'Mathematics maybe, but not money': on balance sheets, numbers and nature in ecological accounting

Structured abstract
Purpose: To consider and compare different ways of using numbers to value aspects of nature-beyond-the-human through analysis of cases of ecological and natural capital accounting practices in the UK that create standardised numerical-monetary values for beyond-human natures. In addition, to contrast underlying ontological and ethical assumptions of these arithmetical approaches in ecological accounting with those associated with Pythagorean nature-numbering practices and fractal geometry. In doing so, to draw out distinctions between arithmetical and geometrical ontologies of nature and their relevance for 'valuing nature'.

Design/methodology/approach: Close reading and review of policy texts and associated calculations in 1) UK natural capital accounts for 'opening stock' inventories in 2007 and 2014, and 2) in the experimental implementation of biodiversity offsetting in land-use planning in England. Tracking the iterative calculations of biodiversity offset requirements in a specific planning case. Conceptual review, drawing on and contrasting different numbering practices being applied so as to generate numerical-economic values for natures-beyond-the-human.

Findings: In the cases of ecological accounting practices analysed here, the natures thus numbered are valued and 'accounted for' using arithmetical methodologies that create commensurability, thereby facilitating appropriation of the value so created. Notions of non-monetary value, and associated practices, are marginalised. Instead of creating standardisation and clarity, however, the accounting practices we consider for natural capital accounts and biodiversity offsetting create nature-signalling numbers that are struggled over and contested.

Originality: This is the first critical engagement with the specific policy texts and case applications considered here, and, we believe, the first attempt to contrast arithmetical and geometrical numbering practices in their application to the understanding and valuing of beyond-human natures.

Keywords: mathematics, money, numbering, accounting, balance sheets, value, nature-beyond-the-human, natural capital, biodiversity offsetting, Pythagoras, fractal geometry, ethics

Article classification: Research paper

> … capitalism cannot be fully attained or practiced [*sic*] until... we have an accurate balance sheet [that places] natural capital on the balance sheets of companies, countries, … [and] the world. (Hawken, 1999: xiii)
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> In a system where the "logos" is profit, and more profit is better than less, then, perhaps if we started to account for nature, even more profits would be squeezed from nature. (C. Cooper, 1992: 26)

Introduction[1][2]

The title of this article, 'Mathematics maybe, but not money', comes from a paper by the Reverend Canon and environmental philosopher Nigel Cooper, delivered at a workshop on Natural Environments and Cultural Services in which one of us (Sullivan) was a participant (N. Cooper, 2014: 4). Cooper's paper highlights the discontinuities of resemblances (Latour, 2013) created by the transitions and translations required in ecological accounting. These transitions move from real material natures, to human uses and experiences of these, to numerical abstractions used to denote these uses and experiences, and to monetised values used to 'account for' these uses and experiences (see Castree 2003; Fourcade, 2011; Sullivan, 2012, 2014; and the special issue of Accounting, Auditing & Accountability (26(5)) published in 2013).

Focusing on so-called 'spiritual and cultural ecosystem services'[3], Cooper observes problems of both representation and value that arise through these numbering and calculative transitions. He states that:

> [t]he authors of the MA [Millennium Ecosystem Assessment] should be commended for alerting a world of potential Philistines that 'ecosystems' have spiritual value not merely a use value. But the world of valuing ecosystems has a hard time incorporating these spiritual services into its methodologies. […]
> Of course, there are some religious uses of ecosystem services that are potentially assigned a monetary value by the common methodologies. The National Ecosystem Assessment in 2011, in the chapter on Cultural Ecosystem Services, discusses possible travel-cost valuations based on visits to retreat centres and the value of proximity of churches based on hedonic-pricing using house prices. One might even consider the consumptive use of cut flowers in decorating churches. *Might not most people, though, consider these examples as trivial and effectively missing the point*? (N. Cooper, 2014: 3, emphasis added)

In more recent work, Cooper and colleagues elaborate these views, arguing that:

> the core conceptual framework of ecosystem valuations (that combines science and economics) is at odds with the conceptual frameworks for beauty and the spiritual that are in common use in Western cultures, however dominated by economic thought these cultures appear to be. The aesthetic and the spiritual are refractory under the discourse of ecosystem services valuation. We argue that they are contrary ontologically in their conceptions of nature and axiologically in their conceptions of the value relationship between nature and human life. (N. Cooper *et al*. 2016: 219).

These examples and perspectives cut to the core of Cooper's phrase, 'mathematics maybe, but not money'. At the very least, they affirm that not all benefits experienced by humans from the natural world are 'amenable to monetary valuation' (Bateman *et al*., 2011: 184). We thus use the phrase 'mathematics maybe, not money', to signal that while certain numbering practices may indeed be resonant with an affect of 'valuing nature', using money as a measure of nature's value(s) may effectively 'miss the point' and thereby trivialize and *devalue* both 'nature' and human relationships with natures-beyond-the-human[4] (Kohn, 2013). This insight raises concerns about the indexical legitimacy of the signs that, in ecological and 'natural capital' accounting, come to represent the value(s) of entities and materialities constituting beyond-human-natures. Related concerns arise regarding the roles played by these signs in the construction and normalisation of specific human actions (Mennicken and Miller, 2012).

At the heart of these connected concerns is the observation that numbers denoting natures have performative agency. They *make* as well as *reflect* the natures thus numbered, simultaneously shaping people's actions and values with regard to natures numbered according to the calculative devices to which they become subjected (Mackenzie and Millo, 2003; Callon, 2006; Mackenzie, 2008). If and when numbers signaling nature values become able to act as prices within a market and are negotiated and valued as such, the socioeconomic as well as ecological effects can be both profound and sometimes unpredictable (Carver and Sullivan, 2017). As such, the practice of numbering and monetising aspects of nature acts to normalise – even to 'naturalise' – particular conceptual, instrumental and ethical relationships with the natures thus (ac)counted (Robertson, 2006; Pawliczek and Sullivan, 2011). These numbering practices do not simply reflect an objective and impartially knowable state of affairs (Mackenzie, 2008). They function normatively and ideologically to bolster particular interests, ontologies and political economy structures whilst occluding others (Sullivan, 2017a).

