Seeking an ecologically defensible calculation of net loss/gain of biodiversity

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Abstract

Purpose: This paper explains how proponents of biodiversity offsetting have sought to produce an ecologically defensible mechanism for reconciling economic development and biodiversity conservation.

Methods: The paper analyses a case study biodiversity offsetting mechanism in New South Wales, Australia. Michel Callon's framing and overflowing metaphor is used to explain how accounting devices are brought into the mechanism, to (re)frame a space of calculability and address anxieties expressed by conservationists about calculations of net loss/gain of biodiversity.

Findings: The analysis shows that the offsetting mechanism embeds a form of accounting for biodiversity that runs counter to the prevailing dominant *anthropocentric* approach. Rather than accounting for the biodiversity of a site in terms of the economic benefits it provides to humans, the mechanism accounts for biodiversity in terms of its ecological value. This analysis, therefore, reveals a form of accounting for biodiversity that uses numbers to provide valuations of biodiversity, but these numbers are ecological numbers, not economic numbers. So this is a calculative, and also *ecocentric*, approach to accounting for, and valuing, biodiversity.

Originality/value: This paper contributes to extant literature on accounting for biodiversity by revealing a novel conceptualisation of the reconciliation of economic development and biodiversity conservation, producing an ecologically defensible form of sustainable development. The paper also makes a methodological contribution by showing how Callon's framing and overflowing metaphor can be used to enable the kind of interdisciplinary engagement needed for researchers to address sustainable development challenges.

1. Introduction

Society's current model of economic development is set to become the cause of a mass extinction event (Barnosky et al., 2011; Ceballos et al., 2015). Extensive conversion of land to human use is causing rapid degradation of natural habitats and consequent decline in species abundance (Tilman et al., 2017). The United Nations Sustainable Development Goals (UN-SDGs) identify halting biodiversity loss as a vital component of achieving sustainable development (UN, 2016). A fundamental challenge for accounting researchers, therefore, is to explain how accounting can create conditions conducive to a form of sustainable development that conserves biodiversity (Bebbington & Unerman, 2018; Cuckston, 2018b).

Biodiversity offsetting is a rapidly proliferating mechanism that proposes to reconcile the competing demands of economic development and biodiversity conservation (Devictor, 2015). This is done by allowing losses of biodiversity caused by development of land in one place to be "offset" by supposed biodiversity gains from conservation work in another place. Biodiversity offsetting is made possible by accounting devices that purport to provide measures of respective losses and gains of biodiversity, thus enabling calculations of overall *net* loss/gain of biodiversity. As such, by securing sufficient offsets, economic development may be portrayed as being "sustainable development" in respect of causing *no net loss* of biodiversity (Boiral, 2016).

The extant accounting literature examining biodiversity offsetting has characterised it as little more than a legitimising strategy. Tregidga (2013, p. 827) argues that biodiversity offsetting may be seen to 'represent a mechanism through which particular species and habitat destruction can be justified, or at least hidden in its accounting'. Ferreira (2017) argues that the complexities of biodiversity make it highly resistant to the kinds of quantification and measurement needed for commodification. The consequent 'inability to present a consistent and trustworthy metrological regime', he argues, fuels a perception that biodiversity offsets represent nothing more than a 'licence to trash nature' (p. 1579). Similarly, Sullivan and Hannis (2017) attack biodiversity offsetting's central premise, that it is possible to speak meaningfully of overall *net* losses/gains of biodiversity. This idea, they suggest, rests upon 'contested assumptions about commensurability between different habitats, between different sites, and between the present and the future' (p. 1470).

But should biodiversity offsetting be so comprehensively dismissed? Might it actually have a role to play in halting biodiversity loss? In a world in which economic development is widely regarded as paramount (cf. Gray, 2010), can biodiversity offsetting offer a way of reconciling such development with biodiversity conservation? Within the nature conservation literature, there are stark differences of opinion on whether biodiversity offsetting can be made to serve the cause of conservation (Evans et al., 2015). Some conservationists have expressed deep anxieties about biodiversity offsetting as an approach to protecting nature (Moreno-Mateos, Maris, Bechet, &

Curran, 2015; Spash, 2015). However, proponents of biodiversity offsetting have focussed their attention upon seeking to 'strengthen the potential for offsets to provide an *ecologically defensible* mechanism that can help reconcile conservation and development' (Gardner et al., 2013, p. 1254, emphasis added).

The purpose of this paper is to explain how proponents of biodiversity offsetting are seeking to produce an ecologically defensible mechanism for reconciling economic development and biodiversity conservation. In order to do so, this paper will examine one such effort to create a mechanism for biodiversity offsetting that might be seen to be ecologically defensible. In doing so, this paper seeks to answer the call by Russell, Milne, and Dey (2017, p. 1443) for 'contemporary case studies of calculative practices that mediate human-nature relations'. Callon's (1998) metaphor of framing and overflowing, which explains how calculability is a collective achievement of socio-technical arrangements, will be used to analyse a case study of biodiversity offsetting, deployed in the state of New South Wales, Australia. The analytical aim will be to explain how accounting devices have been incorporated into the biodiversity offsetting mechanism, so as to (re)configure the calculability created between development and conservation in ways that are designed to address[1] the expressed anxieties of conservationists. The paper contributes to extant accounting for biodiversity literature by revealing a way of conceptualising sustainable development that is based on an *ecocentric* approach to accounting for, and valuing, biodiversity.

The remainder of this paper will be structured as follows: the next section will describe Callon's (1998) notions of framing and overflowing and explain how these will be used in this paper to conceptualise calculations of net loss/gain of biodiversity; section 3 will outline the data collection and analysis that has informed this paper's case study; section 4 will report on the analysis of the case; section 5 will discuss the implications of this analysis for understanding the role that accounting can play in enabling sustainable development; section 6 will conclude the paper.

2. Calculation and biodiversity offsetting

Accounting for biodiversity research seeks to explain the role that accounting plays in nature conservation efforts (Cuckston, 2017, 2018b; Feger & Mermet, 2017). Dominant policy discourse conceptualises accounting for biodiversity as a way of bringing the economic impacts of biodiversity

[1] Throughout this paper, the term *address* will be used in the sense of to 'think about and begin to deal with (an issue or problem)' (OED, 2018). Thus, to *address* conservationists' anxieties does not mean these are definitively resolved, but rather that efforts have been made to respond to them and work towards resolving them.

loss into organisational decision-making (ACCA, Flora and Fauna International, & KPMG, 2012; Natural Capital Coalition, 2016; TEEB, 2010). This inherently *anthropocentric* approach to accounting for biodiversity has informed much of the extant literature in this field, particularly work examining corporate reporting on biodiversity (see e.g. Adler, Mansi, & Pandey, 2018; Atkins, Maroun, Atkins, & Barone, 2018; Rimmel & Jonall, 2013; van Liempd & Busch, 2013).

> In the sense of accounting as a calculative technology, biodiversity can only be "accounted for" if species can be "valued" in financial terms (Jones & Solomon, 2013, p. 678).

However, this approach has met fierce resistance from scholars concerned that it encourages a mindset whereby nature is understood to have value only in terms of the economic benefits it provides to humans (Barter, 2015; Samkin, Schneider, & Tappin, 2014). This mindset leads inexorably to a logic whereby the destruction of nature can be justified by showing that the economic benefits of development are larger than the calculated economic benefits of the biodiversity that is being lost (Cuckston, 2013; Hrasky & Jones, 2016). It is this fundamental critique that informs extant accounting literature on biodiversity offsetting.

Biodiversity offsetting proposes to reconcile the competing demands of economic development and biodiversity conservation (Vaissiere, Levrel, & Pioch, 2017). To do so, biodiversity offsetting mechanisms set out means of quantifying and measuring the impacts of both development and conservation upon biodiversity, such that these can be directly compared. This quantification and measurement of respective biodiversity losses and gains, to render acts of development and conservation commensurable, creates a relation between these acts that did not previously exist (cf. Espeland & Lom, 2015; Espeland & Sauder, 2007). A key question for proponents of biodiversity offsetting mechanisms, therefore, concerns how this newly produced relation should be configured: how should losses and gains in biodiversity be made commensurable such that calculation of a *net* loss/gain becomes possible?

