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Current Opinion in Environmental Sustainability

Biodiversity offsets: from current challenges to harmonized metrics

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Biodiversity offsets are compensatory mechanisms increasingly used to address ecological impacts resulting from human activities. We review the scientific literature on biodiversity offsets, published between 1999 and 2014. We found that biodiversity offset studies have increased through time. The majority of studies have been carried out in the USA. The development of biodiversity offsets schemes faces conceptual and practical challenges. The conceptual challenges discussed in the literature are: choice of metric, spatial delivery of offsets, equivalence, additionality, timing, longevity, ratios and reversibility. The practical challenges reported in the literature are: compliance, monitoring, transparency and timing of credits release. Amongst these, choice of metric and location are paramount and are related to the multidimensional nature of biodiversity and the values society places on biodiversity. Harmonized metrics such as the Essential Biodiversity Variables (EBVs) help to address these challenges by providing comparability of biodiversity loss and gain amongst locations.

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Current Opinion in Environmental Sustainability 2015, **14**:61–67

This review comes from a themed issue on **Open issue**

Edited by **Eduardo S Brondizio**, **Rik Leemans** and **William D Solecki**

Received 02 December 2014; Accepted 30 March 2015

http://dx.doi.org/10.1016/j.cosust.2015.03.008

Introduction

Biodiversity offsets are a mechanism to compensate unavoidable impacts of a project or plan on biodiversity through conservation or restoration actions [1,2••]. Compensatory measures should only be considered after exhausting the previous steps on the mitigation hierarchy: avoidance and minimization [3]. If avoiding and minimizing the impacts did not neutralize the negative effects of a project development on biodiversity, then compensatory measures such as biodiversity offsets potentially become the next step. Biodiversity offsets are different from other ecological compensatory measures because they target residual impacts and enforce measurable outcomes, that is, losses to biodiversity caused by the project and the gains obtained by the conservation action are quantified in the same way and must be comparable [1,4].

Hence, not all compensatory actions are offsets. For a compensatory action to qualify as a biodiversity offset, a range of criteria should be met. Besides compensating for residual ecological damage [5,6], and delivering quantifiable outcomes, an often stated goal of biodiversity offsets is to deliver 'no net loss' of biodiversity, and preferably net gain [1]. However, most biodiversity offsets compensate for one or just a few dimensions of biodiversity, like species composition, habitat structure, ecosystem function or cultural values [7,8], and it can be difficult to achieve full equivalence between the impact and the biodiversity offset. Finally, biodiversity offsets should prove additionality. Additionality refers to the conservation benefit or gain produced as a result of delivering an offset that would have not arise in the absence of the compensation action [3,7,9]. The additional conservation value generated by an offset is the difference between the outcome of when a biodiversity offset is put in place relative to when is not [10•]. The most common form of guaranteeing 'additionality' is though habitat restoration [11]. But additionality can also be achieved through measures like habitat creation [6,12] or by affording protection to areas under imminent, or projected, biodiversity loss [1,13].

Biodiversity offsets gained momentum in the last decade in the policy arena and within the private sector [8,14,15]. There is an increasing number of policies, directly or indirectly, referring to biodiversity offsets, such as the EU No Net Loss initiative for 2015, part of the EU 2020 Biodiversity Strategy [16]. In the private sector, a growing number of investment institutions demand offsetting as a condition to access credit, for example the International

Finance Corporation has a performance standard that requires development projects to consider biodiversity offsets [17].

However, the implementation of biodiversity offsets still faces many challenges [2••,18]. Bull *et al.* [2••] distinguishes two main types of challenges: conceptual issues which can be addressed by ecological research; and practical issues related to the governance and implementation of biodiversity offsets. Solving these challenges, could allow biodiversity offsets to mature and deliver the promised benefits locked in the concept behind them, thus creating new opportunities for conservation. Here we aim to understand how the academic community has contributed to solve these pressing issues and how future research can enhance biodiversity offsets implementation.