There has been a proliferation since the 1990s in 'calls for accountants to become involved with environmental issues through "environmental accounting"' (C. Cooper, 1992: 17) and to operationalize the costs and benefits of environmental impacts through environmental accounting (Milne, 1991: 83; also Gray, 1992; Gray and Bebbington, 2001). Although not the explicit focus of our paper, this expanded attention to environmental accounting also complements an intensified focus on valuation methodologies in ecological and environmental economics (for review see Åkerman, 2005; Kallis et al., 2013; Sullivan, 2014; Coffey, 2016).

This proliferation, however, has been mirrored by calls for the interrogation, refraction and subversion of arithmetical accounting rationalities in their application as valuation strategies for natures-beyond-the-human. Contributors to this debate have pointed to the disruptive capacities of feminist/feminine positionalities in relation to the calculative rationalities underscoring accounting methodologies (C. Cooper, 1992), 'deep green' and systems perspectives that emphasise intrinsic values as well as the unquantifiable complexity of ecosystems (Hines, 1991; Gray, 1992), and the incommensurabilities arising through different valuation and value practices embedded in varied socio-cultural contexts (Graeber, 2001; O'Neill *et al.,* 2008). Recent interventions emphasise the ways in which expansionary deliberative practices might better draw out shared and plural values so as to effect more 'tangible improvements in terms of environmental outcomes' (Kenter *et al.*, 2015: 87; also Kallis et al., 2013; N. Cooper *et al*., 2016).

Some of the conceptual, societal and ecological implications of making natures visible through numerical-economic practices are the focus of this article. Our thinking is shaped by three main influences. First, we draw on prior experience by one of us of measuring plants and vegetation assemblages in the course of quantitative ecological field research and multivariate statistical analysis (Konstant *et al*., 1995; Sullivan *et al*., 1995; Sullivan 1999). We combine this experience of abstracting, objectifying and quantifying entities of the natural world with an 'anthropology of nature' that highlights cultural differences in how natures-beyond-the-human are understood and become known by people in diverse circumstances globally (Descola 2013; Kohn 2013; Sullivan, 2013a, 2017b). From this perspective, differences between what Bruno Latour (2013) calls modes or ontologies of existence invite curiosity regarding the view that metrological accounting and valuation techniques are the most appropriate routes towards better valuing natures-beyond-the-human so as to reduce ecological damage due to economic activity. Our third influence draws on consideration of modes of ethical reasoning informing numerical-economistic valuations of nature (O'Neill, 2007; Hannis 2015, 2016a and b; Boylan, 2016; Sullivan and Hannis, 2016).

In the following two sections we focus our reflections on two empirical examples in the UK in which accounting balance sheet structures gather and reconcile monetised quantifications of the natural world as a route towards the better care of the natures thus quantified. Our examples are:

1. the (ac)counting practices shaping values for 'natural capital' for 'opening stock' levels in 2007 and 2014, published recently in the UK's new natural capital asset accounts (ONS, 2016);
2. the application and negotiation of biodiversity offsetting (BDO) metrics in a specific case of BDO in England (in conjunction with a housing development in Thaxted, Essex), representative of a consolidating policy approach intended to support the maintenance of aggregate levels of the 'renewable natural capital' of biodiversity.

These examples illustrate how particular calculative devices enable the partitioning, calculation and comparison of nominal numbers signaling selected material natures so as to create balance sheets of the natures thus accounted. The second case additionally illustrates how such numbering practices facilitate marketised offset exchanges claiming to mitigate development impacts on biodiversity. We believe that this paper constitutes the first combined and critical analysis of the value-making practices and effects in these two cases.

In working through our examples we thus seek to add to work in critical accounting studies and social studies of accounting that documents and problematises an accelerating territorialisation of ecological domains through arithmetical accounting practices (for example, Milne, 2007; Asdal, 2008; Mennicken and Miller, 2012; Jones and Solomon, 2013 and the special issue that this paper introduces; Verran, 2013; Sullivan, 2014). In responding to Cooper's phrase 'mathematics maybe, but not money', then, we juxtapose the linear arithmetical accounting and monetising practices highlighted in our case analyses with some different ways in which numbers have historically been evoked to denote values associated with nature. In particular, in our conclusion we briefly consider the application of geometrical practices for numbering nature, as well as the different eco-ethical effects engendered by these alternative numbering practices. In doing so we highlight the divergent understandings of natures-beyond-the-human signaled by arithmetical and geometrical numbering practices respectively, and comment on possible structural and ethical effects of these practices.

The balance sheet of nature? UK monetary estimates of natural capital

A global consolidation of ecological accounting, and particularly natural capital accounting, is taking place. This consolidation is part of a concerted effort to make nature values visible and legible economically, both as stocks of 'natural capital' and as associated flows of 'ecosystem and/or environmental services' (for review see Bateman *et al*., 2011; Read and Scott Cato, 2014; Sullivan, 2014, 2017a; Coffey, 2016; Nadal, 2016). These innovations extend an older social accounting and 'full cost accounting' impetus to account for those social – and now environmental – costs that have conventionally been considered external to financial transactions (see discussion in Milne, 2007; also Gray and Bebbington, 2001). Through mutually supportive discourses, institutional assemblages and calculative devices, this multiscalar movement towards natural capital accounting is creating conditions in which beyond-human natures – or, at least, numbers considered to represent these – are further enrolled into the formal economic sphere (Sullivan, 2014). This 'economisation' (Çalişkan and Callon, 2009, 2010) formally values the presence and generative powers of diverse beyond-human natures in economic terms, thereby bringing natures valued as such closer to the realm of commoditised exchange value (see empirical cases worked through in Robertson, 2006; Pawliczek and Sullivan, 2011; Sullivan, 2013b; Carver and Sullivan, 2017). As John O'Neill (2007: 106) writes, '[t]he fact that the metaphor of natural capital lends itself to monetisation is neither accidental nor … surprising'.

