substantial.

Section 3 identifies two ways of relevance to regulation in which the human/ecosystem relationship has been changed by the extension of human influence to the Earth System level. First, there has been a widening of the gap lying between human knowledge and understanding of ecosystems and of their response to disturbance due to the fact that human-driven change in ecosystems is now caused not only by direct disturbance but also by change in the Earth System and its components such as the climate system with which all ecosystems interact. Second, the Anthropocene has seen significant growth in bodies of knowledge which would be viewed as indicating under the regulatory approach proposed in Section 2.2 that ecosystem functionality may be at risk. The knowledge derives from comparison of human-driven change in climate, ocean chemistry and biodiversity with past episodes of alteration in planetary conditions for which we have knowledge of ecological effects as well as from evidence of negative ecological impacts that the change currently being experienced is already having. Section 3.1 considers what these two impacts of the Anthropocene mean for ecological law. It argues that they underline the need for a new approach to ecological regulation of the type proposed in Section 2.2. In addition, knowledge indicating that all ecosystems may have been placed at risk by planetary change elevates the problem of ecological deterioration to the global level. In doing so, it necessitates international commitments by states to collaborate on tackling the collective ecological threat which confront them if this is to be addressed effectively. I suggest that this should involve interstate cooperation on worldwide transition of socioeconomic systems away from unsustainable practices whilst working together on developing more sustainable ways of living which incorporate restoration of ecosystem resilience as a valued activity in economic models.

Ecological Law is understood for the purposes of this chapter as encompassing laws aimed at achieving goals which contribute to preserving and restoring the capacity of ecosystems to support life. It includes laws concerned with the conservation of components of ecosystems including species and their habitats and of ecosystems as a whole as well as those which regulate activities that may impact on the functioning of ecosystems in some respect. It also includes laws concerned with planetary systems and activities affecting them (e.g. the impact of greenhouse gas emissions on the climate system) as change in planetary conditions contributes significantly alongside excessive human exploitation to ecosystem deterioration. Ecological law may be a very broad category under this definition, but its breadth reflects the fact that systemic outcomes derive from the interaction of all living components of ecosystems with their non-living environments and external conditions as affected by the combined impact from human and natural sources of disturbance acting on them.

2. The Unchanged Human/Ecosystem Relationship

The term 'Anthropocene' denotes that humans have become a driver of planetary change, but this fact does not tell us how to respond to the new situation through ecological law. One of the roles of ecological law is to moderate the relationship between humans and ecosystems in order to achieve a desired outcome such as the continuity of an ecosystem's capacity to yield 'services' from which humans benefit (Keiter 1998, Woolley 2014). The key question therefore is how the Anthropocene has changed this relationship in ways affecting human ability to achieve ecological goals through law.

Answering it requires reflection both on the human/ecosystem relationship's fundamental characteristics and on how, if at all, they have been altered by humanity's planetary influence.

This line of thought reveals that ignorance of ecological conditions and of how anthropogenic disturbance affects them, a constant characteristic of the relationship throughout the presence of humans on the Earth, *has not changed*. Much has been learnt from millennia of direct experience about how excess exploitation can lead to the decline of valued outputs (Ponting 1991, Bosselmann 2017, 8-54). The emergence and development in the 20th century of ecology as a natural science discipline has seen significant growth in understanding of ecosystems, of how relationships between their components give rise to systemic outcomes, and of how change in the resulting systems affects their components (Worster 1995, Gaichas 2008). Even so, establishing the ecological effects of human activities with any accuracy remains problematic.

Human and natural impacts on individual ecosystem components combine to have a cumulative effect on the system. The fact that individual impacts take effect not directly but in combination with many others makes it hard to link them with or predict systemic outcomes (Woolley 2014, 21-23, Young 2001, 1-10, 46-59). The nature of ecosystems as complex adaptive systems adds to the difficulty with predicting how activities will affect them (Levin 1998, 431-2, Harris 2007, 19-27). Ecosystems are non-linear, meaning that outcomes are not proportionate to inputs and may occur long after the events giving rise to them (Levin 1998, 433, Harris 2008, 22, Walker and Salt 2006, 34-6). They are also dynamic, meaning that snapshots of ecological conditions and assessments of activities as being ecologically tolerable become obsolete as benchmarks against which precise statements can be made.