2.1 Framing net loss/gain of biodiversity

In his seminal work *The Laws of the Markets*, Michel Callon (1998) describes how creating the conditions of possibility for calculation requires work to construct a socio-technical arrangement capable of materially manipulating and combining objects so as to achieve a meaningful outcome. Any particular form of calculation is a distributed achievement of a networked assemblage of human beings and material devices, arranged in a way that collectively constitutes a space of calculability.

To help conceptualise this idea, Callon makes use of Goffman's (1974) metaphor of framing, whereby a socio-technical arrangement of humans and devices may be understood to frame a space of calculability. Calculation is understood to take place within this framed space, with the objects of calculation separated from the complexities of the outside world such that, within the frame, the relation between these objects comes to be seen as comprehensible and calculable:

> In short, a clear and precise boundary must be drawn between the relations which the agents will take into account and which will serve in their calculations, on the one hand, and the multitude of relations which will be ignored by the calculation as such, on the other (Callon, 1999, pp. 186-187).

Thus, for biodiversity offsetting mechanisms to be able to perform calculations of net loss/gain of biodiversity, work must be done to build socio-technical arrangements that frame development and conservation in ways that create a calculable relation between them. To understand the calculability achieved by biodiversity offsetting, it will be necessary to study the work of framing that makes the performance of such calculations possible. Further developing the conceptualisation of framing a space of calculability, Callon and Law (2005, p. 719) describe the performance of a calculation within a framed space as a three-stage material process:

> First, the relevant entities are sorted out, detached, and displayed within a single space. Note that the space may come in a wide variety of forms or shapes: a sheet of paper, a spreadsheet, a supermarket shelf, or a court of law – all of these and many more are possibilities. Second, those entities are manipulated and transformed. Relations are created between them, again in a range of forms and shapes: movements up and down lines; from one place to another; scrolling; pushing a trolley; summing up the evidence. And, third, a result is extracted. A new entity is produced. A ranking, a sum, a decision. A judgement. A calculation.

This characterisation of calculation highlights three problems, corresponding to these three stages, which must be answered by anyone seeking to frame a space of calculability. Firstly, what are the entities that are to be brought into account within the framed space of calculability? For proponents of biodiversity offsetting, this means specifying how both development and conservation are to be defined. Secondly, how are these entities to be manipulated and transformed within the framed space of calculability to render them commensurable? For proponents of biodiversity offsetting, this means specifying how biodiversity losses and gains are to be quantified and measured. Thirdly, how will these entities be combined to produce a result? For proponents of biodiversity offsetting, this means specifying how a net loss/gain of biodiversity is to be extracted. These problems of framing a space of calculability are summarised in table 1.

	Stage of calculation (Callon and Law, 2005)	Problem regarding framing space of calculability	Problem regarding framing space of calculability for biodiversity offsetting
1	Entities are brought into a single space	What are the entities brought into account?	How are development and conservation defined?
2	Entities are manipulated and transformed	How are these entities to be made commensurable?	How are the biodiversity losses and gains from acts of development and conservation quantified and measured?
3	A result is extracted: a judgement, a calculation	How are these entities combined to produce a result?	How are biodiversity losses and gains "offset" to produce a net loss/gain of biodiversity?

Table 1: Summary of Callon and Law's (2005) three stages of calculation, corresponding to three problems of framing a space of calculability, and how each of these three problems applies to biodiversity offsetting.

Within the extant accounting literature, two mechanisms of biodiversity offsetting have been studied in detail: one in New Zealand and one in England. Tregidga's (2013) study of a biodiversity offsetting mechanism used by a New Zealand state-owned mining company finds that the actual process of calculation, that supposedly underpins the company's claims of causing no net loss of biodiversity, are almost entirely opaque. The company claims to base these calculations on some kind of points system for biodiversity values, but they do not disclose (even when interviewed by Tregidga) how these points are measured for any particular loss or gain of biodiversity. It is therefore practically impossible to understand how calculability has been achieved in this particular biodiversity offsetting mechanism. Conversely, the English biodiversity offsetting mechanism, studied by Sullivan and Hannis (2017) and Ferreira (2017), provides much more detailed information about how net losses/gains of biodiversity are calculated. It is therefore possible to get a sense of how this mechanism has been designed to answer each of the three problems of framing a space of calculability.

In respect of the first problem, the English biodiversity offsetting mechanism defines development and conservation in terms of their impacts on natural habitat. Development is defined in terms of the clearance of habitat, such that all the flora and fauna on a development site are understood to be destroyed. Conservation is defined in terms of the enhancement of habitat as a result of being managed for conservation to improve its ecological condition. In respect of the second problem, losses and gains in biodiversity are quantified and measured in terms of habitat distinctiveness, habitat condition, and area. For each site, scores are attributed to habitat distinctiveness (six points for high distinctiveness, four points for medium, two for low), and to habitat condition (three points for good condition, two for moderate, one for poor). These scores are multiplied together and then multiplied by area (in hectares) to give an overall score for the biodiversity value of the site. Development of a site is understood to result in the loss of this biodiversity value. Conservation of a site is understood to lead to improvement in the condition score of the site (e.g. from poor to moderate, or from moderate to good), thus improving the overall score for biodiversity value of the site. In respect of the third problem, gains in scores of biodiversity value from conservation of any site may be straightforwardly deducted from losses in scores of biodiversity from development of any site. As such, calculations of net loss/gain of biodiversity may set gains from conservation of one habitat type against losses of a different habitat type.

By examining how biodiversity offsetting mechanisms have been configured to answer the three problems of framing a space of calculability, it becomes possible to explain how any particular mechanism proposes to reconcile development and conservation. However, Callon (1998) explains that no framing is ever perfect or complete. The space within the frame can never be entirely isolated from the world beyond. There will always be relations between things inside the frame (and thus taken into account in calculations) and things outside the frame (and thus excluded from calculations). These relations may be said to *overflow* the frame. Indeed, any framing – and thus any calculation – may be challenged on the basis of identifying overflowing relations. When overflows are identified, further work of (re)framing may be required to capture these and bring them within the frame. To capture an overflow, and bring it into account in calculations, new devices may be brought into the socio-technical arrangement to (re)configure the space of calculability. But any reframing will inevitably create conditions for further overflowing relations to arise: no framing is ever perfect or complete. Thus, framing and overflowing is a perpetual dynamic and the work of framing spaces of calculability is never finished.

2.2 Overflows in net loss/gain of biodiversity

Callon's (1998) framing and overflowing metaphor has had considerable influence on the accounting literature, particularly in theorising the role of accounting and calculative devices in creating conditions conducive to particular ways of thinking and acting. An early example is Lohmann's

(2009) study of how calculative devices frame spaces of calculability within carbon emissions trading markets. By examining how these spaces are configured, Lohmann identifies numerous overflows that, he argues, potentially undermine the integrity of carbon trading as a mechanism for addressing climate change. Using framing and overflowing as a way to understand how spaces of calculability are produced within organisations, Skaerbaek and Tryggestad (2010) study how calculative devices create conditions that enable particular forms of strategic thought and action. They offer a conceptualisation of 'strategy as an emerging calculative collective and temporary achievement' (p. 122). Building on this conceptualisation, Jollands and Quinn (2017) show how framing is used in the pursuit of government reforms and how overflows to this framing form the basis of resistance to such reforms. Similarly, Georg and Justesen (2017) show how calculative devices frame spaces of calculability that enable organisations to make claims about their environmental performance. They find that these claims can be undermined by overflows to this framing, which render organisations vulnerable to challenges from environmentalists. Applying the framing and overflowing metaphor to the study of accounting's role in enabling biodiversity conservation, Cuckston (2018c) shows how a calculative device – the Red List of threatened species – frames a space in which species extinction risk becomes calculable. Cuckston also shows how overflows to this framing create opportunities for further framing efforts by conservationists to make various conservation strategies thinkable and possible.

