On Capital's Watch: Derivative Ecology and the Temporal Logic of Biodiversity Credits

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Abstract: How is it possible to profit from protecting the environment, rather than through deepening its terminal crisis? In recent years, a growing group of investors, economists and governments have answered this question with a range of market-based instruments designed to facilitate the commodification and trade of everything from carbon to wetlands. A popular approach has been to establish ecological credit schemes that allow businesses to destroy a discrete ecosystem in return for the restoration of an ecological site elsewhere. Numerous scholars have already emphasised the questionable spatial politics inherent to such initiatives. Focusing on the UK's emergent biodiversity credit policy regime, this article, by contrast, considers what effect credit schemes have on the temporal dynamics of the ecosystems they capture. Drawing on discussions of financialisation in the social sciences, we show how biodiversity credits rearticulate ecosystems as units of 'derivative ecology', which makes the future of these ecosystems actionable in the present, at the same time as it restricts their capacity to adapt to anthropogenic climate change. When discussed alongside recent currents in ecological theory that emphasise novelty, futurity and resilience through change, the gap widens between ecological and financial approaches to restoration. Consequently, we argue that market-based instruments such as biodiversity credits are constitutively unable to embrace the futurity of ecology on its own terms, because they have their own temporal logic that cannot help but petrify their bearers of value.

Keywords: ecological finance, biodiversity, temporality, nature, environmental humanities

> While the manifold projects of capital, empire, and science are busy making Nature with a capital 'N' external, controllable, reducible – the web of life is busy shuffling about the biological and geological conditions of capitalism's process
>
> Jason W. Moore[1]

> […] the way to manage a resource is to stop its autonomous historical action. As long as trees make history, they threaten industrial governance.
>
> Anna Lowenhaupt Tsing[2]

1. Jason W. Moore, 'Wall Street is a way of organizing nature: An interview with Jason Moore,' *Upping the Anti: A Journal of Theory and Action* 12, May, 2011, p2–3.

2. Anna Lowenhaupt Tsing, *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins*, Princeton, Princeton University Press, 2015, p168. (Hereafter *The Mushroom*).

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INTRODUCTION

In 1983, the German ecologist Frederic Vester conducted a thought experiment in which he calculated the monetary value of a bluethroat, a small migratory bird that breeds in Europe and western Asia.[3] Vester demonstrated that the value of the bird is only around €0.02 when calculated purely on the basis of its material components such as feathers, bones and meat. Slowly factoring in a range of other criteria, the ecologist considered its diet, which consists mainly of insects, and how this amounts to a form of pest control. He also considers the capacity for the bluethroat to act as a bio-indicator for the health of the ecosystem it is living in, which adds another layer of value. A final consideration is the bird's potential to affect the wellbeing of humans, prefiguring more recent discussions of 'natural prescriptions' for a range of medical conditions.[4] When these values and others are factored in, Vester considers that the value is closer to an equivalent of €700 than €0.02. While his argument can be seen to demonstrate the absurdity of taking a one-dimensional approach to value, Vester does not oppose assigning a monetary value to species per se, but simply argues that if this is not done carefully the resulting price may not fully capture its total value.

If Vester's thought experiment seemed far-fetched in the 1980s, over thirty-five years later it now represents a relatively accurate, if basic, description of one aspect of environmental capitalism. In the intervening period the range of institutions involved in assigning monetary value to non-human species, and biodiversity as a whole, has expanded greatly. The scale of this marketplace is now truly vast. By 2018, thousands of credit and compensation schemes were active in thirty-seven countries, and in many of these countries legislation actively requiring their use was in full force.[5] It is estimated that the global transactions of mitigation bank credits and financial compensation totalled $4.8 billion in 2016, which is more than double the annual transactions five years previously.[6]

As market-based approaches to ecological restoration have spread, the chorus of criticism from a range of institutions and individuals has grown. In the first section of this paper we briefly review some of the academic critiques of what has been variously labelled the 'neoliberalisation of conservation' and the 'financialisation of nature'.[7] The majority of these analyses have emerged from the field of critical geography and consequently pay close attention to the spatial logic of how market-based conservation instruments operate. We argue that such instruments not only fold ecosystems into particular spatial logics, but also require them to march to the rhythm of specific temporal regimes, restricting their future development in the process. In order to emphasise the temporal aspect of the financialisation of nature, in part two we attempt to unearth a 'derivative logic' inherent to the operations of ecological credit schemes, taking biodiversity credits as a case study. The concept of derivative logic is drawn from the social sciences, where it is used to think through the

3. Frederic Vester, *Der Wert eines Vogels*, München, Kösel-Verlag, 1983.

4. Severin Carroll, 'Scottish GPs to begin prescribing rambling and birdwatching' *Guardian*, 5 October 2018. See also: Patricia Habasch, 'Prescribing nature: Techniques, challenges and ethical considerations' in M. Jordan and J. Hinds (eds) *Ecotherapy: Theory, Research and Practices*, London, Palgrave Macmillan, 2016, pp138-147.

5. Joseph William Bull and Niels Strange, 'The global extent of biodiversity offset implementation under no-net-loss policies', *Nature Sustainability* 1, 12, 2018, pp790-98.

6. Genevieve Bennett and Melissa Gallant, *State of Biodiversity Mitigation 2017: Markets and Compensation for Global Infrastructure Development*, Washington, Forest Trends, 2017, p4.

7. Dan Brockington and Rosaleen Duffy, 'Capitalism and conservation: The production and reproduction of biodiversity conservation,' *Antipode* 42, 3, 2010, pp469-84; Neil Smith, 'Nature as accumulation strategy,' *Socialist Register* 43, 2007, pp1-21. (Hereafter *Nature as Accumulation*).

8. Dick Bryan and Michael Rafferty, 'Financial derivatives as social policy beyond crisis,'

financialisation of a range of processes outside of the operations of finance narrowly defined.[8] We isolate three aspects of this logic as they work in and through biodiversity credits, looking in particular at how they bind the future to the present in particular ways. The final section of the paper looks to new approaches in ecological theory that emphasise the capacity for ecosystems to change in ways that exceed the linear models that previously dominated the field and which underpin their management as controllable resources. What emerges from this discussion is a friction between two modes of futurity, one stemming from the derivative logic of biodiversity credits; the other from ecological theory itself. In conclusion, we seek to pinpoint reasons why the two are fundamentally irreconcilable.