We know that ecosystems possess resilience, a property which enables them to retain their structures and functions in the face of disturbance (Woolley 2014, 27-37, Gunderson 2000). However, the complexity of interaction between living and non-living elements giving rise to systemic outcomes precludes exact knowledge of what contributes to resilience, of how resilient a system is at a point in time, of tipping points at which an ecosystem may be vulnerable to undergoing radical change, and of how close the system is to a tipping point. In addition, the impossibility of knowing the scale of future challenges that ecosystems may encounter and therefore of whether they are *resilient enough* to maintain structure and function in the face of disturbance would preclude such judgments even if the cumulative ecological effects of human activities in the present could be known with any accuracy (Woolley 2014, 31-2, Holling and Gunderson 2002, 32). The dynamism of ecosystems and of systems with which they interact call into question judgments that an activity is ecologically tolerable which do not take into account this temporal dimension.

Ecosystems do not disappear when disturbance overwhelms their resilience. They undergo a shift to a new regime with a structure and functions that differ from those of the preceding regime (Woolley 2014, 22-3, Walker and Salt 2012, 4-9, Chapin III, Matson and Vitousek 2009, 433-6). Resulting systems often have much reduced capacities to support a diversity of species and to provide humans and other species with 'services' that are essential for their well-being (Folke 2006, 257, Biggs, Peterson and Rocha 2018). A consequence of the non-linearity of ecosystems is that they may not themselves behave in ways indicating that a risk of collapse has arisen before a regime shift occurs (Hastings and Wystrom 2010, Scheffer 2015). Indeed, shifts have been known to become apparent only some years after having become unavoidable (Hawkins Bohn and Doncaster 2015, R667, Sguotti and Cormon 2018). This presents a particular challenge for regulation whether by reference to prediction of ecological effects or of an ecosystem's likely evolution.

2.1. Warning Signs

The factors outlined above make regulation of human activities by reference to knowledge and understanding of their ecological effects problematic. However, this does not mean that information enabling decision-making on whether intervention is required to preserve ecosystem functionality is completely lacking. A second circumstance which passage from the Holocene to the Anthropocene *has not changed* is that information on how some aspects of ecological and planetary conditions are evolving *is available*. Such information, although it would not support accurate assessment of how exposed an ecosystem is to collapse, does indicate that circumstances have arisen in which an ecosystem may have been placed at risk of failure. This may be because the information suggests that the resilience of ecosystems has already been significantly impaired and hence that they are vulnerable to lower levels of disturbance than would be the case if they were more robust; or that the magnitude of disturbance is rising to levels which ecosystems could find overwhelming, even if they are highly resilient; or both, as is increasingly the case in the Anthropocene.

Factors identified in ecological literature as potential indicators of risk to suggest three categories of such knowledge. First, a substantial body of theoretical literature in ecology uses general understanding of how ecosystems function and case studies to argue that certain types of deterioration evidence that an ecosystem may have become vulnerable to collapse (Keith 2013, Bland 2017). For example, the IUCN's Red List for Ecosystems project draws from this literature to propose four indicators of emerging risk, these being decline: in spatial occurrences of an ecosystem type; in an ecosystem's geographical distribution; of an ecosystem's abiotic environment; and of its characteristic biota (Keith 2015, Bland 2017, IUCN). The indicators are used as a basis for assessing whether ecosystems may be exposed to risk of undergoing a regime shift. Second, commentators in ecological science argue that the more diversity exists between species and within them in an ecosystem, the more resilient the ecosystem supporting this biodiversity is likely to be (Folke 2006, 253, Oliver 2015). One reason for this is that a highly diverse system is more likely to harbour species capable of performing key functions which are able to cope with changing conditions even if others performing the same function are unable to cope and are lost. Evidence that biodiversity is in decline in an ecosystem may be viewed as consistent with growing vulnerability to disturbance (Barnard 2012, Oliver 2015).