In this section we review the presentation of monetary estimates for UK 'natural capital', based on a 'statistical bulletin' published in November 2016 by the UK's Office for National Statistics (ONS). This report utilises accounting and valuation methods developed by the Department for Environment, Food and Rural Affairs (DEFRA), as advised by the UK's Natural Capital Committee (NCC) established in 2012 in order to advise Treasury of the status and value of 'environmental services' provided by the UK's 'natural assets[5]. The intent to log such values on a balance sheet constituting a national natural capital account, and thereby 'to highlight the *relative importance* of services provided by the UK's natural assets' (ONS, 2016: 1, emphasis added), is set within a global context of a recently invigorated UN System of Environmental-Economic Accounting (SEEA)[6]. Bolstered by the World Bank through its programme on Wealth Accounting and Valuation of Ecosystem Services (WAVES, 2012), as well as by the EU and UN programme on The Economics of Ecosystems and Biodiversity (TEEB) which encouraged natural capital accounting[7], the UN's SEEA provides technical accounting methods, drawn on by the NCC, for including national environmental assets in national accounts. As the UK ONS bulletin states, 'natural capital accounts' create the ability to present and compare nature's values in the form of statements of assets, liabilities and capital at specific moments in time', such that 'natural capital accounts offer a consistent way of looking at the significance of nature [contributing non-produced forms of wealth] and can help identify drivers of change' (ONS, 2016: 4).

Towards the close of the ONS statistical bulletin considered here, a balance sheet of monetary estimates for UK natural capital is presented (ONS, 2016: 21). This balance sheet appears as a table of two columns of figures providing monetised values for the 'opening stock' inventories of disaggregated 'natural capital asset categories' at 'year end' in 2007 (mostly) and 2014 (see Table 1). A series of quantities constituting 'nature' – water, fish, wind captured in wind energy installations, carbon sequestered in trees, and so on – are represented as single figures in billions of pounds, from which losses and gains in economic value between two points in time can be assessed. 'Natural assets' are thereby known in terms of arithmetical numbers, their monetised numerical values are counted, their relative importance is clarified, and their quantitative change between two temporal moments is calculated.

Table 1 around here

These calculated certainties notwithstanding it seems important to look behind the balance sheet to see how the values entered are created, whose values they represent, and what they exclude and may thereby *de*value. We consider these aspects below.

Where does 'value' comes from?

For the majority of environmental service categories valued in the balance sheet depicted in Table 1 values are based on resource rents to industry owners of 'natural capital'. These resource rents are calculated as the residual value of income to the owners of a natural capital resource beyond all costs of production, fixed capital maintenance and relevant taxes and subsidies (ONS, 2016: 6). Natural capital values are thus computed as income to natural capital owners, i.e. to those able to accumulate surplus value from property rights to productive 'natural capital assets'. Value is defined in terms of contribution to income under conditions of private ownership, reinforcing a paradigm in which exchange values that can be traded require circumstances of private property (Farber *et al*., 2002: 388; Reid 2013: 12).

The value of nature-as-natural-capital is indeed being signaled in these accounts, but it is being signaled in a very specific way: as the value of 'non-produced assets' to industry, measured ultimately in terms of 'rent' to the owners of productive natural capital assets (combined with a discounting of the future values of flows from these assets) (ONS, 2016: 6, 20). Value is thereby directed towards the maintenance of a particular system of political economy that rewards the owners of land and natural resources as income-generating assets. In doing so, it can be observed that value replenishes 'the forward-driving force of capital' so as to feed 'the conditions of its own continuing' (Massumi, 2015: 72). The new information that UK 'natural capital accounts' add to conventional national accounts is thereby generated simply by disaggregating the amount of income that can ultimately be attributed solely to elements of owned 'environmental service'-producing 'natural capital'. In other words, the accounts in Table 1 demonstrate the market value of 'natural capital' to industry, not the value of nature's materiality in itself, or any non-industrialised or non-commercial values of nature held by people less directly connected with profit-generating dimensions of 'natural capital'.

The latter point is illustrated by the figures given for 'environmental services for recreation'. The natural capital accounts report a decline in the monetary value of admission fees, parking and transport tickets associated with 'recreational services', and infer from this a decline in the relative value of these 'services' (ONS, 2016: 18). In the same period, however, both the number of visits and the amount of time spent 'in the natural environment' increased, suggesting that the non-economic value of 'being in the natural environment' remained at least constant, and could be said to have increased (ONS, 2016: 19). Echoing Nigel Cooper's (2014) observations at the start of the paper, the use of travel-cost valuations alone to generate proxy values for the 'recreation services' provided by the natural environment misses the point entirely regarding peoples' valuing of access to such spaces[8].

Value derives from broader market contexts rather than materiality of natural capital stocks

In observing that the natural capital accounts calculate value in terms of its market value to industry, the reasons provided in the ONS report for changes in the 'environmental service' values signaled on the balance sheet in Table 1 are also of interest. These reasons rarely seem to have anything to do with the 'stock levels', i.e. with the materiality, of the 'natural capital stocks' themselves. The decline in value of oil and gas, for example, is explained by high volatility in broader market prices for these commodities combined with 'a decrease in revenues due to falling prices', with both of these explanations working against an interpretation that rising operating costs may be due to increasing scarcity of underlying 'natural capital stocks' (ONS, 2016: 7-8). Similarly, a 'downward trend in ecosystem service values' for public water supply early in the accounting period is explained as related to higher built capital (physical infrastructure) depreciation costs as well as industry-wide adjustments in taxes and subsidies; a later rise in value was associated with industry-wide price increases (ONS, 2016: 11). With regard to trees valued in terms of timber, the only source of accounted value is the market price paid for produced timber (i.e. stumpage price) (ONS, 2016: 10).

Overall, then, the figures in this balance sheet for UK natural capital tell us almost nothing about the condition of the natures from which the calculated values are derived. Indeed, the figures seem strangely disconnected from the interconnected materialities of the natural capital 'stocks' themselves. They are connected instead with the broader volatility of prices on global commodity markets, changing industry costs of production (as, for example, for the service category of 'fish'), and occasionally with political pressures (as in the case of peat production for which environmental concerns over extraction 'mean that no new planning permissions for peat are granted' (ONS, 2016: 8)). The causes for change in asset values summarised in the last column of Table 1, then, indicate the significance of broader (market) contexts that care little for the materiality of 'stocks' themselves. Natural capital asset values, as such, provide little indication of the present and future material state of the natures thus valued.

New 'externalities', discounting the future and dynamics

The ONS report explicitly excludes a larger number of 'environmental service' categories (n=17) from its list of calculated asset values than the number it includes (n=13). Excluded environmental services range from 'wild animals' to 'flood, erosion and landslide protection' to 'value placed on nature simply existing' (ONS, 2016: 5). Currently these identified service categories are unvalued: i.e. they remain external to UK natural capital accounts. The broader point here, however, is that attempts to cost in, i.e. to define and territorialise, un-costed externalities always create new boundaries on the other side of which are unvalued externalities or 'overflows'. As others have observed (Callon 1998; Lohmann, 2009, 2014: 178), this creation of new externalities is in the nature of the partitioning, numbering and calculative technologies that accompany economisation practices. The implication is that new '*dis*values' are created even as previously un-economised natures are brought into the economic fold of value via natural capital accounts.