PLACELESS 'NATURE'

Biodiversity credits are part of a growing list of financial instruments that respond to ecological destruction through the market. Conservation credits of all kinds have been subjected to much criticism in academic debates. Scholars have critiqued the violence of abstraction that renders 'nature' – and its conservation – amenable to the process of capitalist valorisation by cutting it up into discrete but fungible services or parcels of habitat.[9] While the cutting process is 'functionally' problematic because it does not – and cannot – recognise the mutual interdependence of the purportedly discrete elements it isolates from one another,[10] a larger concern is the way it seems to decontextualise and separate 'nature' from its specificity and situatedness, particularly in regard to the socio-historical importance of place and 'the social ties between communities and particular habitats and ecosystems' (*Cutting Nature,* p25). The socio-political stakes of these processes crystallise in Apostolopoulou *et al*'.s observation that a credit scheme 'authorises nature's radical "rescripting" as *placeless*, obscuring the fact that it facilitates the production of space(s), place(s), and nature(s), according to the interests of developers'.[11] Spatial abstraction is thus the precondition for a conservation subordinated to accumulation in land development projects and other corporate initiatives associated with 'green grabbing'. At its worst, this gives the financialisation of nature a particularly neo-imperial character inasmuch as it enables large Western corporations to profit from a whole host of destructive activities in 'the West' by conserving nature(s) in the Global South. Drawing from critiques made by indigenous groups, Julia Dehm argues that the unseen consequences of such offsetting schemes is often the dispossession and exclusion of indigenous people from their environment in the name of conservation.[12]

Accordingly, the spatial techniques subtending ecological credit schemes are a crucial mechanism by which capitalism achieves what Marxist geographer, Neil Smith, has called the 'real subsumption of nature' by capitalism (*Nature as Accumulation,* pp28-29). Although, as Smith notes,

Sociology, 48, 5, 2014, pp887-903; Randy Martin, 'A precarious dance, a derivative sociality', *TDR: The Drama Review*, 4, 56, 2012, pp62-77. (Hereafter *Precarious Dance*). Randy Martin, *Knowledge LTD: Toward a Social Logic of the Derivative*, Philadelphia, Temple University Press, 2015 (Hereafter *Knowledge LTD*). Michelle Ty, 'Austerity and the speculative logic of derivatives', *Symploke*, 22, 1-2, 2017, pp133-48. (Hereafter *Speculative Logic).*

9. Evangelia Apostolopoulou and William M. Adams, 'Cutting nature to fit: Urbanisation, neoliberalism and biodiversity offsetting in England,' *Geoforum*, 98, 2019, pp214-225. (Hereafter *Cutting Nature*).

10. See Morgan Robertson, 'Measurement and alienation: Making a world of ecosystem services', *Transactions of the Institute of British Geographers*, 37, 3, 2012, pp386-401. (Hereafter *Measurement and Alienation*).

11. Evangelina Apostolopoulou, Elisa Greco, and William Adams, 'Biodiversity offsetting and the production of "equivalent natures": A marxist critique', *ACME* 17, 3, 2018, pp861-892 p877. (Herafter *Biodiversity*).

12. Julia Dehm, 'Authorizing appropriation? Law in contested

forested spaces', *European Journal of International Law*, 28, 4, 2017, pp1379-1396.

13. Such positioning of nature as external echoes discourses of rewilding, which, until recently, figure nature as an outside relatively untouched by human influence.

14. Perhaps the most vocal opponent of this approach is Andreas Malm, who in *The Progress of this Storm* argues forcefully against both constructivist and hybridist approaches to nature, society and the relationship between the two. Malm contends that it is essential to maintain a clear distinction between humanity and nature if we are to save the latter from environmental catastrophe. The problem, at least from our perspective, is that in drawing this line so forcefully, Malm shuts down the possibility of combatting the kinds of anthropocentric thinking that conceptually underpin the destruction of 'Nature' as he defines it. To speak of the latter as a construction does not necessarily deprive environmental activism of a focus for its activities, as Malm suggests, it simply compels us to 'take care of our abstractions', to speak with Whitehead, and pay attention to how the abstractions of nature and society in particular shift

capital has always 'incidentally' circulated through nature (in the process of agricultural production, for example), the real subsumption of nature describes capitalism's intensive production of nature(s) as an intended strategy to integrate the latter into capital by commodifying it 'all the way down' and financialising it 'all the way up'. Ecological credits thus reflect a new logic of capitalism, which is 'no longer content to simply plunder an available nature'. Rather, their procedures of cutting and commensuration underpin an on-going effort by capital 'to produce an inherently social nature as the basis of new sectors of [...] accumulation' (p33).

But if Smith's insights contextualise the role of ecological credits in capitalism's environmental turn, they also require some careful clarification. His distinction between a first 'available' or 'incidental' nature – seemingly external to society – and a second 'social nature' carries the significant danger of essentialising nature as an abstract entity outside the sphere of human culture, which only enters the latter as the result of its financialisation.[13] By contrast, a key insight emerging from the environmental humanities, albeit one not without its critics, is that our conceptualisations of nature are culturally conditioned, and ultimately inextricable from the social contexts from which they emerge.[14] As Jason Moore has forcefully argued, 'Nature' is not outside the sphere of human action, either spatially through notions of untouched wilderness, or temporally through an imagined Edenic past, but constructed by a capitalist modernity that shifts the boundaries of what is considered natural according to its own interests.[15] Considered in these terms, Smith's 'available nature' is neither prior nor external to the social but a consequence of relations instantiated by capitalist modernity and exacerbated by market-based conservation that produce 'nature' and 'culture' as separate entities.[16]

Consequently, we argue that the financially produced natures heralded by ecological credits are not so much the 'real' entry of nature into capitalism, but a new means by which the boundary between nature and culture is reimagined and further entrenched. What is distinct about the forms of financialisation represented by ecological credits is that they enable the production of an externalised nature at higher levels of abstraction, dematerialising it through 'the transformation of its sensual and embodied aspects into the transcendent zeros and ones of more easily manipulable digital information'.[17] Conservation credits are thus representative of a market environmentalism that, as Sullivan notes, facilitates the 'release of "nature value" from the world of embedded materiality to increasingly virtual realms' whilst also redoubling the separation of nature and culture made by capitalist modernity (p121). To be sure, this process of literally and figuratively uprooting nature from its embedded materiality predates the introduction of market-based instruments into conservation, but the latter nevertheless represents a new mode by which this abstraction takes place, bundling attributes derived from the already externalised nature constructed by modern, capitalist epistemologies.

In this respect, ecological credits harbour a set of processes that ensure features of an ecosystem are translated into a 'nature that capital can see', so that environmental destruction can be offset through market exchanges.[18] This has often taken place through the construction of nature as a set of 'ecosystem services', which can be paid for through market transactions. Accordingly, this increasingly hegemonic approach to ecological conservation ostensibly reframes nature as a 'corporation'; a provider of goods and services that can and should be priced and traded as commodities (*Ecosystem Service*, p116). This 'reframing' is predicated on the 'unbundling' of ecosystems into discrete services, or packets of services (*Measurement and alienation)*. But, crucially, the only goods and services that are visible through this economic prism are those provided by nature to humans. The ecosystem services approach is therefore constitutively anthropocentric. Through the interwoven techniques of ecological science, economics and financial mathematics, the 'nature-culture' that both surrounds and flows through a river, for example, is reductively reframed as a set of provisioning services (water, food etc.), regulating services (floods, droughts etc.) and so on, which can be quantified according to the size of the service and its quality and priced accordingly. In doing so, nature, as a set of services, is rendered as a fictional commodity.[19]

As well as the extraordinarily anthropocentric figuring of nature involved in its reification as services, equally striking are the ways in which different ecosystems thus become commensurable or fungible as equivalent bundles of services, which can be substituted across space. As Robertson notes in his study of a wetland credit scheme, the abstraction process that created the commodities allowed 'the 'wetland service' to escape from the messy physicality and uniqueness of the wetland itself' (*Measurement and alienation*, p374). The production of ecosystems as fungible entities lays the conceptual groundwork for any ecological credit scheme. It enables capital to make an economic costing of ecological destruction as the loss of a bundle of ecosystem services, which in turn can be offset by the purchasing of credits that ensure the restoration, enhancement and management of a similar set of ecosystem services elsewhere. The ecosystem services approach is part of the conceptual construction of 'earth as a giant abstract environmental 'ledger',' whose pages record the financial contributions that 'nature' makes to local, national and international economies (*Ecosystem Service*, p119). The logic often used by environmental capitalists to promote this approach is that such contributions can no longer be ignored as externalities, and the true price of environmental despoliation is finally incorporated into the calculations of those responsible for ensuring continued economic growth. This is no more so than in the case of biodiversity offsetting, which in recent years has become an influential method for financing and implementing conversation projects in the UK, following its widespread adoption in other countries such as Australia.[20]

in ways that may be unhelpful to climate activism in the future. See Malm, Andreas, *The Progress of this Storm: Nature and Society in a Warming World*, Verso, 2018.