Third, knowledge of how the Earth and its ecosystems have responded to past change in planetary conditions allows conjecture about risks posed for ecosystem functionality by change currently being experienced (Steffen 2004). Relevant considerations include the comparative scales and rates of change. Change in systems with which all ecosystems interact such as the Earth's climate system may provide grounds for generic concern over their ability to withstand disruption of conditions to which they are adapted, and particularly where current change is found to be equivalent to past episodes which had negative ecological effects or to exceed them.

The value of information falling into the above categories is that it offers warning signs that ecosystems' ability to retain current structures and functions may be under threat. Those with policies aimed at preserving existing ecological capacities to support life should heed and respond to them if their commitments were made seriously. To do otherwise would be to ignore the only evidence which may become available to them that an ecosystem could be at risk of collapse in view of challenges with predicting ecological effects, and, indeed, with knowing whether or not a regime shift is imminent or has already occurred.

2.2. Reappraising Ecological Law

Prediction-dependent regulation is not effective for preventing ecological harm. The significant gaps in knowledge and understanding examined in Section 2 prevent precise judgments about the ecological tolerability of activities and actions under consideration. In any event, the dynamism of ecosystems and of the Earth System and socio-economic systems with which they interact raises questions about decisions based on knowledge of ecological conditions at a point in time, and particularly during a period of volatility in all of the systems concerned. It is surprising therefore that regulation based on the prediction of likely ecological effects remains a frontline component of efforts to protect ecosystems. Procedural environmental assessment laws assume that a proposal's anticipated environmental effects can be predicted reliably, thereby enabling relevant authorities to make decisions with knowledge of their likely environmental consequences (Morgan 2012). For example, the EU's Environmental Impact Assessment Directive, whilst it does not refer to ecosystems expressly, requires that each assessment should identify, describe and assess the direct and indirect significant effects of a project on biodiversity and its abiotic environment as well as on the interaction between them (European Union 2011, Art. 3(1)). They should cover not only direct effects of a project, but also its indirect, secondary and cumulative impacts (European Union 2011, Annex IV, para 5). Laws which place substantive requirements on actors to keep the cumulative effects of activities within the carrying capacity of ecosystems also assume that the knowledge is or will become available to make that possible. For example, the Marine Strategy Framework Directive aims at achieving good environmental status in the European Union's marine waters, a state of affairs in which 'the structure, functions and processes of the constituent ecosystems' allow them 'to function fully and maintain their resilience to human-induced environmental change' (European Union 2008, arts 1 and 3(5)). This is to be achieved by developing regulatory strategies based on an intensive programme of knowledge gathering about the condition of ecosystems and how sea uses are affecting them, an approach which I have argued elsewhere does not take into account sufficiently the gaps in knowledge and understanding noted at 2 above (Woolley 2015). I am not suggesting that these types of law should not be used in ecological regulation. As we have seen when discussing warning signs, relevant knowledge is of immense value for detecting when intervention to protect ecosystems is needed, and its acquisition should be promoted (Woolley 2014, 215-233). With regard to substantive requirements of the type mentioned above, preventing the cumulative effects of human activities from exceeding ecologically tolerable bounds is central to ecological law. However, the acquisition and use of knowledge must take place within a substantive legal context which recognises that much about the condition of ecosystems is unknown or unknowable and which grapples with this fact when determining appropriate responses to risks of their collapse.