In this paper, Callon's (1998) framing and overflowing metaphor will be used to make sense of anxieties expressed by many conservationists, within the conservation literature, in respect of biodiversity offsetting and calculations of net loss/gain of biodiversity. Such anxieties can be understood in terms of the identification of relations that overflow the framing of biodiversity offsetting's space of calculability. These identified overflows may be seen to be challenges to the ecological defensibility of the calculability achieved by biodiversity offsetting mechanisms. Indeed, the nature conservation literature can be seen to identify overflows that challenge the ways that biodiversity offsetting mechanisms (certainly in England, but also in many other mechanisms globally (see Coralie, Guillaume, & Claude, 2015; Mann & Simons, 2015)) have answered each of the three problems (explained above) of framing a space of calculability.

In respect of the first problem, concerning defining acts of development and conservation, conservationists have expressed anxieties regarding what it means to produce biodiversity gains from conservation. Whilst it is generally agreed that a biodiversity loss is quite straightforwardly comprehensible as the destruction or degradation of natural habitat, there is considerable debate over what might constitute a biodiversity gain (Evans et al., 2015). Some offsetting mechanisms, for example, are seen to rely on unrealistic assumptions regarding baseline levels of decline in order to justify supposed biodiversity gains (Bull, Gordon, Law, Suttle, & Milner-Gulland, 2014; Maron, Bull, Evans, & Gordon, 2015; Maron, Rhodes, & Gibbons, 2013). Some offsetting mechanisms also recognise biodiversity gains where the additionality is questionable, such as when they are claimed on the basis of providing funds for areas that are already designated as protected (de Freitas et al., 2017; Maron, Gordon, Mackey, Possingham, & Watson, 2016; Pilgrim & Bennun, 2014). More broadly, there is considerable concern that human capabilities to restore degraded habitats – and thus achieve the claimed biodiversity gains – can be highly questionable (Le Roux, Ikin, Lindenmayer, Manning, & Gibbons, 2015; Morris, Alonso, Jefferson, & Kirby, 2006; Sonter, Barrett, & Soares-Filho, 2014).

> Some habitats and their ecosystem functions can be restored, created or recreated with a high degree of success, whilst others are extremely difficult or impossible to replicate (Briggs, Hill, & Gillespie, 2009, p. 115).

Thus conservationists may be seen, within the conservation literature, to have identified an overflowing relation between the supposed biodiversity gains recognised by biodiversity offsetting mechanisms (inside the frame) and the means of actually producing such gains from conservation (seen to be outside the frame). This failure to bring the actual action of conservation into account undermines the ecological defensibility of the calculability achieved by biodiversity offsetting mechanisms.

In respect of the second problem, concerning the quantification and measurement of biodiversity losses and gains, conservationists have expressed anxieties regarding the highly simplistic ways that biodiversity offsetting has sought to represent the biodiversity value of natural habitats. Some of the metrics that biodiversity offsetting mechanisms have used as proxies for biodiversity value have been seen to be highly questionable (Carver & Sullivan, 2017). Indeed, conservationists have found that in some areas used as offsets, where biodiversity gains have been claimed on the basis of particular (often simplistic) metrics, subsequent ecological surveys find that these claims do not represent the observed on-site ecological reality (Hanford, Crowther, & Hochuli, 2016; Lindenmayer et al., 2017; May, Hobbs, & Valentine, 2017; Regnery, Couvet, & Kerbiriou, 2013a). The quantification and measurement of a biodiversity loss or gain, from development or conservation respectively, therefore risks being seen to be little more than the 'designation of an arbitrary score' (Yu et al., 2017, p. 35). If losses and gains of biodiversity are not sufficiently connected to ecological reality then some conservationists see a 'risk of biodiversity offset policies serving a largely symbolic purpose by neutralizing environmental concerns regarding development effects while providing little real protection for biodiversity' (Gardner et al., 2013, p. 1255). Thus conservationists may be seen, within the conservation literature, to have identified an overflowing relation between quantified and measured biodiversity losses and gains (inside the frame) and the on-site ecological effects of development and conservation (seen to be largely outside the frame). This failure to bring these ecological effects properly into account undermines the ecological defensibility of the calculability achieved by biodiversity offsetting mechanisms.

In respect of the third problem, concerning extracting a net loss/gain of biodiversity, conservationists have expressed anxieties regarding the commodification of nature that this implies, treating different habitats as exchangeable, ignoring their importance as unique natural places. There is fundamental concern that biodiversity offsetting mechanisms seek to turn nature into tradable commodities, when actually some natural places are irreplaceable and their loss cannot be meaningfully offset (Pawliczek & Sullivan, 2011; Walker, Brower, Stephens, & Lee, 2009).

> [Biodiversity offsetting] hides an assumption: that it is possible to assess, compare and equate what is destroyed and what is repaired (Devictor, 2015, p. 483).

There is fear amongst some conservationists that biodiversity offsetting is driven, not by a desire to ensure protection of nature, but rather by 'an economic approach to ecosystem degradation and biodiversity loss that emphasises the principle cause as a missing market value' (Spash, 2015, p. 541). This underlying economic logic is seen to lead proponents of offsetting to reduce natural places to qualities that they have in common, whilst suppressing those qualities that make natural places unique, thereby 'ontologically transform[ing] habitats into commodities' (Dauguet, 2015, p. 533). This is seen to be particularly problematic where offsets are used in cases where losses relate to endangered species, increasing their risk of extinction (Pilgrim et al., 2013a; Pilgrim et al., 2013b; Regnery et al., 2013b). Thus, by challenging the acceptability of setting a biodiversity loss from destruction of nature in one place against a gain derived from elsewhere, conservationists may be seen, within the conservation literature, to have identified an overflowing relation between the notion of a net loss/gain of biodiversity (within the frame) and the unique qualities of natural places (seen to be outside the frame). This failure to bring the uniqueness of particular species and habitat-types into account undermines the ecological defensibility of the calculability achieved by biodiversity offsetting mechanisms.

These identified overflows are summarised in table 2.

	Problem regarding framing space of calculability for biodiversity offsetting	*Overflow* identified in conservation literature concerning biodiversity offsetting
1	How are development and conservation defined?	Calculability achieved does not take account of the means of producing biodiversity gains from conservation
2	How are the biodiversity losses and gains from acts of development and conservation quantified and measured?	Calculability achieved does not take account of the ecological effects of development and conservation
3	How will biodiversity losses and gains be offset to produce a net loss/gain of biodiversity?	Calculability achieved does not take account of the uniqueness of particular species and habitat-types

Table 2: Summary of overflows identified in the conservation literature concerning biodiversity offsetting, corresponding to each of the three problems of framing a space of calculability for biodiversity offsetting.

So conservationists have identified numerous overflows that undermine the ecological defensibility of the calculability achieved by biodiversity offsetting mechanisms. But should anxieties regarding these overflows lead to the wholesale dismissal of biodiversity offsetting as little more than a legitimising strategy (cf. Ferreira, 2017; Sullivan & Hannis, 2017; Tregidga, 2013)? Or can the space of calculability framed by biodiversity offsetting mechanisms be (re)configured to capture these overflows, resulting in a more 'ecologically defensible' (Gardner et al., 2013, p. 1254) form of calculability? The remainder of this paper will examine a case study of one such attempt to (re)frame a space of calculability for net loss/gain of biodiversity. The next section will briefly set out the process of data collection and analysis that has informed this case study. Section 4 will then explain how accounting devices have been brought into the socio-technical arrangement comprising the case study biodiversity offsetting mechanism to (re)configure the framed space of calculability in ways that capture the overflows that have been identified in the conservation literature.

3. Data and analysis

In order to study how proponents of biodiversity offsetting have sought to (re)configure calculability for net loss/gain of biodiversity, to address anxieties expressed by conservationists, this paper will examine a case study of a biodiversity offsetting mechanism that might be seen to be ecologically defensible. This case study is a biodiversity offsetting mechanism deployed in the state of New South Wales (NSW), Australia. The NSW state government describes the mechanism as an attempt to substantially 'improve on the existing approach to biodiversity offsets' (NSW, 2009, p. 3), by ensuring that calculations of net loss/gain of biodiversity are 'scientifically robust' (NSW, 2009, p. 3) and 'based on ecological principles' (NSW, 2007a, p. 15).