15. Jason W. Moore *Capitalism in the Web of Life: Ecology and the Accumulation of Capital*. Verso, 2015, p17-18.

16. Even a cursory glance at non-western, indigenous cultures readily demonstrates that this separation is intellectually arbitrary. In Maori ecologies, for example, any attempt to distinguish between the natural and cultural world is untenable. See Krushil Watene, 'Valuing nature: Maori philosophy and the capability approach,' *Oxford Development Studies*, 44, 3, 2016, pp287-96.

17. Sian Sullivan, '"Ecosystem Service Commodities" - A new imperial ecology? Implications for animist immanent ecologies, with Deleuze and Guattari,' *New Formations*, 69, 2010, pp111-28. (Hereafter *Ecosystem Service*).

18. As Morgan Robertson demonstrates, producing a 'nature that capital can see' requires its 'articulation' through various processes of translation that pass through and bind together 'science', 'capitalism' and the 'state'. One obvious implication of this

AN EMERGING ARCHITECTURE FOR BIODIVERSITY TRADING IN THE UK

What do the smooth newt and the stoat have in common? Sharing very little by way of morphological characteristics, DNA, or ways of inhabiting the world, they are both deemed unprotected species in the UK. As a direct consequence of this, the habitat of one species is able to be legally destroyed as long as the other is enhanced. At least, so long as other avenues of mitigation have been exhausted, and the habitats of both species have been captured through a biodiversity offsetting scheme first.

Like many of the market-based instruments discussed above, biodiversity credits work on the basis that a reduction in a definable property of an ecosystem in one place can be compensated by the creation of gains in this same property in another location. In this case, the definable property is biodiversity itself. These schemes are primarily used by land developers to mitigate the environmental damage associated with development projects through the purchase of credits, which pay for either the improvement or expansion of ecological sites elsewhere. The aim of such exchanges is to ensure that there is 'No Net Loss' (NNL) and even, where possible, net gains to biodiversity, although there are currently moves towards abandoning the NNL principle and moving toward allowing only 'net gains'.[21]

Having gained a reputation for being less crude than an ecosystem services approach,[22] insofar as they are not so blatantly anthropocentric, biodiversity credits have their roots in the promotion of biodiversity in the 1980s.[23] Globally, the first biodiversity credit schemes emerged out of the neoliberal climate of the US in the 1990s, where commercial wetland mitigation banking and, later, species banking were seen as an alternative, market-based response to concerns around habitat loss at a time when government regulation and legal solutions were considered anathema.[24] In Britain, biodiversity offsetting first appeared in the late-noughties, taking shape within a similar policy environment as one part of a suite of responses to climate change that fitted neatly within prevailing assumptions regarding the virtues of the market and the limitations of state regulation.[25] In 2007, the Labour government introduced the idea of offsetting as part of a move towards creating markets for biodiversity. In 2009, it commissioned a study to understand how a biodiversity offsetting market might work in the UK.

Since the election of the coalition government in 2010, successive UK governments have continued to back biodiversity offsetting schemes as 'an option available to developers to fulfil their obligations under the planning [system]'.[26] Such endeavours have been supported by the UK Government's creation of six pilot schemes based across various locations in England, as well as the publication of a technical guidance paper, which includes a standardised metric, based on guidelines developed by the Business and Biodiversity Offsets Programme (BBOP), which stakeholders can use to quantify 'parcels'

point is that making a market function is not simply a matter of creating a product – in this case the biodiversity credit – but also a state-backed regulatory framework which can maintain property relations and so on. Later, our brief outline of the UK biodiversity market draws out some of this work of 'articulation' by signalling how different state and non-state actors have been involved in creating a functional offsetting system. See: Morgan M Robertson, 'The nature that capital can see: Science, state, and market in the commodification of ecosystem services,' *Environment and Planning D: Society and Space*, 24, 3, 2006, pp367-87. (Hereafter *Nature that Capital Can See*).

19. In *The Great Transformation*, Polanyi makes a historical argument that the emergence of a market economy in the late nineteenth and early twentieth centuries was predicated on its ability to produce fictional commodities. These are understood as entities and processes – primarily labour, land and money – that are not commodities in themselves, but are treated 'as if' they are commodities. Under the financialisation of nature we could expand Polanyi's list to incorporate not just land, but ecosystems in general. Karl Polanyi, *The Great Transformation*,

of biodiversity and exchange them as credits.[27] The document provides the technical blueprint for those hoping to develop credit schemes across the UK. Following the completion and evaluation of the pilot schemes, the UK Government is currently modifying its biodiversity offsetting policy, promising to produce a new iteration of the metric it published in 2012.[28] This new iteration promises new tools that can quantify biodiversity more accurately and automate the process of calculating credits.

And while the UK Government continues to go about the business of 'market creation', largely by enlisting local councils and planning agencies, organisations such as the Environment Bank have emerged to support this process.[29] Since its inception, the Environment Bank, which boasts investment from, among others, the Shell Foundation, has supported the development of a biodiversity offsetting market in a number of ways.[30] It has created registries of 'credit' or 'offset sites' – ostensibly parcels of land that can be improved or expanded to offset biodiversity losses, as well as to broker credit exchanges between developers and the owners of offset sites. In 2015, The Environment Bank brokered its first set of credits.[31] At the time of writing, it has either concluded or is in the process of concluding credit sales in Rugby, Warwick, and Cambridge, among other locations.[32] Even if biodiversity credits represent a reasonably new market for conservation in UK, the growing infrastructures that enable them to be established and traded indicate that their place on the climate change policy agenda in the UK is only set to increase.

Such a trajectory is not confined to the UK but instead reflects something of a global turn to biodiversity offsetting in environmental policy. There are now 12,983 known biodiversity offsetting schemes operating in thirty-seven countries under the NNL framework.[33] The EU's on-going efforts to promote the establishment of biodiversity offsetting schemes in conjunction with biodiversity banking are a central pillar of its own NNL initiative.[34] Britain's emerging biodiversity credit markets thus folds it into line with the rest of Europe regardless of on-going uncertainty regarding how Brexit may or may not influence environmental policy. Far from a niche concern, then, focusing critical attentions towards the operations of biodiversity schemes, particularly with respect to the kinds of ecology they enable and foreclose, remains an important issue both in Britain and beyond.

DERIVATIVES, DERIVATIVE LOGIC AND FINANCIALISED NATURES

The ability of biodiversity credits to enable the damage of one site to be offset by the conservation or enhancement of another speaks to a logic that is inescapably spatial. As mentioned above in relation to other ecological finance initiatives, this spatial logic works through the processes of abstraction which tends to cleave nature(s) from their specificity, and in the reproduction of boundaries between Nature and Society that serve as an important prerequisite to capitalist accumulation. But while such criticisms identify a lot of what is

Boston, Beacon, 2001.

20. The supposed success of biodiversity offsetting in Australia was one argument used by Owen Patterson, while Secretary of State for Environment, Food and Rural Affairs in the UK, for its adoption in the UK.