Conceptual and practical challenges in the biodiversity offsets literature

We used the ISI Web of Science database to search for scientific published literature on biodiversity offsets between 1999 and 2014 (see Supplementary information for more details). We selected articles that specifically analyzed biodiversity offsets and not ecological compensation measures in a broader sense. For each paper we identified which biodiversity offsets challenges were analyzed according to the following categories: equivalence, location, additionality, timing, longevity, currency, ratios, reversibility, compliance, monitoring, transparency and credit issuing (Table 1).

We found that research effort on biodiversity offsets has been increasing in the last fifteen years (Figure 1). About 57% of the studies been led by an author affiliated to an USA institution (Figure 1). This result is not surprising since the USA has pioneered biodiversity offsetting with the wetland mitigation program in the early 1970s [19]. The wetland mitigation program focused exclusively on offsetting wetlands lost to development and in 1990 a goal of no net loss of area or functional capacity was established under the Clean Water Act [20]. Since then, the goal of no overall loss of function and area has been applied to other habitats as well as to impacts on protected species, both in the USA and abroad [13,15,21]. The USA Wetland Mitigation program has in many ways influenced the different biodiversity offset schemes worldwide [15,22].

In recent years, scientific research on biodiversity offsets has gained importance in Europe (Figure 1). The research momentum seems to follow an increase in policy and societal attention to biodiversity offsetting in Europe. For instance, the EU Biodiversity Strategy for 2020, in connection to the Aichi 2020 Target 15 on ecosystem restoration, seeks to ensure no net loss of biodiversity and ecosystem services [23]. An European No Net Loss initiative has been initiated which includes the development of biodiversity offset schemes as one of the policy options. Currently compensation of unavoidable negative impacts on biodiversity is a legal requirement in Europe, through the Birds and Habitats Directives and the Environment Liability Directive, but only in the case of