One aspect which seems clearly undervalued, or at least under-signified, in these accounts relates to sources of dynamism in future trajectories of natures-beyond-the-human. As with projections of counter-factual scenarios in calculations of additionality in offset projects (Ehrenstein and Muniesa, 2013), future flows of environmental services from natural capital stocks are ultimately unknowable since they are unobserved. Natural capital accounts are built on the possibly problematic assumption 'that the current [service] flow… is constant over the asset life', leading to a 'default assumption… that the value of the services is constant over time' (ONS, 2016: 26). This assumption seems to disregard multiple sources of variability that may impinge on the potential constancy of service flow, given that ecosystems giving rise to 'environmental services' are complex and metastable, that is they 'can undergo rapid transitions' that may be unpredictable (Limburg *et al*., 2002: 411).

Renewable 'environmental service categories' are not closed biotic systems (Sullivan and Rohde, 2002), however, as indeed is indicated by some of the explanations for changes in category values in Table 1. Variations in air pollution removal by vegetation, for example, are explained as due to 'dry' and 'wet' day conditions (ONS, 2016: 16), themselves associated with broader weather conditions and presumably shaped by anthropogenic climate change. This observation regarding the 'outsides' of natural capital accounting becomes critical if we take seriously the juncture at which we seem to find ourselves, wherein systemic climate changes may make a fiction of assertions of the future constancy of 'environmental service flow' (Steffen et al. 2015; IGBP, 2016; see analysis in Bateman *et al*., 2011).

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The above engagement with recent UK natural capital accounts indicates that the reported 'value' of environmental service flows from natural capital assets is derived from broader economic contexts, rather than from the material state and visibility of the natures constituting these assets. Biodiversity offsetting (BDO), on the other hand, *is* a mechanism that seeks to increase the visibility of biodiversity value, so that species, habitats and ecosystems become less easy to overlook in processes of planning infrastructure development. In BDO in England, standard valuation devices are applied to habitats subjected to transformation through development. Our next case example illustrates how nominal numbers signaling nature-as-biodiversity are thereby similarly placed in a balance sheet structure so as to signal comparable unit values at different places and times. The case again demonstrates both the complexity concealed by such practices of numbering and standardisation, and the contentious nature of the numbers that thereby come to represent nature values.

The economics of the last resort: a case of biodiversity offsetting in England

Biodiversity offsetting (BDO) is a conservation methodology widely promoted as capable of mitigating impacts on species populations and habitats caused through the material transformation of localities due to built infrastructure developments (see review in Benabou, 2014; also Tregidga, 2013; Reid, 2013). BDO claims to facilitate maintenance of the 'natural capital' of biodiversity in aggregate (Helm, 2015), even though habitat losses at specific sites have occurred due to economic development. In this section we offer a brief case study illustrating the operation in practice of a specific calculative device developed to facilitate BDO. This is the BDO metric devised by the Department of Environment, Food and Rural Affairs (DEFRA) for use in the English BDO pilot scheme which ran from 2012 to 2014.[9]

The foundational principle of BDO is that actors causing 'unavoidable' development impacts on biodiversity through habitat destruction or degradation are enabled to compensate for these impacts by paying for an 'equivalent' amount of habitat conservation to take place elsewhere. These transactions may potentially take place through a commercial market in 'biodiversity units', these units being traded as offset credits. Development of such a market has been high on the agenda for BDO proponents in the UK.[10] Offset providers may sell credits to developers from a 'habitat bank', i.e. a dedicated area of conserved habitat, perhaps located in alignment with broader strategic conservation objectives.[11] There has been a well co-ordinated global movement towards BDO, driven not least by significant lobbying and promotion by brokers, globally active consultants, developers and extractive industries (as analysed in Benabou, 2014). Pre-existing schemes in the US and Australia have been cited by DEFRA (e.g. 2012) as examples to follow.

In the English context BDO is also strongly linked to a reorientation of the land-use planning system aimed at making this system a driver of economic growth rather than a brake on it, through removing obstacles to new and intensified development in rural and peri-urban areas (see discussion in Sullivan and Hannis, 2015). Land-use planning policy for England and

Wales thus now frames BDO as a potential last resort for the mitigation of harm to biodiversity that is added to the bottom of the existing mitigation hierarchy. As the National Planning Policy Framework (NPPF) states:

> [i]f significant [biodiversity] harm resulting from a development cannot be avoided (through locating on an alternative site with less harmful impacts), adequately mitigated, or, *as a last resort*, compensated for, then planning permission should be refused. (DCLG 2012, para. 118: emphasis added)

Offset brokers The Environment Bank Ltd., however, have called BDO 'a very important last resort, because it gives developers more options to make sure that what they do is sustainable' (The Environment Bank, 2013: 1). In other words, offsetting can render otherwise unsustainable development permissible, such that an offset turns a development that may previously have been impermissible into desirable 'sustainable development'.

This 'offsetting' of impacts is achieved by applying a calculative device – the DEFRA metric, shown in Table 2 – in order to calculate apparent equivalence in the biodiversity units per hectare between development and offset sites. Apparent commensurability between habitats is thereby created by translating the biodiversity value of different places into the potentially tradeable common currency of 'biodiversity units' with both the negative biodiversity impact of the development and the positive impact of the proposed offset scored according to this matrix.[12] If conservation activity on the offset site can be shown to yield an equivalent (or greater) number of units to the number lost on the development site, the development's biodiversity impact is considered to have been successfully offset, achieving 'no net loss of biodiversity' overall. Applying the metric then, the loss of two hectares of medium distinctiveness habitat in good condition would be counted as 12x2 = 24 units. This might be offset by purchasing the improvement of four hectares of high distinctiveness habitat from moderate to good condition, calculated as (18-12)x4 = 24 units. For further details and empirical examples, see DEFRA (2012), Sullivan (2013c) and Carver and Sullivan (2017). For conceptual engagement with BDO policy in England specifically see Hannis and Sullivan (2012), Lockhart (2015), Sullivan and Hannis (2015) and Apostopoulou and Adams (2017).