21. The Environment Bank, *Accounting for Biodiversity in Planning: A Toolkit for Local Planning Authorities in England*, 2017, http://www.environmentbank.com/files/eb-planning-toolkit-england-march2017.pdf [accessed 21 March 2019]. At present, the UK Government is consulting on whether to move toward a 'net gain' principle in regard to all development planning. This would likely ensure that any offsets purchased by a development project would have to see gains in the size and/or quality of a bio-diverse habitat in comparison with that which would be lost to development. See: Department for the Environment, Farming, and Rural Affairs (DEFRA), 'Net gain consultation proposals', December 2018: https://consult.defra.gov.uk/land-use/net-gain/supporting_documents/netgainconsultationdocument.pdf

22. For a discussion of the links between biodiversity and ecosystem services

at stake in the development of ecological credits, they also crucially miss the temporal dynamics that are also central to their functioning. In contrast, we argue that while ecological credits purportedly conserve nature in one space in return for its destruction in another, their purchase and exchange also signals the execution of a future-oriented temporal process that is essential to their functioning. Noting that such temporal processes are precisely what are at stake in the logic that characterises financial derivatives, we conceive of biodiversity credits as the product of this 'derivative logic' in order to think through this problem. To do so, we now contexualise and explain what should be understood by the term 'derivative logic'.

At their most basic, financial derivatives are contracts that price risk, and in doing so attempt to limit the effects of future contingencies that may adversely affect the price of a commodity. Although derivative forms such as forwards and futures have been around since the seventeenth century, it is only in the 1970s with the opening of derivatives exchanges and the formulation of new mathematical models for calculating the price of risk that they start to form into markets of unimaginable scale.[35] Derivatives have already become a crucial tool for businesses attempting to mitigate the risks associated with climate change to their business interests. For example, a burgeoning market in weather derivatives has become an important way for corporations to manage the effects that uncertain and unpredictable weather events might have on supply chains or production processes.[36]

In the last decade, financial derivatives have also started to enter the discussion of restoration ecology, conservation, and their financialisation. Mandel, Donlan and Armstrong for example make the case for integrating derivative products into species conservation efforts in the US, arguing that they can serve the dual purpose of minimising the costs of species conservation for governments, and creating incentives for land-owners who stand to lose money if a species on their land is classified as endangered.[37] Under their proposals, the government could issue biodiversity derivatives that would transfer the financial risk of listing a species as endangered to the market, with investors willing to take on this risk lured by the promise of high interest rates as long as the species population does not fall below a pre-defined threshold. More recently, Little et al. have introduced a new level of complexity by proposing the use of simulation models to forecast the future population levels of species, thereby offering a way to accurately calculate the price of the derivatives that would be used to protect these species.[38]

The use of derivatives to manage the potential risks associated with conservation is a small and much more experimental 'market' that is not nearly as widespread as the use of ecological credits such as those described above. Nevertheless, we argue that it is possible to discern a more general 'derivative logic' that permeates financial approaches to nature conversation, even in cases where derivative instruments themselves are not in use. In other words, we suggest that ecological credits, though not financial derivatives themselves,

see Science for Environment Policy, 2015, Ecosystem Services and the Environment. In-depth Report 11, produced for the European Commission, DG Environment by the Science Communication Unit, UWE, Bristol. Available at: http://ec.europa.eu/science-environment-policy

23. As David Takacs has noted, the history of the term biodiversity is rooted in the founding of the discipline of conservation biology in the late 1970s and 1980s, where it emerged as a way of bringing together scientific discourses regarding species extinction with older conservation ideologies including the protection of the 'wilderness'. By the early-1990s, 'biodiversity' enabled these concerns to be articulated in economic terms, insofar as diversity was figured as the background which supported and enriched economically valuable natures in the form of food, chemicals, ecosystem services, and so on. See: David Takacs, *The Idea of Biodiversity: Philosophies of Paradise*, Baltimore and London, The John Hopkins University Press, 1996.

24. William Adams and Evangelina Apostopoulou, 'Biodiversity offsetting in the UK: A beginner's guide,' *CESINE Policy Briefing*, 1,

harbour a derivative logic that when explicated pulls their dynamics into clearer focus.

The notion that a derivative logic operates in the context of conservation bears resemblance to the concept of 'derivative nature' proposed by Büscher, but crucially moves beyond it.[39] Büscher's argument is grounded in a discussion of ecotourism in South Africa where the idealised images of nature that circulate through branding initiatives, public relations and marketing serve as sources of value and investment for conservation initiatives. For the author, these images constitute 'representations of nature' that are derived from 'actual nature'. Büscher's intervention thus helpfully introduces a broader, conceptual notion of the derivative to think about the operations of market-based conservation. And yet, in doing so, the underlying asset for the derivative form appears to be needlessly essentialised. The rift opened up between an 'actual' nature and its representation replays the risk Smith takes in delineating a first 'incidental', external nature and a second which passes through the circuits of capital. By contrast, we would stress that the 'actual nature' denoted by the 'underlying asset' is not so much an essential nature but an already-externalised product of the Nature-Society distinction set in motion by capitalist modernity. This is not to claim that the resulting abstraction is not operative in the world, or perhaps even useful as a pole around which environmental activism might be organised. Rather, it is to reintroduce and problematise questions surrounding our responsibility for how conceptualisations of 'actual nature' might help or hinder the protection of those physical entities and systems that it groups together as a concept.

Moreover, in characterising 'derivative nature' as simply a secondary representation of an underlying asset, Büscher also passes over the complex operations required to render a derivative form. To elucidate these operations – and avoid the problematic tendency to essentialise nature – it is necessary to supplement political ecology with a set of conceptual resources made available by the notion of 'derivative logic' developed in the social sciences. This conceptual terrain brings the derivative operations required to render biodiversity credits into clearer focus. On the one hand, it allows a more complex analysis of the spatiality of derivative logic, one that enables the reintroduction of the spatial critiques of ecological credits delineated above. On the other hand, it introduces temporality as the key feature of derivative logic, which in turn enables an analysis that pays greater attention to the temporal dimension of ecological commodities. In short, the derivative logic of biodiversity credits brings together the bundling of fungible spatial attributes with the construction of a probabilistic future that transforms 'risk' into a resource available in the present.

To demonstrate this process, the following section draws out three central components of derivative logic and uses them to understand the complex operations required to produce biodiversity credits. In summary, these are 1) the process of disassembling and reassembling an underlying asset into

2016: https://www.geog.cam.ac.uk/research/projects/biodiversityeconomy/

25. As Dardot and Laval point out, the 'Third Way' pursued by the New Labour government between 1997 and 2010 was very much an attempt to squeeze traditional issues associated with the political left into an approach that did not disrupt the machinations of market forces. See: Pierre Dardot and Christian Laval, *The New Way of the World : On Neoliberal Society*, London, Verso, 2013.

26. DEFRA and Natural England, *Collections: Biodiversity Offsetting*, UK Government 2013, https://www.gov.uk/government/collections/biodiversity-offsetting [accessed 20 March 2019]

27. DEFRA, 'Technical paper: the metric for the biodiversity offsetting pilot in England,' 2012, https://www.gov.uk/government/publications/technical-paper-the-metric-for-the-biodiversity-offsetting-pilot-in-england [accessed 1 July 2018]. (Hereafter *DEFRA Technical Paper*).