To inform the analysis of this case, documentary data has been collected from the online archives of the NSW state government. The aim was to collect documents to inform explanations of the calculations involved in the NSW biodiversity offsetting mechanism. These are shown in table 3.

Title	Year	No. of pages
Biobanking: scheme overview	2007	17
Pilot report of the May 2007 draft Biobanking assessment methodology	2007	34
Peer review of the May 2007 draft of the Biobanking Assessment Methodology	2007	17
Biobanking compliance assurance strategy	2008	12
The science behind Biobanking	2009	15
Biodiversity assessment method	2017	132
Guidance to assist a decision-maker to determine a serious and irreversible impact	2017	44
Ancillary rules: biodiversity conservation actions	2017	8

Table 3: List of documents collected and analysed in this research to inform an explanation of the NSW mechanism's framing of a space of calculability.

These documents have been analysed using Callon's (1998) framing and overflowing metaphor as a guiding heuristic. The analysis sought to identify how accounting devices have been brought into the socio-technical arrangement of the biodiversity offsetting mechanism to (re)frame its space of calculability and capture the overflows that have formed the basis of anxieties expressed by conservationists (as discussed in section 2.2 above).

The purpose of this research is to explain how proponents of biodiversity offsetting are seeking to produce an ecologically defensible mechanism for reconciling economic development and biodiversity conservation. This research therefore aims to study the innovations in this evolution of biodiversity offsetting that are meant to move it towards ecological defensibility. The focus here is thus on the calculability achieved by the mechanism, and the accounting devices that frame the space in which calculations of net loss/gain of biodiversity are performed. Accordingly, the principal unit of analysis in this case study research is the NSW biodiversity offsetting mechanism. This will enable an analysis of how the biodiversity offsetting mechanism has been (re)configured to address anxieties expressed by conservationists. To further explicate and clarify the findings of this analysis, section 5 will include an illustrative example of how this calculability has been applied on a specific site to generate biodiversity gains.

The analytical aim has been to synthesise coherent narratives concerning how anxieties relating to each of the three problems of framing a space of calculability (explained in section 2.1 above) have been addressed within this case. The next section will present these synthesised narratives.

4. An ecologically defensible calculation

The NSW *Biodiversity Offsets Scheme* is a mechanism that provides developers with a means of demonstrating that their particular development project (when taking offsets into account) causes no net loss of biodiversity. In NSW, this is a requirement of gaining planning permission. The mechanism was established by the NSW government in the *Biodiversity Conservation Act 2016*. It replaced a very similar biodiversity offsets mechanism within NSW called Biodiversity Banking, which had been operating since 2008. The mechanism is underpinned by a Biodiversity Assessment Method, which defines 'a repeatable and transparent assessment of terrestrial biodiversity values' (NSW, 2017, p. 2). When developers wish to develop an area of land, they must apply the Biodiversity Assessment Method to ascertain the value of the biodiversity that will be lost as a result of the development and, consequently, the number of biodiversity offset credits that the developer will need to purchase to be able to claim that the development causes no net loss of biodiversity. Biodiversity offset credits can be generated by landowners who designate their land as a Biodiversity Stewardship Site. These landowners must apply the same Biodiversity Assessment Method to ascertain the gains in biodiversity that will supposedly result from the management of this site for conservation and, consequently, the number of biodiversity offset credits that can be produced and sold.

Considerable efforts have been made by the NSW government to ensure that the Biodiversity Assessment Method represents a 'scientific approach to assessing biodiversity' (NSW, 2009, p. 1) and is thus seen to be 'ecologically credible' (NSW, 2007b, p. 1). The Biodiversity Banking Methodology, upon which the Biodiversity Assessment Method is based, was peer reviewed by three independent ecologists, described by the NSW government as 'leaders in the field of biodiversity assessment methods' (NSW, 2009, p. 3), to ensure the method was 'based on sound science … [and] as simple as possible without compromising its scientific integrity' (NSW, 2007b, p. ix).

The following three subsections will analyse how three specific devices – a Management Plan device, a Vegetation Integrity Score device, and an Offset Rules device – within the Biodiversity Assessment Methodology have been brought into this mechanism to address conservationists' anxieties concerning each of the three problems of achieving calculability, discussed in section 2.2 above. In doing so, this analysis will explain how the NSW government has sought to (re)frame the relation between development and conservation to achieve an ecologically defensible calculability for net loss/gain of biodiversity.

4.1 Defining gains from conservation

As seen in section 2.1 above, the first problem of framing a space of calculability for biodiversity offsetting is how to define development and conservation. As seen in section 2.2 above, conservationists have expressed anxiety that biodiversity offsetting mechanisms do not adequately take into account the means of producing biodiversity gains from conservation. The act of conservation thus overflows the frame. The NSW biodiversity offsetting mechanism seeks to capture this overflow and bring the act of conservation into account. This is done by bringing a new device into its socio-technical arrangement: the Biodiversity Stewardship Site Management Plan.

In order to establish a Biodiversity Stewardship Site (and so be able to earn biodiversity offset credits), the owner of the land is required to prepare a Management Plan setting out the management actions that will be conducted on the site. A Management Plan specifies two types of management actions: required management actions and active restoration management actions. Required management actions are set out by the NSW Office of Environment and Heritage and are mandatory for all Biodiversity Stewardship Sites. These include fire management, grazing management, pest control, weed management, and management of human disturbance. For each required management action, the Management Plan must describe the specific activities (e.g. particular ecological burning activities, fencing, access restrictions, etc.) that will be conducted at the site. The required management actions represent the minimum expected effort necessary to manage the land for conservation to produce biodiversity gains. Active restoration management actions may be conducted in addition to the required management actions. These include habitat enhancement, native vegetation augmentation, and hydrology management. The Management Plan must describe the specific activities (e.g. nesting boxes, supplementary planting of native vegetation, creation of artificial frog ponds, etc.) that comprise each additional active restoration management action. These active restoration management actions represent extra efforts, over and above the minimum conservation requirements, to produce additional biodiversity gains at the site.

Biodiversity gains from conservation of Biodiversity Stewardship Sites become understood, within this framing, to result from conducting the management actions specified in the Management Plan.

These biodiversity gains arise from, firstly, averted loss from the expected decline in the condition of native vegetation if the site was not managed for conservation and, secondly, improvements in the condition of native vegetation from its present state. The idea behind averted loss is that, without management for conservation, the condition of the native vegetation on the site is assumed to decline into the future due to ongoing threats such as invasive weed species and human disturbance. Conversely, management actions are assumed to bring about improvements in native vegetation condition by encouraging the site to recover from historic degradation and move towards a desirable state. The quantification and measurement of these gains in biodiversity is explained in section 4.2 below.

The Management Plan device thus addresses the first problem of framing a space of calculability. In the NSW biodiversity offsetting mechanism, acts of development are defined in a similar way as in other offsetting mechanisms, as straightforward destruction of habitat. However, the introduction of the Management Plan device means that acts of conservation are much more explicitly defined within the NSW mechanism. Management actions are also explicitly linked to gains in biodiversity. So, whilst the mechanism does, like other offsetting mechanisms, assume a baseline decline in ecological condition, the stemming of this decline (as well as improvement to current ecological condition) is understood to arise from conducting these management actions. In this way, bringing the Management Plan device into the mechanism results in a reconfiguration of the framed space of calculability that captures the overflowing act of biodiversity conservation, and brings it into account in calculations of net loss/gain of biodiversity. This (re)framing may be seen to address anxieties expressed by conservationists regarding what actually constitutes a biodiversity gain.