Table 2 around here

The metric is presented as a means of *simplifying* impact mitigation by providing a standard formula to be followed that will thereby reducing complexity, controversy and the need for expert judgement. In the case study that follows, however, we demonstrate that both complexity and controversy are in fact merely suppressed and displaced by the metric and associated numerical tabulations of the natures thus calculated, rather than reduced or resolved. Numbering practices here, then, create new foci for negotiation, contestation and political struggle over the natures thus represented and their new economic values (see Carver and Sullivan, 2017). Whether or not they work well in terms of caring for the material aspects of the natures thus numbered is, again, uncertain.

Thaxted: application to offset the offset

In the district of Uttlesford in Essex (one of DEFRA's six BDO pilot areas), permission was granted on appeal in 2014 for a development of 47 houses on the edge of the small town of Thaxted.[13] Unusually, the 2 hectare parcel of grassland on which it was proposed to build these houses was providing 'wildlife mitigation' for the same developer's adjacent earlier development of 55 houses, granted permission on appeal in 2012 and still under construction at the time of this second application. Protected flora and fauna including lizards (*Lacerta* *vivipara*) had been physically translocated *onto* the current development site as part of this former mitigation role.

The new planning application included a proposal for a biodiversity offset, calculated for the developer by the Environment Bank using the DEFRA metric. The ecological appraisal appended to the application stated:

> *As a last resort*, it is proposed to use the new biodiversity offsetting scheme currently being trialled in Essex by DEFRA as a means of ensuring and demonstrating a long term biodiversity gain. Offsetting is a form of compensation for loss which cannot be avoided or mitigated on site, an option recognised by the NPPF in para. 118. The offsetting site would provide 20 credits through an agreed enhancement plan. This represents an overall gain of 2.9 credits, i.e. an increase of >10% [over the value of the original site, calculated at 17.1 credits]. This land would also act as the receptor site for Common Lizards. (RPS Group, 2013, para. 5.7 - emphasis added)

The calculation submitted with this appraisal in April 2013 categorised the grassland at the development site as of 'medium distinctiveness, in moderate condition' (RPS Group 2013, Appendix D). Based on this assessement, it quantified the overall biodiversity impact of the development at 17.1 biodiversity units or 'credits', as shown in the unit totals for the 'application stage' of the habitat assessment process in Table 3.

Table 3 around here

Uttlesford District Council were unconvinced by these offset proposals, and refused permission for the development (Uttlesford District Council, 2013). In so doing they were following detailed advice from their ecological consultant, who pointed to local policies mandating no loss of old grassland except in very exceptional circumstances, and objected to the 'salami slicing' of habitats by sequential small developments (Simmonds, 2013). She contested the developer's assessment of the condition, quality and history of the grassland, their population estimates of specific fauna and flora on the site, and their interpretation of the key policy criterion of 'significant harm'. She further questioned both the use of BDO in principle, and the details of the developer's offset calculations, particularly the key assessment of the site's habitat distinctiveness as 'medium' rather than 'high'.

Thaxted: appeal stage and decision

In their submissions to the ensuing appeal, the developer's own ecological consultants argued strongly against all these objections, presenting evidence purporting to show that the grassland (on the development site) was of lower ecological value than the Council claimed. The developer obtained a combative barrister's opinion backing this view, and making it abundantly clear that the underfunded Council would be risking substantial legal costs if they persisted in contesting the appeal on the basis of the ecological advice they had received. However the Environment Bank did at this stage reassess the site's habitat distinctiveness as 'high', and recalculated the offset requirement accordingly, raising this to 25.2 units (Wade 2013, Appendix 13) (see Table 3).

The developers also, for the first time, offered details of the proposed offset. Acknowledging that '91.5% of the biodiversity onsite will be lost', they revealed that the 25.2 credits now required to compensate for this loss (see above) would be provided by improving the condition of five hectares of grassland of a different type on a site nine miles away at

Hempstead, predicting a gain from its current 'poor' condition to a 'good' condition by year 10 of a 25-year management agreement. This improvement was to be achieved by bringing in seed-bearing green hay from another (fourth) site.[13] The lizards (which have a life span of five to six years) were to be trapped and translocated (again) to the offset site.

Faced with this combination of carrot and stick the Council gave in, withdrawing their objections and finally declining to contest the appeal. The DCLG Planning Inspector gave permission for the development to proceed, saying:

> [w]hilst it is accepted that the proposed compensation site is not located next to or close to the appeal site, it seems clear that, with suitable management, it would provide a suitable habitat for the Common Lizard and would provide a grassland of greater value and size than the appeal site does or could. In these circumstances, I consider that *the proposal would not have any unacceptable effects on biodiversity, when taken as a whole and would enhance it*. As a consequence, the proposal complies with … paragraph 118 [of the NPPF]. (Wood 2014, para. 10, emphasis added)

The end result is that a small area of old grassland being managed to compensate for an earlier loss, will itself now disappear. This loss of existing habitat (and by proxy, of biodiversity) is considered to be fully offset by the future improvement of a different site. No compensation was offered for the loss of publicly accessible green space.

(Re)assessments

Close examination of the case documents reveals that The Environment Bank's initial assessment as provided to the developer in January 2013 (Hallam, 2013) had in fact categorised the grassland at the development site as of 'high' distinctiveness, and had also given a slightly higher estimate of the area affected, thereby calculating a total offset requirement of 31.6 units (see Table 3).

It may well be that the successive revisions of the offset requirement were based on more accurate data arising from successive closer investigations, although this is not clear from the case documents. On the contrary, a strong impression is given that the numbers changed as part of a recognisable haggling process. The figure of 17.1 units put forward with the original application looks very much like an opening gambit, an initial negotiating price allowing leeway for upwards revision to 25.2 units at appeal stage, while still remaining significantly 'cheaper' than the initial 'in-house' valuation by the developer's offset broker of 31.6 units.

It also appears that all three of the habitat variables considered in the metric (distinctiveness, condition and area) were contested, becoming subject to significant revision and negotiation. The use of the metric thus did little to simplify or reduce conflict in the process. Instead, negotiations over the numbers generated by the metric displaced 'macro level' contestation of the development's biodiversity impacts (rendered illegitimate by the use of an apparently 'objective' formula) into numerous 'micro level' arguments over what number should be entered into each cell of the offset-calculating spreadsheet. The apparent authority, simplicity and objectivity of the offset calculation (accepted uncritically by the final decision maker, the Planning Inspector) effectively disguised fierce battles over alternative expert interpretations of complex ecological data.