28. Natural England, *Updating the Defra Biodiversity Metric*, Natural England 2018, http://publications.naturalengland.org.uk/publication/6020204538 888192 [accessed 20 March 2019).

29. A recent UK

Government consultation on Biodiversity Offsetting revealed that 42% of all Local Planning Agencies had now carried out some form of off-site compensation to mitigate environmental destruction. This includes ad-hoc species re-locations as well as the more standardised use of biodiversity offsetting. See: DEFRA, *Consultation on Biodiversity Offsetting in England: Summary of Responses*, DEFRA, 2016, p13, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/501240/biodiversity-offsetting-consult-sum-resp.pdf [accessed 13 March 2019].

30. See presentation by David Hill, Chair of the Environmental Bank, 'Environmental markets for ecosystem services in the UK: Scope, opportunity and challenge', http://www.environmentbank.com/files/pesenvironmental marketsforbes.pdf [accessed 19 March 2019]

31. The Environment Bank, *Newsletter, Spring 2016*, The Environment Bank, 2016, pp6-9, http://www.environmentbank.com/news/post.php?s=2016-05-24-spring-newsletter [accessed 21 March 2019].

32. The Environment

a bundle of quantifiable characteristics, 2) the way this bundle consequently acts as a double, or virtual representative of the underlying asset, and 3) the attempt, once the first two logical operations have been accomplished, to use the resulting creation to reduce the complexity and contingencies of the future. In undertaking the foregoing analysis, we show that a relatively sophisticated process is at work which allows biodiversity credits to authorise futures that purportedly contribute to avoiding irreversible diversity loss. Such claims should not be taken at face value, however, and the final sections of the article turn towards a critique of the futurity of biodiversity credits. There we argue that the futures authorised by biodiversity credits are severely limited and inadequate as a response to climate change, which requires a much more speculative and imaginative approach to ecology.

THE DERIVATIVE LOGIC OF BIODIVERSITY CREDITS

As Martin reminds us, the use of the term 'derivative' is not restricted to finance; it is used in fields as diverse as medicine, mathematics and music. In each case, it refers to 'the transmission of some characteristic from an originating source to a consequent site, or expression, or manifestation' (*Precarious Dance*, p65). This is the first aspect of derivative logic, and requires the disassembly of the originating source into a bundle of characteristics. Making a weather derivative, for example, involves the disaggregation of global weather systems into attributes such as temperature, frost, snowfall and wind speed.[40] In the agricultural sector, a metric known as 'growing degree days' (GDD) takes a specific aspect of the local weather conditions and uses it to predict the growth stages of a particular crop, the time that pesticides and fertilisers would be most effective, and even provide estimates of the life cycle of insects that may affect the crop. The attributes of the weather that are likely to affect the value of the asset in the future are measured closely, and their variability through time becomes the object of trading, speculation, and arbitrage.

At the same time, the derivative logic is always in some way assembling or (re)bundling its attributes together. Again, in the case of growing degree days, aspects of the weather are bundled together with aspects of the lifecycle of the particular crop they affect. The growth rate of a carrot, for example, may be isolated above other features of the plant (how the weather affects the way it tastes, its colour, etc.), and bundled together with a selection of weather variables that affect this rate of growth. Neither the weather in its entirety, nor all aspects of the carrot's life cycle are taken into account; rather, select features of each are isolated and assembled with one another. As disaggregation and recombination, the derivative logic thus 'speaks of a lateral orientation, which is an effect of intercommensurability' (*Knowledge LTD*, p76).

Already one can begin to see how this process of disaggregation and recombination recalls the 'spatial' critique of ecological credits referred to above. There, it was shown that the creation of ecological credits required the disaggregation of an ecosystem into a bundle of fungible, interchangeable services. By reading biodiversity credits through the lateral possibilities of 'intercommensurability' afforded by derivative logic, it is possible to see how the dual process of disaggregation and recombination, of cutting apart and blending, operates at several different moments.

Like other ecological credits, biodiversity credits rely on a similar kind of mechanism to integrate 'biodiversity' into the logic of capital. Methods of quantification render an 'ecological equivalence' so that biodiversity destruction in one site can be compared and exchanged for gains in the 'credit' or 'offset' site (*Biodiversity*, p27). In the UK, the conceptual heavy-lifting required to render 'biodiversity' into units of tradeable credits is performed by the aforementioned 'biodiversity metric' adopted by the UK Government.

At one level, the biodiversity metric disaggregates and recombines 'biodiversity' into measurable quantities of particular attributes that correspond to, and thus attempt to value, its uniqueness and ecological importance within discrete parcels of habitat. Biodiversity is measured through the attribute of 'distinctiveness', a quantifiable score which is itself calculated through the aggregation of sub-attributes such as species richness, diversity, and rarity within a standardised unit of land.[41] The more distinct a parcel of habitat is, the higher its score. 'Distinctiveness' is then multiplied by the quantified 'condition' of the site to calculate the number of biodiversity units per hectare of habitat (*DEFRA Technical Paper*, pp6-7). Highly distinctive sites in excellent condition will score higher than more commonplace sites in poor health. Here, intercommensurability refers to the ways that specific attributes can be blended together through their multiplication as quantified numbers.

On another level, however, these metrics enact a process of abstraction that enables both development and offset sites to become equivalent as parcels or units of biodiversity that can thus be compared according to their scores. Methods of quantification render an 'ecological equivalence' so that biodiversity destruction in one site can be compared and exchanged for gains in the 'credit' or 'offset' site. But it is important here to point out that while the metric itself generates an abstraction that makes all plots of biodiversity commensurate, the execution of a credit also ties the fate of one specific space to another. In this respect, the intercommensurability of biodiversity credits does not simply 'remove the place specificity of nature'; insofar as it concretely ties the fates of two seemingly unrelated spaces together, it also then re-establishes specificity on entirely different terms.[42]

Needless to say the isolation and recombination of a bundle of attributes does not eliminate those attributes of the underlying asset that are unquantified, or unquantifiable. Isolating temperature as it affects the life cycle of a carrot does not mean that other features of either the weather or the carrot simply disappear. Likewise, tracking the population numbers of

Bank, 'Building the foundations of a restoration economy – raising investment for habitat banks. Webinar presentation slides,' The Environment Bank, 2019, http://www.environmentbank.com/files/the-value-of-habitat-banking-jan19.pptx.pdf. [accessed 19 March 2019].

33. Joseph William Bull and Niels Strange, 'The global extent of biodiversity offset implementation under no-net-loss policies', *Nature Sustainability* 1, 12, 2018, pp790-98.

34. GM Tucker et al., *Supporting the Elaboration of the Impact Assessment for a Future EU Initiative on No Net Loss of Biodiversity and Ecosystem Services: Report to the European Commission*, London, Institute for European Environmental Policy, 2016, http://ec.europa.eu/environment/nature/biodiversity/nnl/pdf/NNL_impact_assessment_support_study.pdf [accessed March 21 2019].

35. Jakob Arnoldi, 'Derivatives: Virtual values and real risks,' *Theory, Culture & Society*, 21, 6, 2004, pp23-42.

36. Melinda Cooper, 'Turbulent worlds: Financial markets and environmental crisis,' *Theory, Culture and Society* 27, 2, 2010, pp167-90 (Hereafter *Turbulent Worlds*). Michael Pryke, 'Geomoney: an option on frost, going long on clouds,' *Geoforum* 38,

an individual species does not automatically entail that its entanglements with other species are severed. Rather, the attributes blended together by a derivative continue 'to bristle with reference' (*Precarious Dance,* p116). What emerges is a process of doubling, whereby a bundle of attributes acts as a metonym for a whole that is nevertheless affected by the manipulation and trading of these attributes. This act of doubling an underlying entity is the second feature of derivative logic we wish to highlight. As Martin puts it, 'Derivatives, in the very manner in which they come to be, *reference a double life*: they are reinventions of things for themselves into matters of interest to others, of local capacities viewed from the perspective of global attentions, of future prospects seen as present opportunities'(pp66-67 italics added).