Interestingly, this (re)framing has created conditions amenable to a form of 'compliance assurance' (NSW, 2008, p. 1) for ensuring that landowners comply with their conservation commitments. When land is designated as a Biodiversity Stewardship Site, the landowner enters into an agreement to manage the land for conservation in perpetuity. This means that the landowner commits indefinitely to conducting the management actions specified in the Management Plan. Landowners must report annually to the NSW government on their compliance with the Management Plan. The NSW government can also make inspection visits to monitor compliance with the Management Plan. This assurance regime, which is meant to 'ensure the integrity' (NSW, 2008, p. 1) of the NSW biodiversity offsetting mechanism, thus focusses attention on the act of conservation. This reinforces the conception that biodiversity gains result from managing a site for conservation. There is no requirement to monitor the ecology itself, to assess whether the estimated biodiversity gains are actually realised. By emphasising the means of conservation, rather than the ecological results, the calculability achieved here is built upon a premise that biodiversity gains are produced by human action. The absence of human action is understood to lead to ecological decline. Only by bringing land into active management can this decline be stemmed and biodiversity gains produced. Within this frame, therefore, the notion of producing a biodiversity gain from conservation becomes ecologically defensible.

4.2 Quantifying and measuring biodiversity losses and gains

As seen in section 2.1 above, the second problem of framing a space of calculability for biodiversity offsetting is how to quantify and measure biodiversity losses and gains. As seen in section 2.2 above, conservationists have expressed anxiety that biodiversity offsetting mechanisms do not adequately take into account the ecological effects of development and conservation. These ecological effects thus overflow the frame. The NSW biodiversity offsetting mechanism seeks to capture these overflows by bringing a new device into its socio-technical arrangement: the Vegetation Integrity Score.

The quantification and measurement of biodiversity losses and gains takes place in two stages. Firstly, a site (whether subject to development or conservation) is assessed for current biodiversity value. Then, using this current biodiversity as a basis, the losses or gains from development or conservation respectively can be derived. An initial step in quantifying and measuring the biodiversity value of a site is to produce a site map, which divides the site into vegetation zones. Each vegetation zone must be classified as an example of a particular recognised plant community type, as defined by a database of NSW native vegetation. Each vegetation zone is assessed separately using the Vegetation Integrity Score device. The biodiversity value of the native vegetation in a vegetation zone is understood to derive from three aspects of its ecology: composition, structure, and function[2]. The Vegetation Integrity Score assesses each of these aspects and combines them into an overall score representing the biodiversity value of the zone's native vegetation.

A zone's integrity score with respect to composition is a measure of species richness. This is measured in terms of the number of different native species found within the zone belonging to each of six growth form groups: trees, shrubs, grasses, forbs (i.e. herbaceous flowering plants), ferns,

[2] The function aspect of vegetation integrity is only included in the assessment of plant community types that contain trees. It is excluded from other types, such as grasslands, which are assessed only on the basis of composition and structure.

and others. The NSW native vegetation database contains benchmark data on expected species richness for each growth form group for each recognised plant community type. Using sample plots, measurements are made of species richness for each growth form group within a vegetation zone. These on-site measurements are then compared to the benchmarks for each growth form group for the relevant plant community type. The integrity score with respect to composition therefore reflects how close a zone is to benchmark species richness for its type.

A zone's integrity score with respect to structure is a measure of foliage cover. This is measured in terms of percentage of land covered by each of the six growth form groups. The NSW native vegetation database contains benchmark data on expected coverage percentages for each growth form group for each recognised plant community type. Using sample plots, measurements are made of foliage cover within the vegetation zone for each growth form group, which are then compared with the benchmarks for the relevant plant community type. The integrity score with respect to structure therefore reflects how close a zone is to benchmark foliage cover for its type.

A zone's integrity score with respect to function is a weighted measure of various function attributes: number of large trees (0.35), length of large logs (0.20), litter cover (0.15), tree regeneration (0.15), and tree stem size class (0.15). The NSW native vegetation database contains benchmark data for each of these attributes for each recognised plant community type. Using sample plots, measurements are made of each of the attributes within the vegetation zone, which are then compared with the benchmarks for the relevant plant community type. The integrity score with respect to function therefore reflects how close a zone is to benchmark function for its type.

Once these scores for composition, structure, and function are combined[3] to give an overall Vegetation Integrity Score for each zone, reflecting the current biodiversity value of the native vegetation, this is used as a basis for deriving losses or gains from development or conservation of the land respectively. Development of the land will normally result in the total loss of the current biodiversity value because the native vegetation will be entirely cleared[4]. Conservation of the land, as part of a Biodiversity Stewardship Site, is understood to produce biodiversity gains from averted loss and improvements (see section 4.1 above). Thus to derive the biodiversity gain from conservation, a prediction is made about the future biodiversity value (the Biodiversity Assessment Method specifies a forecast horizon of 20 years) under two scenarios: firstly, with no management for conservation and, secondly, with management for conservation. The expected biodiversity gain

[3] The scores are combined as the cube root of their product.

[4] The Biodiversity Assessment Method contains some provisions for recognising mitigation efforts to reduce the impacts of development on biodiversity, but these are likely to be peripheral.

is the difference between these predictions. The "no management" scenario assumes that each of the elements of composition (i.e. species richness of each growth form group), structure (i.e. foliage coverage of each growth form group), and function (i.e. six function attributes) will degrade at standard annual rates of decline[5]. The "with management" scenario assumes that the elements of composition, structure[6] and function[7] each have an intrinsic rate of increase that will improve their scores each year. In addition to the gains from the intrinsic rate of increase expected from the undertaking of required management actions (see section 4.1 above), gains in specific elements of composition, structure and function can be made from active restoration management actions targeting these elements. The Management Plan must specify the target values for these elements. The expected gains from these are then added to the gains from the intrinsic rate of increase. Thus the biodiversity gain from conservation is measured as the sum of the degradation from the "no management" scenario and the improvements (both intrinsic and targeted) from the "with management" scenario over the 20-year forecast horizon.

The Vegetation Integrity Score device thus addresses the second problem of framing a space of calculability. In the NSW biodiversity offsetting mechanism, the introduction of the Vegetation Integrity Score device means that quantification and measurement of biodiversity losses and gains is interwoven with an ecological conception of the effects of development and conservation. The device brings numerous ecological qualities of habitats – attributes of composition, structure and function – inside the framed space of calculability. These then form the basis of quantification and measurement of losses and gains of biodiversity. In this way, bringing the Vegetation Integrity Score device into the NSW biodiversity offsetting mechanism results in a reconfiguration of the framed space of calculability that captures the overflowing ecological effects of development and conservation. This (re)framing may thus be seen to address anxieties expressed by conservationists regarding the simplistic and apparently arbitrary ways that biodiversity losses and gains have been derived in offsetting mechanisms.

This (re)framing has an effect of reinforcing the credibility of the premise, seen in section 4.1 above, that biodiversity gains are produced by human action. By rendering sites comparable, not just with each other, but also with the benchmarks set out in the NSW native vegetation database, the Vegetation Integrity Score device embeds a comprehensible ecological meaning within quantified

[5] The Biodiversity Assessment Method contains standard annual rates of decline for both high risk and low risk land. Standard annual rates of decline for high risk land are double those for low risk land. High risk land is defined in terms of having been classified by local government as suitable for residential, business, industrial, or agricultural uses. The standard rates for some elements of biodiversity value can also be increased if high threat exotic vegetation is present in the vegetation zone.

[6] The scores for composition and structure for the 'other' growth form group category is assumed not to increase.

[7] The only function attribute with a non-zero intrinsic rate of increase in litter cover.

losses and gains. Losses are moves away from benchmark; gains are moves towards benchmark. This establishes a kind of potential ideal form for the habitats comprising NSW biodiversity: a specific objective for human management of the land. The ecological conception interwoven with the calculability achieved here paints a picture of biodiversity that is presently degraded (i.e. below benchmark) and becoming more degraded (i.e. moving further from benchmark). Moving this biodiversity in the direction of its potential ideal form (i.e. towards benchmark) requires human action to restore habitats by managing the land for conservation. Quantifying and measuring biodiversity losses and gains based on an ecological conception of the effects of development and conservation respectively, therefore, may be seen to provide a basis for an ecologically defensible calculability.

4.3 Extracting a net loss/gain of biodiversity

As seen in section 2.1 above, the third problem of framing a space of calculability for biodiversity offsetting is how to extract a net loss/gain of biodiversity result. As seen in section 2.2 above, conservationists have expressed anxiety that biodiversity offsetting mechanisms do not adequately take into account the uniqueness of particular species and habitat-types. The unique qualities of some natural places thus overflow the frame. The NSW biodiversity offsetting mechanism seeks to capture this overflow by bringing a new device into its socio-technical arrangement: the Biodiversity Offset Rules.