How then should a regulatory approach which does recognise ignorance and dynamism be configured? The precautionary principle could assist with answering the question of whether this is a situation in which action should be taken despite scientific uncertainty, and, if so, what should be done. There are many variants of the principle, but some common features can be identified including direction that a lack of scientific certainty does not justify inaction (Wiener 2007, 602-5, Pyhälä 2010, 211-213, Wiener 2016 165-9). I argue elsewhere, drawing on academic scholarship on decision making under scientific uncertainty and on the knowledge outlined in Sections 2 and 2.1 above, that a precautionary analysis would lend strong support for urgent global action to support ecosystem functionality (Woolley 2019). However, the precautionary principle cannot be relied upon as a basis for developing laws that are consistent with the reality of the human/ecosystem relationship and are therefore suited to controlling human activities from an ecological perspective. A good argument can be made in the view of Sands et al that the basic formulation of the principle in the 1992 Rio

Declaration has become part of customary international law (United Nations General Assembly 1992, Principle 15, Sands 2018, 237-240), but this does not offer guidance on how parties should act in uncertain situations (Dovers and Handmer 1995, Pyhälä 2010, 213-221). To what extent should activities be constrained when full knowledge about their consequences is lacking? In addition, the principle is conceived of as a departure from a default position of decision-making made with the benefit of full scientific certainty (Pyhälä 2010, 204-5, de Sadeleer, 2010, 186-7). The reverse is true in the human/ecosystem relationship.

A focus on the reality of the human/ecosystem relationship offers a good starting point for finding a suitable alternative regulatory approach. Humans lack exact knowledge of the extent to which their actions have left an ecosystem vulnerable to deterioration and failure and, by the same token, of whether or not proposed activities are likely to be ecologically tolerable. Ecologists regard certain types of information as indicators that affected ecosystems may have entered a 'red zone' of exposure to significant risk of decline and deterioration ('warning signs'). A warning sign does not reveal the degree of risk to which an ecosystem is exposed, but this lack of information should not be viewed as justifying delay. Rather, it should be heeded as notice of a potentially serious threat of collapse which may not be repeated before this occurs in view of ecosystem non-linearity. Bearing these considerations in mind, regulation which corresponds to the reality of the human/ecosystem relationship should possess two attributes. First, it should privilege knowledge of the type considered in Section 2.1 as a basis for regulation of projects, plans and policies. Second, it should require regulated actors to respond to a warning sign by alleviating factors that may erode an ecosystem's resilience whilst simultaneously taking positive action to restore resilience if feasible. In effect, a warning sign is the Earth's signal to humans that an affected ecosystem should be placed in the recovery position.

3. Changes to the Human Ecosystem Relationship in the Anthropocene

The Anthropocene has brought two important changes to the human/ecosystem relationship. First, the fact that human activities are altering even more complex and less well understood planetary systems adds new layers of difficulty with predicting ecosystem behaviour. Sub-systems of the Earth System such as climate are also dynamic, non-linear and prone to crossing thresholds and entering new regimes without immediate evidence becoming available that a fundamental shift has occurred (Boardman 2010, 38-42, Steffen 2004, 6-9). Change in them can have significant negative impacts on ecosystems adapted to function within well-established parameters such as minimum and maximum temperatures and rates of temperature change (Montoya and Raffaelli 2010, Scheffers 2016). For example, the Intergovernmental Panel on Climate Change's report on Climate Change and Land of

2019 advises that '[i]t is very likely that terrestrial ecosystem and land processes will be exposed to disturbances beyond the range of current natural variability as a result of global warming, even under low to medium range warming scenarios, and these disturbances will alter the structure, composition and functioning of the system' (Jia and Shevliakova 2019). The effect of altered conditions on ecosystem components may impair an ecosystem's functioning and resilience. At the same time, it may, if it is of sufficient magnitude, cause a regime shift by overwhelming the ecosystem's resilience. Change in ecosystems may impact on planetary systems in turn due to relationships between them such as the role of natural greenhouse gas sinks in the climate system's functioning (Lenton 2017, 27-37, 84-7, Steffen 2004, 6-9). In view of these extremely complex interrelationships, the unprecedented rate and degree of change in climatic conditions currently being experienced adds significantly to problems with predicting the extent and timing of ecological effects.