Without the 'last resort' of compensation, the biodiversity impacts would probably have justified a robust refusal of permission which would have been upheld at appeal. The development would not have happened, and there would have been no loss to offset. As predicted in theoretical work, not least our own (e.g. Hannis and Sullivan, 2012), the use of biodiversity offsetting has resulted here in development which otherwise would probably not have been permitted. A previous mitigation site has quickly become a development site, resulting in the curious spectacle of 'offsetting the offset'. Claims that biodiversity value 'taken as a whole' (see above) has thereby been conserved rely on contested assumptions about commensurability between different habitats, between different sites, and between the present and the future.

Concluding reflections: on the nature of numbers, and the numbers of nature

Through the two case analyses above we have elaborated some mechanisms whereby nature conceptualised and qualified as service-providing capital is being quantified, accounted for and exchanged as such. Similar enactments of numbering, aggregate rules and exchangeability have been highlighted for different scales of analysis, and for different environmental units to which frequently subjective evaluations are applied that nonetheless purport to create numerical comparability and commensurability. These numbering practices involve combinations of:

i. the production of comparable columns of arithmetically manipulable numbers deemed to be representative of particular nature aspects or 'indicators' in different temporal moments;

ii. the apparent equivalence and/or exchangeability of these numbers on the resultant balance sheet, such that aggregate quantities appear to be maintained even though losses have occurred;

and iii. the association of financial values with these quantified representations of material natures.

The arithmetical numbers denoting nature in the natural capital accounts and BDO scoring mechanisms reviewed here are thus constructed to align with the debit/credit binary of double-entry accounting practices (C. Cooper 1992: 25). In doing so, nature's multiplicity is forced into 'accounting's binary oppositions', providing the illusion that environmental problems can be 'got on top of' (C. Cooper 1992: 25). In 'sum', iterative processes of abstraction, counting and measurement are applied that conceptually *extract* 'entities' from the broader relational assemblages in which they are embedded. This extraction enables the fabrication of 'natural entities' as atomised units that can be counted as cardinal numbers signalling quantities that can subsequently be added together to indicate aggregate values (on such numbering practices see discussion in Crump 1992: 68-69, 77, 89; also Dauguet, 2015). Aspects of nature numbered arithmetically are able to undergo a further ordering in which counted quantities are utilised to create ordinal rankings of the numbers signalling levels of nature-value. It is this particular fabrication that guides offset exchanges or 'trade-offs' between sites of harm and health so as to apparently facilitate 'no net loss' of the numbered quantity in aggregate. At every step of this process, specific value-laden choices make and shape the value entities that get counted (see broader discussion in Maier, 2013).

When mobilised for policy decisions and/or in exchanges, these new numbers for nature act not only to represent the world, but also to change it. One well-known historical example of this process is described by James Scott (1998). Scott relates that in the nineteenth century foresters began to use mathematical averages to calculate maximum sustainable yields from existing multi-species forests characterised by enormous variety. Before long, these mathematical models were being applied in an effort to actually (re)produce the hypothetical 'normal tree' as one of millions of identical real trees, grown in manageable lines in monoculture plantations. The abstraction had made or performed reality, a process that enhanced standardised timber production but caused the loss of large areas of diverse old-growth forest.

Our case examples illustrate new ways in which 'nature is enacted' through bringing 'nature into account/ing', such that 'the enactments of nature and the enactments of economy go together' (Asdal, 2008: 125, 123). We have suggested that the numbers used to account for nature in applications such as natural capital accounts and biodiversity offsetting conceptually simplify the natures thus represented, allowing their enrolment into capitalist enterprise in new ways that may also generate concern (also see McAfee, 1999; Castree, 2003; Robertson, 2006; Sullivan, 2009, 2013b, in press; Fourcade, 2011; Pawliczek and Sullivan, 2011; Verran, 2013; Dempsey, 2015). New arithmetical ecological accounting practices format the world as measurable and potentially controllable (Boylan, 2016), as well as able to be 'valued' in the narrow economic sense of being given a monetary worth that under conditions of private ownership may potentially be(come) profitable. This, then, is a codifying and thus a territorialising endeavor (Mennicken and Miller, 2012; after Deleuze and Guattari, 1987(1980); also Scott, 1998), via which numbering and accounting practices are creating value(d) entities of nonhuman nature that can be recruited for a strongly neoliberal governmentality in environmental governance (as discussed in Sullivan, 2006, 2013b; Murray Li 2007; Fletcher, 2010; Tregidga, 2013; after Foucault, 2008(1979)). The conduct of multiple actors, organisations and policies is thereby oriented towards 'the truth regime of the market', such that environmental health and harm becomes governed through market-based instruments applied to social and ecological parameters that are overwhelmingly economised.

This, however, is not the first time that numbers have been used to denote and enrol nature values. As we bring this article to a close, we wish to to draw attention to the diversity of numbering practices by which groups of people have signaled nature values and nature's value, as well as indicating some differences in their social, material and ethical effects. In so doing, we return to Nigel Cooper's statement 'mathematics maybe, but not money' with which we opened this contribution, to briefly consider some other mathematical practices historically used to describe, evoke and point towards relationship with observed aspects of human and beyond-human natures.

Mathematics arose in ancient times as the signifying system that echoes the numinous quality of nature's mysteries and particularly its patterned yet dynamic order. The Pythagoreans, for example, considered themselves engaged in a mystical relationship with numbers as embodying ultimate reality, which they saw all around in the repetitive sacred geometry exhibited by the forms of nature (Martineau 2010; Watkins and Tweed 2010). An easily accessible example consists of the many spirals observed in the natural world that can be described mathematically (see Figure 1a and b), revisited in detail, amongst other observable 'rules' of shape, scale and mechanics, by mathematical biologist by D'arcy Wentworth Thompson (1917) in his magnum opus *On Growth and Form*.

Aristotle observes in his Metaphysics that for the Pythagoreans:

> all … things seemed in their whole nature to be modelled on numbers, and numbers seemed to be the first things in the whole of nature, they supposed the elements of numbers to be the elements of all things, and the whole heaven to be a musical scale and a number (Metaphysics, 985b 23-986a 3; see also 1090a20-29).