The NSW biodiversity offsetting scheme has two kinds of biodiversity offset credits that can be produced at Biodiversity Stewardship Sites: ecosystem credits and species credits. Ecosystem credits represent gains in the composition, structure and function of the native vegetation comprising particular plant community types (see section 4.2 above). The number of ecosystem credits produced is a function of the predicted gain in Vegetation Integrity Score and the area of the vegetation zone. Species credits represent gains in the habitat suitability of the site for particular threatened fauna or flora species. Eligible threatened species are listed in a NSW database. To generate species credits, a species survey is carried out on-site to identify the presence of the threatened species. The number of species credits produced is a function of the gain in Vegetation Integrity Score and either the area of identified suitable habitat for the species or else the number of individuals of that species identified on the site.

Where a development site records a biodiversity loss, this loss can be offset by purchasing credits produced by one or more Biodiversity Stewardship Sites. However, developers are required to follow Offset Rules, which require that such biodiversity offsets are like-for-like. That is, developers can only offset biodiversity losses with credits that represent gains of the same kind of biodiversity. A NSW database of native vegetation classifies each plant community type into one of 99 vegetation classes, based on ecological characteristics. This database also classifies each plant community type into one of four offset trading groups based on the extent to which that plant community type has already been cleared within NSW. These groups are very high threat status (>90% cleared), high threat status (70%-90% cleared), moderate threat status (50-70% cleared), and low threat status (<50% cleared). Losses in the biodiversity value of native habitat of a particular plant community type can only be offset with ecosystem credits generated from the conservation of a plant community type of the same vegetation class and in the same or higher offset trading group. Additionally, such losses can only be offset with credits generated in the same subregion of NSW. Losses of biodiversity value of threatened species habitat can only be offset with species credits generated from conservation of habitat of the same threatened species.

In addition to the like-for-like rules, the Offset Rules also stipulate that some losses of biodiversity can be classified as Serious and Irreversible Impacts, such that they cannot be offset. If a development causes biodiversity loss that is classified as serious and irreversible, then this loss cannot be offset by purchasing biodiversity offset credits (and so planning permission for the development should be denied). Biodiversity losses are classified as being serious and irreversible where the loss concerns a threatened species or habitat that is rapidly declining, has a very small population size, has a very limited geographic distribution, or is unlikely to respond to conservation measures aimed at improving habitat. Detailed criteria, based on IUCN Red List criteria for critically endangered species[8] (see Cuckston, 2018), are set out by the NSW government to aid determination of whether biodiversity losses should be classified as serious and irreversible.

The Offset Rules device thus addresses the third problem of framing a space of calculability. In the NSW biodiversity offsetting mechanism, the introduction of this device adds a new qualitative dimension to the extraction of a net loss/gain of biodiversity result. Combining losses in biodiversity from development in one place with gains in biodiversity from conservation in another place becomes dependent on the kind of biodiversity that is being lost or gained. The like-for-like rules ensure that net loss/gain of biodiversity refers to an overall loss or gain of one species or one habitat-type. The Serious and Irreversible Impacts provision ensures that some natural places are recognised as irreplaceable and, as such, their loss is not offsettable. In this way, bringing the Offset

[8] For example, a rapid rate of decline means that >80% of a population of a species over 10 years or 3 generations (whichever is longer) is observed, estimated, inferred, or reasonably suspected. Similar quantified criteria are specified for small population, limited geographic distribution, and lack of response to conservation measures.

Rules device into the NSW biodiversity offsetting mechanism leads to a reconfiguration of the framed space of calculability that captures the overflowing unique qualities of natural places and brings them into account in calculations of net loss/gain of biodiversity. Within the space of calculability framed by the NSW biodiversity offsetting mechanism, significant restrictions have been established on the exchangeability of natural places. This (re)framing may thus be seen to address anxieties expressed by conservationists regarding the commodification of nature.

This (re)framing has an effect of enriching the ecological conception of biodiversity embedded within the mechanism, discussed in section 4.2 above. The implied objective for human management of NSW biodiversity becomes a matter of preserving examples of all recognised native species and habitat-types. Losses of biodiversity are acceptable, and can be offset, only where this does not undermine this preservation of these types. In this way, this (re)framing recognises that different forms of life – different species and habitat-types – have qualities that they do not share in common. As such, these forms of life cannot be wholly reduced down to those things (e.g. attributes of composition, structure, and function) that they do share in common. The Vegetation Integrity Score provides a means of commensurating different forms of life in different places, but the Offset Rules ensure that commensurability does not necessarily mean exchangeability. The qualities that make different forms of life unique cannot be made commensurable, yet they are taken into account in the offset calculations here, through the Offset Rules device. Within the space of calculability that includes this device, the extraction of a net loss/gain of biodiversity can only be achieved where the respective losses and gains relate to natural places that share (at least some of) these qualities. This recognition of a fundamental infungibility of different forms of life, and the consequent restrictions on their exchangeability, therefore, may be seen to provide a basis for an ecologically defensible calculability.

5. Discussion

The purpose of this paper is to explain how proponents of biodiversity offsetting have sought to produce an ecologically defensible mechanism for reconciling economic development and biodiversity conservation. To do this, the paper has analysed how the NSW Biodiversity Offsets Scheme has framed a space of calculability that enables calculations of net loss/gain of biodiversity. The analysis identified three devices that address anxieties expressed by conservationists concerning biodiversity offsetting. The effects of these three devices, in terms of how they have captured the overflows identified in the conservation literature, are summarised in table 4.

	Overflow identified in conservation literature concerning biodiversity offsetting	Device brought into NSW mechanism to reframe space of calculability and capture overflow	Reframing addresses anxieties expressed by conservationists
1	Calculability achieved does not take account of the means of producing biodiversity gains from conservation.	*Management Plan*: Specifies management actions that must be performed on a particular biodiversity stewardship site. Biodiversity gains are defined as the difference in ecological condition between two scenarios: one with and one without these management actions.	The act of conservation is explicitly defined as the performing of the management actions specified in the management plan. Biodiversity gains are understood to be produced as a result of performing these actions.
2	Calculability achieved does not take account of the ecological effects of development and conservation.	*Vegetation Integrity Score*: Measures biodiversity losses and gains in terms of scores for ecological attributes relating to the composition, structure and function of a habitat. Compares scores with benchmarks for relevant habitat-type.	The quantification and measurement of losses and gains of biodiversity within a site is explicitly derived from an ecological conception of the effects of development and conservation respectively.
3	Calculability achieved does not take account of the uniqueness of particular species and habitat types.	*Offset Rules*: Restricts the exchangeability of species and habitats, such that net loss/gain in biodiversity refers to net loss/gain of one species or one habitat-type. Losses of biodiversity that are understood to be serious and irreversible cannot be offset within the mechanism.	The extraction of a net loss/gain of biodiversity can only be achieved in ways that ensure preservation of unique qualities of different forms of life.

Table 4: Summary of analysis of NSW biodiversity offsetting mechanism, highlighting three accounting devices used within the mechanism to capture the three identified overflows and how each of these devices addresses the anxieties expressed by conservationists within the conservation literature.

The remainder of this section will discuss these key findings of the analysis. Firstly, an illustrative example will show how these devices affect the calculability of biodiversity gains generated within the NSW mechanism. Secondly, the discussion will consider how the analysis contributes to extant understanding of ecologically-informed accounting for biodiversity and the implications for conceptualising sustainable development. Thirdly, the discussion will highlight some of the limitations of the NSW case study. Finally, the discussion will consider how the novel form of analysis developed within this paper opens up opportunities for further research.

5.1 Illustrative example

In order to illustrate the key findings of the analysis in section 4, summarised in table 4 above, this sub-section will describe how the three devices identified in the NSW mechanism have affected the calculability of biodiversity gains within a specific biodiversity stewardship site. This will provide a concrete example of how this mechanism frames the biodiversity offsetting calculation.