In the case of biodiversity credits, the doubling enacted by metrics renders biodiversity not only visible for local authorities, land developers, offset site owners, and brokers such as the Environment Bank but also composes it for them as a site of action. The metric is thus a doubling that, to recall Robertson's phrase, produces a 'nature capital can see'. In its simplest terms, the 'derivative ecology' produced by the biodiversity metric allows fairly abstract worries about habitat loss to be turned into quantifiable measures that 'double' for biodiversity, and which thus become the 'site' where concerned actors can mitigate against these losses through the purchase of credits.

But, importantly, the derivative construction of an already-externalised nature instigated by biodiversity credits is not simply an abstraction process with no material effect on the Nature from which it is composed. Rather, the 'underlying asset' is affected by the transaction of a credit, which initiates a process of destruction in one site in exchange for ecological practices on another. These latter processes are designed to gradually improve the offset site through the proxy of the unbundled attributes measure by the biodiversity metric. Here, the concepts of 'distinctiveness' and/or 'condition' come to shape the ways in which offset sites are developed, insofar as they become the measures by which the success of a credit exchange is measured.

The invocation of process made here alludes to the temporal dimension of credit schemes. Biodiversity credits (and other ecosystem commodities) do not simply create interdependencies across different places (the dependency of one ecosystem's assured destruction on the availability of another worthy of protection), but also create interdependencies across different times. After all, when a developer purchases an ecological credit, they are not purchasing the land itself, but paying for a process on an offset site that either seeks to improve its condition or expand it across more space over a specific period of time. For example, the purchase of biodiversity credits might restore a highly distinctive but poorly managed offset site to an excellent condition over an agreed period of time.[43] Value is thus located in the temporal process itself, and, consequently, the temporality set in motion by ecological credits requires at least as much critical attention as their spatiality

These temporal dynamics are already a key concern for stakeholders

3, 2007, pp576-88; Jo Bates, 'Climate risk, big data and the weather market', *SPERI Paper* 13, 2014, pp1-16.

37. James Mandel et al, 'A derivative approach to endangered species conservation,' *Frontiers in Ecology and the Environment*, 8, 1, 2010, pp44-49.

38. Richard Little et al, 'Environmental derivatives, risk analysis, and conservation management,' *Conservation Letters*, 7, 3, 2014, pp196-207. Other discussions of the use of derivatives in conservation efforts include Dalton, R. 'Fishy futures,' *Nature*, 437, 2005, pp473-474; Eli P Fenichel et al, 'Real options for precautionary fisheries management,' *Fish and* Fisheries, 9, 2008, pp121-137; Sian Sullivan, 'Banking nature? The spectacular financialisation of environmental conservation,' *Antipode*, 45, 2013, pp198-217.

39. Bram Büscher, 'Derivative nature: Interrogating the value of conservation in "Boundless Southern Africa".' *Third World Quarterly*, 31, 2, 2010, pp259-76. (Hereafter *Derivative Nature*).

40. Erik Banks, *Weather Risk Management: Markets, Products and Applications*, New York, Palgrave Macmillan, 2001.

41. The way in which this score is calculated throws up a number of

in the UK's burgeoning biodiversity market, whose discussions revolve around the time scales appropriate to the establishment, enhancement and maintenance of offset sites and their associated risks. A fundamental issue is defining the length of time a biodiversity credit will last. If development projects necessarily destroy their sites both irreversibly and indefinitely, there is a compelling argument that conservation credits should also restore and maintain offset sites indefinitely. But while DEFRA recommends that offset sites are managed in perpetuity, it also makes allowances for some rather vague 'practicalities' (*DEFRA Technical Paper,* p15). Such practicalities are clarified by the Environment Bank, which argues that indefinite management of an offset site runs the risk 'of becoming exorbitant in terms of development viability'.[44] The Bank recommends offsets are managed for a minimum of twenty-five years but 'not necessarily in perpetuity'. These questions of temporality foreground the capitalist dynamics inherent in biodiversity credit schemes: a credit unleashes a specific temporality in motion, which, even while it provides an opportunity for accumulation, is also a financial risk that needs to be managed.

This relationship between temporality and risk is the third defining feature of derivative logic. Just as derivatives double their underlying assets into bundles of attributes of lesser complexity, they also reduce the complexity and contingencies of the future to a collection of symbolic units that become meaningful, manageable and tradable.[45] Through derivatives, the uncertainty and risks of the future can be embraced and mitigated by the exchange of contracts. A weather derivative, for example, may enable a company to mitigate and even profit from the risks associated with unpredictable weather events (*Turbulent Worlds*). Indeed, as Melinda Cooper notes, the pre-emptive power of financial derivatives has now transformed the turbulence engendered by unpredictable events – be they financial, political or meteorological – into opportunities for profit-making. From this perspective, derivatives turn 'the otherwise impracticable notion of temporal manipulation into a socially objective fact' (*Speculative Logic*, p140).

As the bearers of their own derivative logic, biodiversity credits are also designed (in a similar if not entirely identical way to the examples above) to embrace the risks of unpredictable futures. In general, the temporal risks associated with offsetting are integrated into biodiversity credits through multipliers that are designed to price in the uncertainty involved in the restoration or expansion of the offset site, which, after all, may or may not succeed. For example, the UK Government's guidelines recommend the use of a multiplier in order to try and account for 'the difference in time between the negative impact on biodiversity and the offset reaching the required quality or level of maturity' (*DEFRA Technical Paper*, p13).[46] Moreover, DEFRA expects that planning authorities, brokers and developers can calculate the risks of failure, including the time taken for offset habitats to develop, and thus 'work out the necessary multiplier to achieve a suitable level of confidence'

questions, such as the precise meaning of 'richness', why it is considered by DEFRA as a sub-attribute of distinctiveness, and how richness differs from other attributes such as condition. See Jo Treweek et al, 'Biodiversity offsets: Possible methods for measuring biodiversity losses and gains for use in the UK', *In Practice*, 69, 2010, pp29-32.

42. Evangelia Apostolopoulou and William M. Adams, 'Biodiversity offsetting and conservation: reframing nature to save it,' *Oryx*, 51, 1, 2017, pp23-31. (Hereafter *Offsetting*).

43. The Environment Bank, 2017, op cit.

44. The Environment Bank, 2017, op cit., pp26-27.

45. Michel Aglietta and Régis Breton, 'Financial systems, corporate control and capital accumulation,' *Economy and Society* 30, 4, 2001, pp433-66.

46. Another way to address this difference in time is through the practice of 'advanced offsetting', where the offset site can be prepared *before* the impact of the development is felt. The aim is to ensure that no net loss occurs to biodiversity as a result of the delay between destroying one habitat and protecting another.

(p12-13). It is recommend that if the difficulty of recreation is very high then a multiplier of ten be applied to work out the size and/or value of the credits a developer would need to buy.