Indeed, for the Pythagoreans the perfect, sacred number 10, as embodied in the mystical symbol the Tetraktys, was considered the 'source of the roots of ever-flowing nature' (attributed to Iamblichus, Syrian neoplatonist philosopher, Mason, 2016: 18). In these ancient contexts numbers were considered to describe a movement of the stars and other celestial bodies that was mathematically harmonious and thus known as ‘the music of the spheres’, with which human life and activity could (and should) also be attuned.

More recently, and building on such ideas, the field of fractal geometry extends these observations of the relationships between numbers, often relatively simple but greatly iterated ones, and the evocation of form, pattern and complexity observed in the natural world. Fractals exhibit a repeated pattern at different scales, such that the pattern can be recognised at these different scales, even if the repetition is not identically the same at each scale. Thus ‘the structure of every piece [of the fractal] holds the key to the whole structure’ (Mandelbrot, 2006: 52; also Limburg *et al.,* 2002: 411). Benoit Mandelbrot, the mathematician associated with developing the field of fractal geometry, states that fractals assist with understanding how the world is put together - both statically and dynamically (Mandelbrot, 2006: 51). In many cases the images fractal numbers are able to generate using modern computers mysteriously appear almost indistinguishable from images taken as photographs of ‘real things in nature’ (see Figure 1c and d). These elegant geometric numbers seem able to include and honour the non-linearity, unpredictability and nonequilibrium dynamics so widely exhibited in nature – all of which tend to be filtered out as ‘noise’ in the pedestrian arithmetic of conventional economics and accounting.

Figure 1 around here

The numbers gestured towards here, and the images they provoke, are tremendously powerful in describing and invoking *qualitative* aspects of the natural world. Mandelbrot (2006) describes fractal geometry as ‘a geometry able to include mountains and clouds’ (p. 46), noting that ‘people respond to fractals in a deeply emotional way’ (p. 49), so as to strike ‘almost everyone in forceful almost sensual, fashion’ (p. 61). These are numbers the modelling of which has an affective resonance that seems to connect observers with the forms and dynamisms of the natural world, in ways that pull in a completely different direction to that emphasised by the calculative abstractions of ecological accounting. The mimetic possibilities of the images that fractals are able to generate perhaps permits nature to ‘speak back’ to us (Taussig, 1993: 97) more completely, by evoking qualities of mystery, complexity, self-similarity and immanence, rather than quantities of numbered units that can be counted and potentially accumulated.

Importantly, connections between mathematics and the mystery embodied in the simultaneous order, diversity and dynamism of nature have, since ancient times, also been associated with an ethical praxis built on honouring what was experienced as the cosmic harmony of the universe. They seem to have been deployed with an attitude of harmony and humility, rather than monetary ‘value’ or gain, inspiring a contemplative and abstemious lifestyle characterised by communal living, property held in common and shared, relative equality between women and men, and a sense of kinship between all living entities. Ethical praxis here, then, is seen to be concerned with intentional and relational choices arising from one’s view of the basic structure of things, i.e. from one’s ontology, such that actions are understood to be connected to assumptions about the nature of Being. For the Pythagoreans, their view that the cosmos is harmonious led them to the ethical position that the task for human beings is to ensure that they live in conformity with the harmony of the cosmos, a harmony that was embodied and described in numbers. It might perhaps be said that their ethics derived from a geometrical rather than arithmetical ontology.

As theorised by philosopher Michel Foucault in his later work (e.g. 2005(1981-1982): 48, 2012(1983-1984), Pythagorean ethics and its association with the ascetic communities of the Cynics, Stoics and Epicureans, appears to have emphasised a 'care of the self' based on a set of practices: a certain temperance in relation to the consumption of things, the sharing of property by those in the Pythagorean community, a high value placed on self-responsibility, self-testing and self-care as connected with the care of others, living in accord with cosmic order, and relative gender equality (discussed further in Sullivan, forthcoming). Given contemporary hyper-consumption, the displacement (or 'offsetting') of responsibility, and extreme inequality – as well as the effects of these on beyond-human natures – such ethical praxis seems a relevant corrective for our times.

Natural capital accounting, payments for so-called ecosystem services, and so forth arguably pull in exactly the opposite direction. These calculative approaches to nature valuation and management seem designed to remove ethical considerations both from decision-making processes and from individual action. They do this by turning 'nature management' into a technical accounting exercise, and creating incentive structures intended to trigger and control 'right' behaviour without the need for any internalisation of ecoethical values by 'actors' conceived purely as rational maximisers. Thus, in seeking to create regularity, predictability and rules, arithmetical accounting practices miss the insight that ethical action is relational and affective, not calculative (Boylan, 2016, after especially Bakhtin, 1993). Or as Hines (1991: 29) asserts, '[q]uantifying our environment must inevitably further alienate people from nature'. As such, we think ecological accounting practices require critical reflection, as well as juxtaposition with the alternative values encouraged and energised by different practices of numbering nature. In pursuing this aim, we hope in this article to have drawn attention to diversity in the numbering practices that are, have been, and might be applied to natures-beyond-the-human. We hope additionally to have gestured towards possibilities for creative disruption of technocratic arithmetical numbering practices, as well as ways in which alternative valuation practices might engender different ethical perspectives on ecological sustainability.

Notes

[1] This paper was first given as a plenary talk at the workshop 'Ecological Accounts: Making Non-human Worlds (In)visible During Moments of Socio-ecological Transformation', 26th August 2014, University of St. Andrews.
[2] Contribution statement: Sian Sullivan generated the majority of the text for this paper. Mike Hannis contributed case research and text for the section entitled 'The economics of the last resort: a case of biodiversity offsetting in England', as well as editing the full paper.
[3] In ONS (2016) 'Ecosystem services' include provisioning, regulating and cultural services, as constructed and disaggregated in the Millennium Ecosystem Assessment (MA, 2005).
[4] We use the terms 'beyond-human nature(s)' and 'natures-beyond-the-human' after anthropologist Eduardo Kohn (2013) as a way of signaling that humans are both part of the organic and inorganic materialities comprising the world and exist in diverse relationships with the multiplicitous differences in entities and processes comprising this world. After Abram (1996) we avoid the term 'nonhuman' nature due to its defining of natures-beyond-the-human in negative terms, i.e. as 'not human'.
[5] A history of the UK Natural Capital Committee or of the evolution of the UK framework set against older accounts is beyond the scope of this paper. The Committee was established