The site used for this illustrative example is an eight hectare patch of land located in the north-west Sydney suburbs. It is a forest habitat and an example of the plant community type known as *Castlereagh Ironbark Forest*, listed as endangered in NSW (NSW, 2018). The owners of the land decided to designate it a biodiversity stewardship site and employed a firm of consultant ecologists to calculate the biodiversity credits that the site will generate[9]. The following will explain how the three devices identified in the analysis of the NSW mechanism have affected this particular calculation.

Firstly, the *Management Plan* device is used to specify the management actions that will be conducted to manage the site for biodiversity conservation. The main points from the management plan for this site are as follows:

- The site will be permanently fenced to prevent unnecessary access.
- Permanent signage will identify the site as a Conservation Area.
- The site will be subject to restrictions so as to prohibit any dumping, grazing, agriculture, removal of woody debris or bush rock, use of vehicles, and establishment of tracks or paths.
- All existing paths and other disturbed areas must be allowed to regenerate.
- All invasive weeds on the site will be removed and subsequently controlled. This will require the following activities:
    - Hand-removal of weeds in areas where small woody weeds, herbs and grasses occur in small densities;
    - Hand-removal of all weeds in close proximity to threatened flora species;
    - Spot-spraying with a non-selective herbicide on herbs and grasses occurring in high densities;
    - "Cut and paint" method[10] applied to large woody weeds;
    - Secondary weeding to target re-sprouting or new weed infestations. It is anticipated that secondary weeding will be needed bi-monthly during peak growing seasons and quarterly in cooler periods.

[9] The calculation used the 2014 methodology from the NSW Biodiversity Banking scheme, which was the precursor to the 2017 Biodiversity Assessment Method. The calculation therefore differs in some details, but the essential principles are consistent with the analysis presented in section 4.

[10] The cut and paint method of weed control involves cutting of a plant completely at its base and then painting a herbicide directly onto the exposed surface of the stump, with the aim of killing the stump and root system.

The management plan also includes provision for ongoing monitoring and reporting on the ecological condition of the site. This is to allow management of the site to adapt to changing circumstances on the site.

> Monitoring and reporting are extremely important. Information gained through the monitoring and reporting process will identify works that have and have not been successful, and the reasons for their success or failure.
>
> (*Quoted from site Management Plan*)

The monitoring is to be conducted by a 'suitably qualified ecologist' using fixed photo points throughout the site to monitor changes in the vegetation over time. The ecologist will produce a report detailing all the management activities, including weeding, performed within the site. The report will also establish how successful these activities have been, compared with specified performance criteria for the first five years of the site's management. These criteria include targets for percentage of native and exotic species coverage on the site, shown in table 5.

	Year 1	Years 2-4	Year 5
Native species cover (%)	>50%	>60%	>80%
Exotic species cover (%)	<15%	<10%	<5%

Table 5: Performance criteria for native and exotic species cover on the site over a period of five years.

Thus, by actively protecting the site from disturbances, and controlling invasive weeds, the ecological condition of the site is expected to improve through natural regeneration. The management plan explicitly sets out the actions that are to be conducted on the site that will produce the claimed biodiversity gains.

Secondly, the *Vegetation Integrity Score* device is used to quantify and measure the biodiversity gains on the site. This requires data to be collected about the current ecological condition of the site so that this can be compared to benchmark data for the Castlereagh Ironbark Forest plant community type. In order to collect this site data, three 20m x 20m plots were marked and analysed to ascertain the ecological attributes required for calculating the Vegetation Integrity Score. This included measurements relating to composition, structure and function. Composition was measured in terms of species richness (a total of 37 native flora species were identified across the three plots, compared with a benchmark for this plant community type of 38). Structure was measured in terms of foliage cover (e.g. the average foliage cover for native trees across the three plots was found to be 21.1%, compared with a benchmark for this plant community type of 44.0%). Function was measured in terms of various attributes conducive to providing good quality habitat (e.g. the average total length of fallen logs across the three plots was found to be 26.7m, compared with a benchmark for this plant community type of 68.0m). The collected site data from the three plots was compared against the benchmark values for Castlereagh Ironbark Forest plant community type to ascertain an overall current site value for the Vegetation Integrity Score. This was calculated to be 58.33. Applying the intrinsic rate of increase to some of the measured attributes, the with-management scenario was calculated to lead to an increase in score of 20.66 to a future value of 78.99. Due to the nature and location of the site, the consultant ecologists concluded that the without-management scenario would lead to a future score similar to the current value. So the current score was used as the future value in the without-management scenario. This means that the biodiversity gain produced from the site's management for conservation, in terms of Vegetation Integrity Score, was calculated as 20.66. This calculation of biodiversity gain on the site has been derived from an ecological conception of the effects of conservation on particular ecological attributes of the site.

Thirdly, the *Offset Rules* device dictates how the biodiversity gains from the site can be used to offset biodiversity losses from other sites. The site generates both ecosystem credits and species credits. The number of ecosystem credits is calculated as a function of the gain in Vegetation Integrity Score and the area of the site. The site is calculated to generate 79 ecosystem credits for

Figure 1: Images of the four threatened species identified on the site for which species credits are generated. Top: Dillwynia tenuifolia, bottom-left: Acacia bynoeana, bottom-centre: Micromyrtus minutiflora, bottom-right: Grevillea juniperina.

the plant community type Castlereagh Ironbark Forest. Under the Offset Rules, these can be used to offset biodiversity losses of a plant community type that is the same vegetation class (which, in this case, is Cumberland Dry Slerophyll Forests) of an equal or higher threat status (which, in this case, is *very high threat status*). The credits can also only offset biodiversity losses occurring in the same sub-region of NSW (which, in this case, is Cumberland).

The site also generates species credits for four threatened flora species (see figure 1)[11]. These were calculated as a function of the number of individuals identified on the site and the projected gain in the structure component of the Vegetation Integrity Score. In order to ascertain the number of individuals on the site, the consultant ecologists conducted a three-day, two-person targeted survey. The two ecologists walked 20m apart, recording individuals of the targeted threatened flora species that they identified 10m either side of them. The numbers of individuals of each threatened species is shown in table 6.

Scientific name	Threatened status	Number of individuals identified in ecological survey	Species credits generated
Acacia bynoeana	Endangered	27	192
Dillwynia tenuifolia	Vulnerable	7055	50090
Grevillea juniperina	Vulnerable	4826	34265
Micromyrtus minutiflora	Endangered	142	1008

Table 6: Threatened flora species identified on the site for which species credits have been generated.

These species credits can only be used to offset biodiversity losses relating to these specific threatened flora species. They are not fungible with losses of any other species. Thus, the Offset Rules device restricts the ways that the calculated biodiversity gains from this site can be combined with biodiversity losses in other places so as to extract a net loss/gain of biodiversity.

[11] Photographs of Grevillea juniperina, and Micromyrtus minutiflora used with permission from Royal Botanic Gardens and Domain Trust, Sydney, Australia. Photo credit: J. Plaza.

Photograph of Dillwynia tenufolia used with permission from Australian Native Plants Society. Photo credit: B Walters.

Photograph of Acacia bynoeana sourced from Atlas of Living Australia. Photo credit: D McKenzie © CC-BY.

5.2 Ecologically-informed accounting for biodiversity

Within the extant accounting literature, biodiversity offsetting has been characterised as little more than a legitimising strategy, used to justify destruction of nature (Ferreira, 2017; Sullivan & Hannis, 2017; Tregidga, 2013). However, the analysis of the NSW biodiversity offsets mechanism has shown that biodiversity offsetting is evolving to become more ecologically defensible. By bringing new accounting devices into its socio-technical arrangement, the NSW mechanism has framed a space of calculability in which calculations of net loss/gain of biodiversity are made in ways that address some of the anxieties expressed by conservationists within the conservation literature (identified above in section 2.2). This is not to say that biodiversity offsetting has necessarily become a force for genuine biodiversity conservation; the present analysis does not provide a basis for a judgement either way on that. But the analysis has shown that proponents of biodiversity offsetting are engaged in ongoing efforts to reframe its space of calculability to capture the overflows that have caused conservationists to express anxiety.