In this way, speculations about the changing risks over time involved in offsetting are built into the abstraction process of biodiversity credits. Multipliers recognise the inherently temporal process that is set in motion by the purchase of credits and become a kind of 'hedge' against these uncertainties, which is priced into the credit through a process of multiplication.[47] While multiplier calculations are, according to critics such as Apostolopoulou *et al*. 'by necessity quite arbitrary and reflect the desire of the analyst to make a conservative calculation rather than any underlying ecological logic,' they nevertheless have the potential to levy powerful effects over time (*Biodiversity*, p867). Each credit produced through the application of multipliers carries a speculation on the health of a given ecosystem in the future, and embodies a faith that this ecosystem can be protected from a range of risks whose probability of occurring can both be calculated and acted upon in advance.

Probability here should not be confused with predictability, however. For while both bind the present to the future, they do so in different ways. A risk is predictable if it conceptualises the future as a linear sequence of events; if a risk is considered probable (or improbable), it represents one of many possible future scenarios that may branch out in a non-linear fashion. Biodiversity credits rely on an ability to conceptualise the future as a space of probabilities that may affect the value of the underlying asset. This gives the future a functional existence in the present, which is summarised by Arnoldi as a shift from a future as something merely possible to something that has being 'in practice'.[48] This ability to operationalise the future in the present effectively transforms the future into a resource, and as Arnoldi points out, this is only made possible by specific technologies and knowledges. The transition from scientific knowledge based on certitude to other models based on complexity, chaos, and non-linear dynamics feed into technologies that are able to conceptualise open futures with much greater confidence. These dynamics also feed into new approaches to ecology, as will be discussed in the final section below.

In summary, the use of derivatives to distribute the financial risks to governments posed by nature conservation may still be relatively small scale, but this does not prevent a tripartite derivative logic from suffusing a range of market-based approaches to conservation. In contrast to Büscher's 'derivative nature' the extent to which this logic penetrates such approaches to conservation licenses us to speak of a broader *derivative ecology*, in the dual sense that the derivative logic of biodiversity credits pertains to specific non-human ecologies, and that derivative logic in itself operates within a social ecology of institutions, regulations, specialists, trading platforms and the parcels of time and space that they shape. Where 'derivative nature' builds

47. As the DEFRA notes, this kind of hedging can also be supported by another form of 'hedge betting' solution whereby multiple offset sites are used to hedge the risk of failure. This poses the prospect of multiple and parallel temporalities that nevertheless all aim to achieve the same kind of future. DEFRA, 2012, op cit., p12.

48. Jakob Arnoldi, 'Derivatives: Virtual values and real risks'. *Theory, Culture & Society*, 21, 6, 2004, pp23-42, For Arnoldi this curious (non)existence of the future in the present is best described as 'virtual', in the sense that Giles Deleuze and Félix Guattari gave the term.

49. The theory of vegetative succession

its conceptual architecture along the border between nature and culture, 'derivative ecology' speaks of the relational entanglements of conservation, finance and the ecosystems they condition.

THE ABERRANT TEMPORALITIES OF ECOLOGICAL COMMUNITIES

The etymology of the word 'derivative' is bound up with a vocabulary of rivers and flows. It is therefore ironic that derivative ecology involves reducing the inherent dynamism of ecosystems to a single, relatively stable set of measurements. While biodiversity credits are the carriers of flows of a financial kind – a flow of capital from one organization to another, from one space to another, or one time to another – the underlying 'asset' that supports them is locked into a particular trajectory of development over a given period of time.

The idea of nature as inherently dynamic is now so commonplace as to seem clichéd. But within ecological science there has been a steady shift in how dynamism is conceptualised. Once dominant ideas such as vegetative succession, whereby an ecological community was thought to progress through a series of predictable changes until it reaches a 'climax community' have been largely disputed.[49] Where such ideas provided a linear model of how ecosystems change over time, more recent paradigms emphasise decidedly non-linear accounts of how ecosystemic change might occur.[50] As Scheffer et al note, an ecosystem may respond to changes in environmental conditions such as a gradual reduction in soil nutrient levels as one might expect; in a way that is correspondingly gradual.[51] But it may also respond in a way that is rapid, involving a 'catastrophic' transition from one stable state to another, for example from a vegetated to desert environment. Perhaps even more confounding for linear models, if one were to seek to return the ecosystem back to its former state, it would be insufficient to simply restore the environmental conditions that were present before this transition. This shows that a given set of environmental conditions does not automatically give rise to one single ecological community. Multiple arrangements are possible, each of which could equally form stable states. Each possibility in the life of an ecological community serves as an 'attractor', to borrow a term from the mathematics of dynamical systems, pulling an ecosystem's properties towards it like gravity pulls a ball from one valley to another on an uneven surface. Moreover, there can sometimes be very little indication of when the pull of a given attractor may become weak enough to enable the community to transition into another state. While these processes are all capable of being modeled mathematically, the logic they reveal is not one that is easily accommodated by the suite of market-based conservation instruments discussed above, trapped as they are in a derivative logic that treats ecosystems as simple clockworks that can be counted upon to provide offsets because they behave in predictable ways.

But it is not only the non-linear nature of ecosystemic change that has

pioneered by Frederic Clement dominated plant ecology in the early twentieth century. It modeled the development of vegetation on the development of an individual organism, which progressed through a sequence of stages over time towards a climax community. See Frederic Clements, *Plant Succession: an Analysis of the Development of Vegetation*, Washington, Carnegie Institution of Washington, 1916

50. Chihhao Hsieh et al., 'Extending nonlinear analysis to short ecological time series,' *American Naturalist* 171, 1, 2008, pp71-80; Jan M Baert et al., 'Nonlinear partitioning of biodiversity effects on ecosystem functioning,' *Methods in Ecology and Evolution* 8, 10, 2017, pp1233-40; Ottar N Bjørnstad et al., 'Nonlinearity and chaos in ecological dynamics revisited.,' *Proceedings of the National Academy of Sciences of the United States of America* 112, 20, 2015, pp6252-53.

51. Carl Folke et al., 'Catastrophic shifts in ecosystems,' *Nature* 413, 6856 (2002), pp591-96; Marten Scheffer and Stephen R. Carpenter, 'Catastrophic regime shifts in ecosystems: linking theory to observation,' *Trends in Ecology and Evolution* 18, 12, 2003, pp648-56.

the capacity to evade the derivative logic of biodiversity credits. 'Ecological surprises' are thrown up in another way too.[52] When nutrient levels in a shallow lake cause the water to transition from one steady state to another – for example from clear to turbid – it nevertheless transitions between two states that ecologists recognize, often accompanied by communities of plants and animals found under similar conditions elsewhere. By contrast, what ecologists term 'novel ecosystems' and 'no analog communities' emerge as a consequence of species being reshuffled into communities without precedent.[53] No-analog communities do not represent a new chapter in the evolutionary history of the species that comprise them. The novelty stems from their ability to form new relational entanglements with other species. In some cases this may preserve the same overall structure of the ecosystem in question, for example a top predator might be replaced by a different animal that comes to occupy the same position in the system. In others the result may be compositionally distinct in dramatic ways. Whether the degree of novelty is large or small, financial instruments such as biodiversity credits, which are indexed to specific communities of species worthy of protection, may come under strain when such communities start to reform as a result of rapidly changing environmental conditions.

52. John W Williams and Stephen T Jackson, 'Novel climates, no-analog communities, and ecological surprises,' *Frontiers in Ecology and the Environment*, 5, 9, 2007, pp475-82. (Hereafter *Novel Climates*).