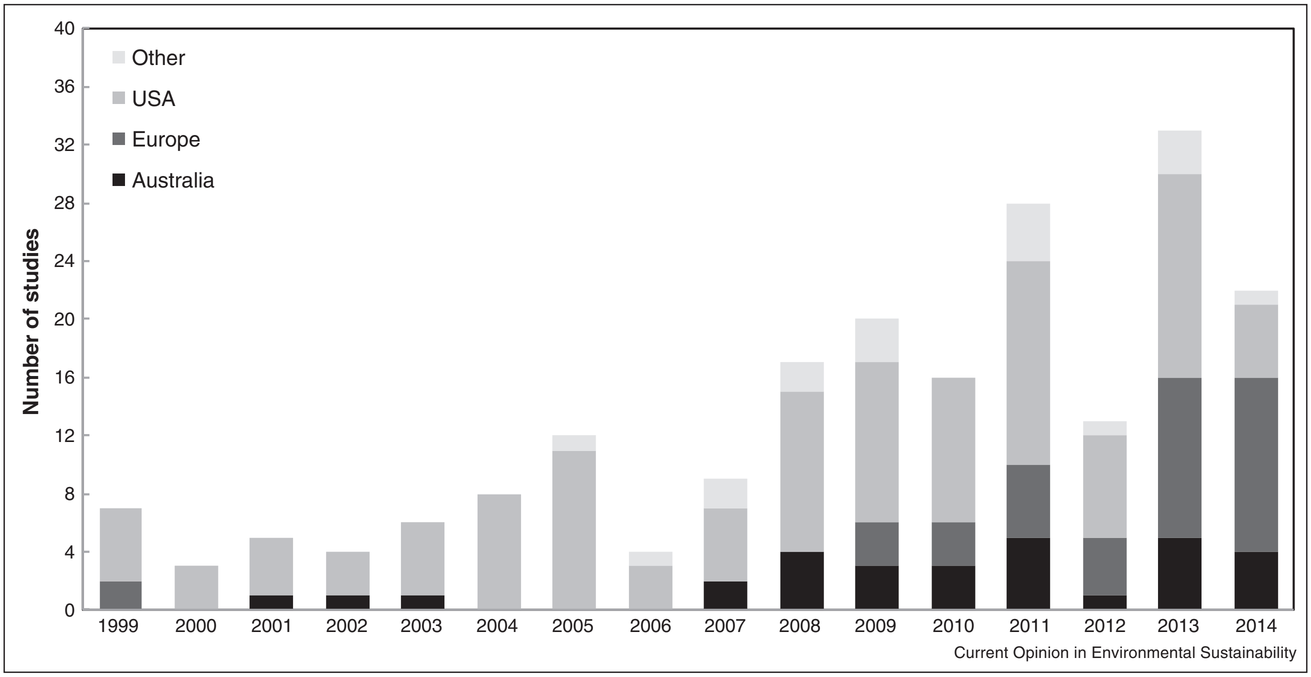
Table 1

Conceptual and practical issues on biodiversity offsets

Conceptual	Practical
Equivalence Whether the loss of biodiversity in one location can be compensated by gains on another location, for instances demonstrate No Net Loss	*Compliance* Whether existing regulations and guidelines are followed
Location Spatial allocation of offsets in relation to impacts (on-site versus offsite)	*Monitoring* How well offsets ecological performance is followed after implementation stage is over
Additionality A new contribution to biodiversity conservation that results from the offset delivery	*Transparency* How transparent is the process of biodiversity offsets implementation and monitoring
Timing Addressing the temporal lag between impact occurrence and compensation benefits accruing (prior versus after)	*Credit issuing* At what stage of offset implementation are the credits issued to the impact proponent
Longevity How long offsets are expected to last for, for example, in perpetuity versus for a long as impact occurs	
Ratios The use of ratios, or multipliers, is commonly used as a strategy to manage uncertainty in offset delivery, for example, correction for time lags	
Reversibility Whether impacts are permanent or temporary and whether the impacted biodiversity has the capacity to fully or partially return to its previous state once the impact is removed	

Adapted from McKenney and Kiesecker [18] and Bull *et al*. [2••].

Figure 1



Number of studies published on biodiversity offsets between 1999 and 2014 per world region.

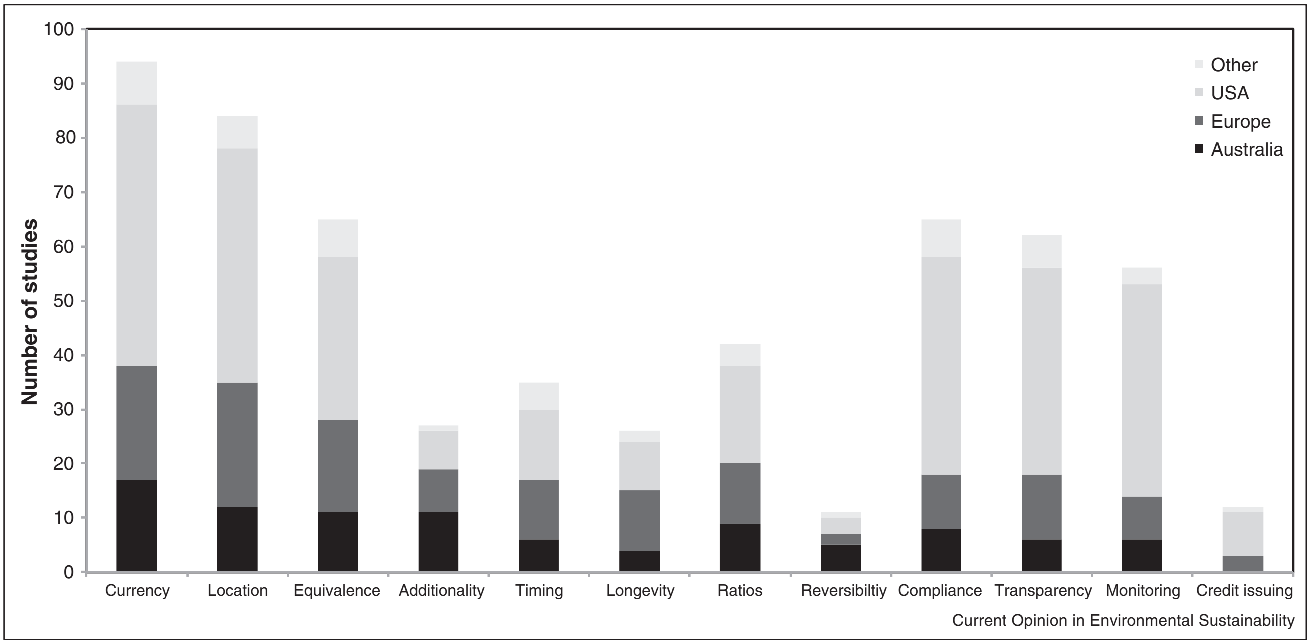
damages to the Natura 2000 network of protected areas. However, given the current rate of biodiversity loss in the EU, the No Net Loss initiative seeks to develop mechanisms beyond the current legal requirements. Another aspect of the discussion of biodiversity offsets in Europe relates to how offsetting could potentially raise extra funding for conservation [24].