to assist with bringing economic assessments of environmental aspects to bear on national policy decisions, following the UK's 2007 National Ecosystem Assessment (http://uknea.unep-wcmc.org/) which took place in the wake of the Millennium Ecosystem Assessment (MA, 2005). Readers are advised to see https://www.gov.uk/government/groups/natural-capital-committee (last accessed 28 February 2017) and references therein, also Bateman et al. (2011) and Helm (2015).
[6] https://unstats.un.org/unsd/envaccounting/seea.asp (last accessed 28 February 2017).
[7] http://www.teebweb.org/areas-of-work/advancing-natural-capital-accounting/ (last accessed 3 March 2017).
[8] To be fair, this point is also discussed to some extent in ONS (2016: 18-19).
[9] The pilot was restricted to England: both conservation and land-use planning are handled by devolved administrations in Scotland, Wales and Northern Ireland. DEFRA documentation relating to the BDO pilot scheme is archived online at https://www.gov.uk/government/collections/biodiversity-offsetting (last accessed 3 March 2017). Documents comprising an official retrospective evaluation of the pilot, commissioned by DEFRA, can be found at http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=18229 (last accessed 3 March 2017).
[9] See, especially, The Environment Bank Ltd at http://www.environmentbank.com/ (last accessed 3 March 2017).
[10] In BDO literature 'habitat' is routinely considered an acceptable and more easily measurable proxy for 'biodiversity'. This assertion of equivalence merits more critical investigation than it has apparently received to date.
[11] 'Multipliers' may be applied to account for delivery issues: see DEFRA (2012) and discussion in Hannis and Sullivan (2012).
[12] Planning Inspectorate case ref. APP/C1570/A/13/2206357. All case documents quoted are available online at http://publicaccess.uttlesford.gov.uk/online-applications/applicationDetails.do?activeTab=documents&keyVal=MM9KAIQN01O00 (last accessed 3 March 2017).[13] At least one grassland expert (King, 2014) has expressed considerable doubts about the chances of success in this endeavour.

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Table 1. Balance sheet of UK natural assets (R = renewable, non-R = non-renewable) by category of environmental service type, showing values for two years of accounts. Values calculated in £ billion at 2014 prices. Source: ONS, 2016.

Environmental service type	Natural Capital asset category	Opening stock, end 2007	Opening stock, end 2014	Direction of change	Main explanation for change
Provisioning:	Agricultural biomass (R)	14.9	32.4	up	Particular conditions in 2007 caused opening low production values at start of accounting period, contributing to large increase in values observed here; volatility caused by increase in production costs associated with fall in value in EU subsidies due in turn to fall in value of sterling; deviations from 'normal' climatic conditions
	Fish (R)	7.9	9.1	up	Fall in industry costs of production; rising fish quotas for certain species
	Timber (R)	3.3	4.2	up	Increase in stumpage price (i.e. price paid to buy standing timber); increase in volume removed
	Water (R)	31.9	29.2	down	Higher built capital (physical infrastructure) depreciation costs; adjustments in industry taxes and subsidies; plus industry-wide price increases
	Minerals (non-R)	1.6	3.7	up	Price driven changes, although accompanied by reductions in physical extraction associated with higher production costs
	Oil, gas and coal (non-R)	190.2	22.6	down	High volatility in energy prices on commodity market; rise in operating costs; falling prices causing decline in revenues
	Wind energy	(end 2010) 11.0	45.3	up	Rapid growth in capacity related to investment
	Hydropower (R)	(end 2010) 10.2	9.2	down	Increased production costs
Regulating:	Carbon sequestration (R)	51.1	60.7	up	Increased grassland sequestration rates; increase in carbon price
	Air pollution* removal (by vegetation)	(end 2006) 129.0	114.2	down	'Dry' and 'wet' day conditions – more 'dry' years in 2006
Cultural:	Recreation (R)	213.5	166.3	down	Decline in expenditure on admission fees, parking and transport tickets

*particulate matter and sulphur dioxide

Table 2. Habitat scoring system for biodiversity offsetting in England, aka 'the biodiversity offsetting metric'. Source: DEFRA, 2012: 7.

		Biodiversity distinctiveness		
		Low (2)	Medium (4)	High (6)
Habitat condition	Good (3)	6	12	18
	Moderate (2)	4	8	12
	Poor (1)	2	4	6

Table 3. Calculation of offset requirement by The Environment Bank at three successive dates, 1. Initial appraisal, January 2013; 2. Application stage, April 2013; 3. Appeal stage, September 2013. Section A shows changing assessments of the distinctiveness and condition of the development site. Section B reflects the need to offset the loss of the 'condition uplift' which would have occurred had enhancement works proposed as part of the site's previous role as a 'mitigation site' been implemented (apparent inconsistencies in lines B1 and B2 do not affect the analysis in this paper). Section C shows the units of credit attributed to a small area of habitat to be retained within the proposed development. Source: all figures in Table 3 are taken from the original Environment Bank documents referenced in the text of the paper.

Time habitat scores were applied (see caption)	Area of Habitat Loss (ha)	Habitat distinctiveness: High=6 Medium=4 Low=2	Habitat Condition: Good=3 Moderate=2 Poor=1	Site Biodiversity Units	Biodiversity Units earned	Biodiversity Units to be offset
A. Unimproved Neutral Grassland (F2) with secondary habitats:						
1.	2.23	6	2	26.8		
2.	1.9	4	2	16.0		
3.	1.9	6	2	22.8		
B. Additional units required to offset loss of enhancement work previously planned and now foregone:						
1.	2	6	0.5	4.8		
2.	1.6	4	0.5	2.7		
3.	1.6	6	0.5	4.8		
C. Units credited for proposed onsite habitat retention (to be subtracted from offset requirement):						
1.	-	-	-		-	
2.	0.2	4	2	-	1.6	
3.	0.2	6	2	-	2.4	
Totals:						
1.				31.6	-	31.6
2.				18.7	-1.6	17.1
3.				27.6	-2.4	25.2

Figure 1. Geometric numbers evoking natures: a. the logarithmic spiral (source: Morn the Gorn - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=9941801); b. nautilus cutaway with logarithmic spiral (source: Dicklyon - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=35543222; c. 'Barnsley fern' fractals in four states (source: DSP-user - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=8932528; d. fern plants at Muir Woods, California (source: Sanjay ach - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=2169955 (all images accessed 3 March 2017).