53. Richard J Hobbs et al., 'Intervention ecology: Applying ecological science in the twenty-first century,' *BioScience* 61, 6, 2011, pp442-50; 0 and Jackson, 2007, op cit.

This emphasis in the field of ecology on the non-linear and novel filters into the writings of scholars in the environmental humanities such as Anna Lowenhaupt Tsing, who consider the capacity for non-humans to make history in collaboration with, opposition to, and isolation from humans. Taking the development of modern forestry in Finland as one of her examples, Tsing documents the way in which the national standards that rule forestry associations in turn shape the forest into a 'static and sustainable resource' that is expected to replenish itself according to regular cycles (*The Mushroom*, p173). The species of pine cultivated in these commercial forests thrive in conditions where other species might struggle. One of the reasons pine is able to flourish in poor soil is because of its symbiotic relationships with fungi, and in particular the matsutake fungi that is the subject of Tsing's book. Over time, the cycle of growth, death, and decomposition in these forests that result from the pine-fungi relationship can improve soil quality, and make space for other species, and historical change to appear.

In this way Tsing claims that together pine and matsutake make a history that is forcefully interrupted by modern forestry, which deliberately keeps soil quality low in order to guarantee a stable monocrop of pine. The capacity of natural processes to create worlds, in sometimes subtle and imperceptible ways, is forced into the procrustean bed of one world making enterprise – that of modern forestry that imposes regular cycles of growth and harvest. The industrial governance of forests stops their capacity to actively make history. Left to its own devices, or managed in a less uniform way, the rhythms of the forest do not necessarily conform to annual cycles; seed dispersal skips a year or two, matsutake save their energy for irregular fruiting. The historical patterns of forest regeneration proceed in dates rather than cycles, 'patches develop on different trajectories, creating uneven forest landscapes' (p175). We could perhaps even say uneven temporal landscapes, forged through historically dynamic processes that are open, and not only shaped by humans.

It is precisely the uneven and non-linear temporal dynamics exposed in these contributions to ecology and the environmental humanities that market based tools such as biodiversity credits curtail. The time scale of their operation, though short, can limit the history making capacities of everything from forests to rock pools. And they do so precisely because of the derivative logic they embody. The bundle of attributes that 'doubles' the underlying asset is elevated to a position of pre-eminence, whereby the ecosystem that it was designed to protect is increasingly derived from the ecological credit, rather than the other way round. This process occurs over time, in which measures such as 'distinctiveness' that underpin the value of biodiversity credits chain an ecosystem to an impoverished abstraction of itself that is created at the time the ecological commodity is 'banked'. Within a twenty-five year time span the parameters of these measures may change dramatically – what scores poorly on the distinctiveness metric today may prove highly distinctive in several decades' time as a consequence of climate change and outbreaks of disease that affect ecological communities elsewhere. The credit that 'captures' these metrics at the time of its creation is not an abstraction from 'actual nature', to recall the point made above, in so far as this is always already shaped through its contact with the historical force of humans. Rather, the snapshot created by an ecological credit is taken of capitalist modernity's externalised nature, which through an additional act of capture, is bounded and shielded from the unsettling and unpredictable dynamics of anthropogenic climate change. The externalisation of nature under capitalism serves as a precondition for its later capture through financial instruments that are employed in the name of its protection. While the resulting snapshot may represent a relatively faithful characterisation of an ecosystem, over time it comes to exert pressure on this ecosystem to change within a narrow set of parameters, limiting its capacity to make history on its own terms, or on more even terms with the humans who make history with it and through it.

This may of course prevent change for the worse, which is, after all, what biodiversity credits are designed to do, but it may also prevent the underlying asset from becoming more distinctive or taking on new characteristics. Change in either direction is to a large extent dependent on the degree to which the buyer of a credit honours the commitments its purchase represents. If commitments are honoured for the credit to be meaningful, then it will inevitably come to act on the underlying asset, only permitting change in the ecological community insofar as this happens within a narrow bandwidth.

Here it might be objected that the time scale necessary for ecosystems to make history in a meaningful way far exceed the twenty-five year guarantee provided through biodiversity credits. This would be true if the changes in question were driven through evolutionary mechanisms alone, but as indicated above, no-analog communities are ecological, rather than evolutionary phenomena, made up of species that are extant today, albeit in unprecedented combinations (*Novel Climates*, p477).[54] Coupled with the capacity for ecosystems to undergo rapid transitions between metastable states, unaccompanied by the warning signals humans have become accustomed to recognise, it becomes more difficult to speak with authority about the time scale upon which non-human histories take shape.[55]

These timescales are being further accelerated through climate change, where an increasing number of no-analog communities are likely to result from climates that are themselves without modern analogs. This has led some to call for a shift in emphasis away from the traditional historical orientation of restoration ecology and embrace a set of 'future-orientated' restoration practices that 'should aim to establish ecosystems that are able to persist in future environments' (p352). Under newly emerging environmental conditions, the restoration of historical ecological communities may be both impossible, and undermine the ability of these communities to adapt to future conditions. This position poses a larger set of questions for restoration ecology in general, but given the growing role that financial instruments have in its operation, it also poses a distinct challenge to tools such as biodiversity credits, which are constitutively unable to accommodate ecological surprises of the kind that ecologists and humanities scholars have come to recognise, respond to, and even embrace.

54. The potential for the dramatic reshuffling of ecological communities in the short term is heralded by a study on bird populations in California, which estimates that by 2070 half of the state could be dominated by novel assemblages of bird species. D. Stralberg et al. 'Re-shuffling of species with climate disruption: A no-analog future for California birds?' *PLoS ONE*, 4, 9, 2009.

55. Young D. Choi, 'Restoration ecology to the future: A call for new paradigm,' *Restoration Ecology* 15, no. 2, 2007, pp351-353, p352.

CONCLUSION

If, for Vester, the problem of assigning monetary value to a species was a question of complexity, rather than an ethical question *per se,* then his objections might have been quelled by the multifaceted derivative logics that inhere in biodiversity credits. For their promise is precisely one of drawing seemingly incommensurable qualities and the risks inherent in temporal processes together for the purposes of discerning and trading value. But as this article has shown, while derivative ecology makes possible kinds of valuation previously unimaginable, it also reproduces many of the problems initiated by capitalist modernity and its assumption that Nature is an external, linear and passive background of human action. By taking capitalism's production of external Nature as its 'underlying asset', the kinds of future that biodiversity credits make actionable in the present are tied to the restoration of a timeless and idealised Nature that is stripped of its capacity to make history through its encounters with human society. In executing a future that is fixed within this image, biodiversity credits thus harbour the considerable danger of disbarring ecosystems from the kinds of transformation that may be necessary to adapt to anthropogenic climate change.

Recent currents in ecological science and the environmental humanities demonstrate the need to rethink the world-making capacity of ecological communities. Time and again, empirical studies of these communities throw up ecological surprises that confound expectations of ecosystemic change working in a linear fashion proportionate to changes in environmental conditions. More often than not, the life of an ecosystem unfolds across multiple paths towards unpredictable endpoints, sometimes undergoing catastrophic transitions between two or more steady states. While catastrophe is generally best avoided, the capacity for ecosystems to make history requires a sensitivity to rhythms and synchronicities of life that rarely stay true to the version of Nature than capital can see. Engaging with ecosystems in a way that helps them to avoid catastrophe, at the same time leaving space and time for them to make history, is a challenge that derivative ecology is constitutively unable to meet.

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