Second, knowledge amounting to warning signs of ecological risk has grown dramatically since humans became responsible for altering the Earth as a whole. Most notably, information abounds in the previously unpopulated category of evidence that ecologically hazardous planetary change is occurring. With regard to climate change, studies of past episodes reveal that the warming experienced to date due to climate change is not unprecedented, but that the rate at which it is occurring is (Steffen 2016). The IPCC's 2014 climate assessment advises that '[w]arming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia' (Pachauri and Meyer 2014, 2). Current concentrations of carbon dioxide, methane and nitrous oxide are 'unprecedented in at least the last 800,000 years' (Pachauri and Meyer 2014, 4). It goes on to observe that future ecological risk is high as 'natural global climate change at rates lower than current anthropogenic climate change caused significant ecosystem shifts and species extinctions during the past millions of years' (Pachauri and Meyer 2014, 13, 51, 67). Brierley and Kingsford note that impacts of unprecedently rapid warming 'on marine organisms and ecosystems are likely also to be unprecedented' (Brierley and Kingsford 2009). They expressed concern in 2009 that marine ecosystems, even if their resilience is 'very great indeed', would struggle to retain structures and functions in the face of global warming to which the Earth was already committed by greenhouse gas emissions (Brierley and Kingsford 2009, R607).

Dramatic change affecting all of the world's marine ecosystems can also be found with ocean acidification, an effect of greenhouse gas growth in addition to global warming which is due to the solubility of carbon dioxide in salt water and lowers the alkalinity of the marine environment (Rockstrom 2009a). A report of 2013 by the International Geosphere-Biosphere Programme advises that acidity of the oceans has increased by 26% since pre-industrial times and that it is growing 10 times faster than at any time in the last 55 million years (IGBP 2013). The geological record evidences that acidification events which contributed to significantly negative impacts on marine species including extinction have occurred previously, but over a much longer timescale and at slower rates than at present (Andersson 2015). Andersson and his colleagues conclude that its unprecedented nature 'suggests that the current acidification event may have more severe outcomes than perturbations observed in the geological record'. Similarly, Honisch and his colleagues advise that 'the current rate of CO_2 release stands out as capable of driving' a potentially unparalleled 'combination and magnitude of ocean geochemical changes', and thereby of creating 'the possibility that we are entering an unknown territory of marine ecosystem change' (Honisch 2012, 1062).

The loss of biodiversity will vary from ecosystem to ecosystem, but it is arguable that this has reached a total rate and scale where it too can be regarded as a planetary-scale phenomenon (Rockstrom 2009b). The deterioration currently being experienced in biodiversity has been likened to the Earth's sixth great extinction event following on from others caused by non-anthropogenic planetary upheaval (Ceballos 2015). It raises concern over the Earth's ecological capacity to support life in view of the central contribution of biodiversity to ecosystem resilience mentioned at Section 2.1 above, and would do so even if the claim that biodiversity loss should be regarded as a planet-altering phenomenon is not accepted (Barnard 2012, Montoya and Raffaelli 2010).

The climate change currently being experienced would on its own constitute an actionable warning sign that ecosystems may be at risk of long-term harm under the regulatory approach proposed at Section 2.2. Ocean acidification and biodiversity would reinforce this conclusion, and could also support an argument in themselves that planetary-level change leaves all ecosystems exposed to risk of permanent decline. The fact that these planetary changes are occurring at a time when many of the world's ecosystems have already been made vulnerable to disturbance by human overexploitation and related loss in biodiversity adds to the case for arguing that risk of ecosystem failure has become endemic (Millennium Ecosystem Assessment 2005, World Wildlife Fund 2018). The principal consequence of this situation becomes apparent when we think about it in terms of the human/ecosystem relationship as described in Section 2. No basis remains following these global warning signs, and particularly when combined with those for individual systems, for confidence that ecosystems are able to support continued human exploitation of them at current levels without being driven to collapse. In such circumstances, the role of law concerned with preserving ecosystem functionality should be to require an urgent worldwide response to an existential threat for species at large rather than to try and keep the individual and cumulative effects of human activities within ecologically tolerable bounds, there being no basis for confidence when the reality of the human/ecosystem relationship is considered that they have not already been exceeded.