The analysis has shown that the NSW mechanism embeds a form of accounting for biodiversity that runs counter to the prevailing dominant *anthropocentric* approach. Rather than accounting for the biodiversity of a site in terms of the economic benefits it provides to humans, the NSW mechanism accounts for biodiversity in terms of its ecological value. The Management Plan device sets out actions that are meant to protect and improve a site's ecological condition. The Vegetation Integrity Score device values the biodiversity of a site based on ecological attributes. The Offset Rules device restricts the fungibility of biodiversity losses and gains based on ecological criteria. Within the NSW mechanism, therefore, the accounting for biodiversity is centred on the ecology (not the economics) of the site's biodiversity. In this sense, the accounting for biodiversity embedded within the NSW mechanism may be said to be *ecocentric*. This term is often used to describe forms of accounting for nature that eschew numbers altogether, instead drawing on narratives of spiritual interconnectedness with nature (see Christian, 2014). In contrast, the accounting for biodiversity seen in this case study is technical and quantitative, but draws on an ecological (rather than economic) conception of biodiversity.

This is an important empirical contribution to the extant accounting for biodiversity literature. Much of this literature conflates a calculative approach to accounting for biodiversity with an *anthropocentric* economic approach (cf. Jones & Solomon, 2013). This analysis has revealed a form of accounting for biodiversity that uses numbers to provide valuations of biodiversity, but these numbers are ecological numbers, not economic numbers. So this is a calculative, and also *ecocentric*, approach to accounting for, and valuing, biodiversity. This is important because it opens up new possibilities for 'reimagining an ecologically informed accounting' (Russell et al., 2017, p. 1426). In particular, this *ecocentric* calculative approach to accounting for biodiversity reveals a novel conceptualisation of the relation between economic development and biodiversity conservation. These are generally held to be antithetical opposing forces: economic development causes destruction of biodiversity and conservation of biodiversity prevents economic development (see especially Sullivan & Hannis, 2017). In contrast, the NSW biodiversity offsetting mechanism frames the relation between development and conservation as being two complimentary aspects of human management of the biosphere. Within this mechanism, conservation of a site is not seen as being merely a lack of development. Both development and conservation are framed within the mechanism as active processes of managing the land to create value. In the case of development, this is economic value. In the case of conservation, this is ecological value.

The accounting for biodiversity embedded within the NSW mechanism makes visible the *ecological* impacts of both development and conservation in a way that renders these commensurable. Reconciling development and conservation therefore becomes a matter of organising these ecological impacts so that, overall, an ecologically defensible *no net loss* of biodiversity is achieved. This offers a possible way forwards for reimagining accounting's role in enabling biodiversity conservation in a world where economic development tends to be seen as paramount (cf. Gray, 2010). If such economic development is to be considered sustainable development then it must be achieved whilst ensuring that the planet's biodiversity, accounted for and valued in a way that is ecologically defensible, is conserved.

5.3 Limitations of the NSW biodiversity offsets case study

Callon (1998) warns that all efforts at framing or reframing will inevitably create conditions for further overflows. No framing is ever perfect or complete: framing and overflowing is a perpetual dynamic. Indeed, the (re)framing witnessed in the NSW case study may be seen to produce further overflows. For example, the quantification and measurement of biodiversity gains from conservation rests on a presumption of future gains from averted loss and future improvements. So there is a time lag in net loss/gain calculations that is not being taken into account, whereby current losses are being offset by (presumed) future gains. As identified in section 4.1, there is no subsequent assessment of a site to see if these presumed gains are actually realised. There is, therefore, an overflowing relation between these presumed biodiversity gains (inside the frame) and the actual future ecological condition of a site (outside the frame and so not taken into account). This is an important limitation of the NSW mechanism's ecological defensibility. Further reframing by proponents of biodiversity offsetting may be necessary to capture this overflow and further enhance ecological defensibility.

Another important limitation of this case, which affects the extent to which proponents of biodiversity offsetting can draw lessons from the NSW mechanism, is that its ecological defensibility is somewhat dependent on its geographical location. NSW is Australia's most populace state. The landscape is dominated by agricultural and urban environments. So the conservation challenge in this location is to protect and enhance the remaining remnants of native Australian habitat. These remnant patches of habitats face two major threats. One is from development: conversion of the land to agricultural or urban use. The other is from invasive species. In particular, invasive weed species are undermining the ecological integrity of native plant communities. These threats are built in to the NSW mechanism. The agricultural and urban surroundings of these remnants of native habitat means that the sites will need ongoing intervention and management to protect them and maintain their ecological condition, hence the need for detailed management plans for biodiversity stewardship sites. In addition, the threat from invasive weeds drives the assumption within the mechanism that without intensive control of these weeds the ecological condition of these sites will be degraded. Hence the production of biodiversity gains within the NSW mechanism is predicated on these particular threats in this particular location. This means that it is unlikely that the mechanism could be straightforwardly transported to other locations. Attempting to do so would likely generate new overflows that would undermine its ecological defensibility. Any attempt to establish a similar mechanism in a different location would likely require further work to reframe its space of calculability, to capture these overflows and maintain its ecological defensibility.

These limitations of the NSW biodiversity offsets case study present challenges to proponents of biodiversity offsetting, but also opportunities for further research. Biodiversity offsetting is rapidly proliferating. Mechanisms in other locations, with different kinds of landscapes and different threats to biodiversity, face similar pressures from conservationists to ensure calculations of net loss/gain of biodiversity are ecologically defensible. So further research is needed to understand how biodiversity offsetting is evolving in different social and ecological settings.

5.4 Framing/overflowing: opportunities for further research

The novel form of analysis developed in this paper significantly extends the way that Callon's (1998) framing and overflowing metaphor has been used in extant accounting literature. In particular, this paper offers a novel methodological approach to identifying overflows to framed spaces of calculability, searching for these in academic literature on the phenomenon being studied (in this case, biodiversity offsetting). A systematic review of conservation literature on biodiversity offsetting revealed various overflows that formed the basis of conservationists' anxieties about calculations of net loss/gain of biodiversity. This provided a starting point for analysis of the NSW biodiversity offsetting mechanism, seeking out the ways that NSW was reframing offsetting calculations to capture these identified overflows.

This novel methodological approach to the use of Callon's (1998) framing and overflowing metaphor opens up opportunities for future research into accounting for biodiversity. Any attempt to account for biodiversity is inherently controversial. However, when critiquing such efforts prior research has tended to rely either on authors' own understandings of nature (e.g. Barter, 2015; Christian, 2014), or on the understandings of actors drawn from the case (e.g. Cuckston, 2018a; Tregidga, 2013). By instead looking to conservation research literature, this paper has been able to meaningfully engage with extant critique expressed within the conservation science community (cf. Feger et al., 2018). This novel methodological approach allows for a potentially more nuanced analysis of efforts to account for biodiversity than is seen in much of the extant accounting literature (see Cuckston, 2018b). This paper's analysis of the NSW case illustrates this approach, revealing efforts to evolve biodiversity offsetting into a more ecologically defensible mechanism.

Furthermore, a similar methodological approach could be developed in relation to other sustainable development challenges facing society. Analysing the role that accounting can or could play in addressing such challenges requires an inherently interdisciplinary approach to research (Bebbington & Larrinaga, 2014; Bebbington & Unerman, 2018). This paper's novel methodological approach to using Callon's (1998) framing and overflowing metaphor offers a way to meaningfully engage with the issues, concepts and concerns of other academic disciplines, using these to inform case study analysis. This opens up numerous opportunities for interdisciplinary engagement and nuanced analyses of efforts to use accounting and calculative devices to address sustainable development challenges.

6. Conclusion

This paper has shown that biodiversity offsetting is evolving as proponents seek to produce a more ecologically defensible mechanism for reconciling economic development and biodiversity conservation. This is being pursued by introducing accounting devices that frame a space in which calculations of net loss/gain of biodiversity are based on a calculative, but *ecocentric*, approach to accounting for, and valuing, biodiversity. In a world where economic development is a somewhat unstoppable force (cf. Gray, 2010), humanity must find ways of managing the biosphere to ensure biodiversity is conserved. The evolution of biodiversity offsetting witnessed in this paper may be seen to form part of ongoing efforts to achieve this kind of sustainable development.

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