3.1 What does the Anthropocene mean for Ecological Law?

New approaches to ecological regulation are required irrespective of human influence on the Earth System for reasons discussed at Section 2.2 above. How, if at all, should the regulatory proposal made in that section be altered to address Anthropocene changes in the human/ecosystem relationship? The fact that humans are altering the Earth System in ways which are known to have had serious ecological impacts planetarily in the past would trigger requirements for ecological regulation everywhere in itself on the basis outlined in Section 2.2. In addition, it would necessitate a common response by all of the world's States at the international level to risks of collapse presented by Earth System change for ecosystems individually and collectively. Commonality is needed as any actions adding to drivers of Earth System change compound warning signs which would already be viewed as actionable under the new regulatory approach. This should involve treaty commitments by States to tackle drivers of the Earth System change at a rate commensurate with the goal of ecosystem preservation; and, as part of this, to preserve and restore ecosystems whose deterioration would lead to an acceleration of Earth System change (Woolley 2019). Many of the biosphere's ecosystems contribute to keeping planetary change in check to some extent due to the carbon regulation service provided by biomass-dominated ecosystems, particularly forests, by soil, and by ocean biomass (Lenton 2017, 29 and 85-7, Redgwell 2012, 132-3, Smith 2008). The functioning of all ecosystems is central to combating global decline in biological diversity if this can be regarded as an instance of planetary change. In addition, a strong argument can be made that such an instrument should include general duties to relieve ecological stresses in ecosystems and for restoration of their resilience as doing so supports ecosystem function in the face of Earth System change (Woolley 2019). Conversely, a parallel decline in resilience due to excessive exploitation makes it more likely that Earth System change will have negative ecological effects and that these will occur more quickly.

When considered in terms of the real human/ecosystem relationship examined in Section 2, the threat posed by the cumulative effects of humans living in centuries past, accelerating in the last eight decades, has reversed the relationship's polarity. The default position formerly was that humans had no reason to believe that ecological bounds may have been exceeded unless warning signs for individual ecosystems suggested otherwise. They are now confronted by overwhelming evidence that their actions have placed ecosystems everywhere at risk of decline and deterioration. An effect of this reversed polarity is to require an extension of ecological law's range so that, in addition to ecological regulation of activities, this is concerned with facilitating socio-economic transition away from practices that have led to the global overshoot with a view to maximising ecosystems' and their living components' prospects of survival in hostile conditions. Addressing inequity due to this shift in focus for peoples whose opportunities to improve living standards have been constrained by the excessive behaviour of others must also be a core aspect of ecological law now that its main concern is with restoration of ecosystem resilience rather than with attempting to strike an 'optimal' balance between the pursuit of socio-economic goals and environmental functioning. Programmes of stress reduction and restoration should be implemented as a matter of urgency due to a combination of warning signs at the planetary level, each one of which would be concerning on its own, from climate change, ocean acidification and massive decline in biological diversity, and to their coincidence with rapid and accelerating deterioration in the conditions of ecosystems worldwide.

4.Conclusion

Humans have blundered into a situation of worldwide threat to their ecosystem support base. The gaps in knowledge and understanding examined in Section 2 have contributed to this unfortunate situation. Alternative regulatory approaches are required to prevent human activities from further undermining ecosystem functionality despite ignorance over their cumulative effects. The Anthropocene highlights the urgent need to introduce effective ecological regulation. It also makes it necessary that this should happen not only at the ecosystem-level which would have sufficed historically, but at the international level due to impacts from Earth System change adding to those caused by direct exploitation. The development of detailed proposals for an international instrument for ecosystem preservation and for implementing laws at multiple levels should be a future focus for legal research concerned with formulating responses in law to the global ecological crisis.

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