In the UK and France offsetting is currently being tested [25,26••,27]. Germany has a well-established system for offsetting and mitigating impacts that goes beyond protected species and protected areas. The German Impact Mitigation Regulations (IMR), based on the Federal Nature Conservation Act, aim to compensate for impacts in entire ecosystems and landscapes. However, there are no legal provisions in the IMR specifying how to assess the initial state of the area to be affected, the probably impacts resulting from the intervention or the appropriate methodology to determine compensation [28].

Recent reviews on biodiversity offsets have identified conceptual and practical issues hindering biodiversity offsets implementation (Table 1). The conceptual issues more discussed in the literature were currency, location, and equivalence (Figure 2). The practical issues more frequently mentioned were compliance, transparency and monitoring. Some issues, were recurrent through the period of time analyzed in our survey, such as the conceptual issues of currency, location and ratios and the practical issue of monitoring. This may be because these issues, which are still under discussion, are at the core of the concept of biodiversity offsetting. By contrast, issues like longevity and reversibility emerged in the literature more recently. Longevity may have emerged later because, as more biodiversity offset projects are implemented, the problem of funding these offsets through time becomes a concern [2••,29,30]. The rise of studies addressing reversibility may be related to the recognition that biodiversity offsets have limitations in addressing irreversible biodiversity loss. According to the mitigation hierarchy perspective, biodiversity offsets are not an option to compensate for impacts on habitats with high irreplaceability [31••]. However, the mitigation hierarchy is not always effectively followed [3,32]. For example, a recent study reviewed national EIA processes and the mitigation hierarchy in Latin America. The study found that in the countries analyzed, most national EIA laws or regulations have been enacted in the last decade. However, only in some of the countries regulations mention the complete mitigation hierarchy and in none of the countries regulations require adherence to it. Requirements for measures of impact avoidance were particularly overlooked [33].

The majority of studies relate to freshwater environments (66%), in particular wetland ecosystems, followed by terrestrial environments (47%), while some recent studies start to explore the marine environment (1%). This

Figure 2



Number of studies on the different biodiversity offsets issues featured in the literature broken by world regions.

dominance of freshwater studies is to be expected since the US Wetland Mitigation Program pioneered offsetting.

We now explore the two most discussed conceptual issues in the biodiversity offsets literature, currency and location, in more detail.

Currency: the choice of metric for biodiversity

The issue of choice of metric is complex and directly associated with the multidimensional nature of biodiversity [34–37]. In addition, it is controversial whether biodiversity values across different dimensions of biodiversity can be converted to a common metric or exchanged between geographical locations [38]. The choice of metric will influence how gains and losses are accounted for and therefore how equivalence and No Net Loss are met. The choice of metric will also influence the calculation of offset ratios to manage uncertainties and the choice of location for the offset actions.

In the early offset projects, area alone was the currency used: the area impacted was offset by at least an equal area elsewhere [39]. However, as our understanding of ecosystem function grew, area by itself became no longer an adequate metric [40••,41]. Several methods have been developed to supplement area measurements in order to account for multiple biodiversity dimensions such as the condition, quality, ecological function and integrity of ecosystems [2••,18,42,43]. The use of compound metrics usually results in a more comprehensive measurement of biodiversity but adds complexity on comparisons across locations [44]. If an aggregated measure is used, the equivalence of the impacts and the restorations actions for each dimension can be difficult to assess.

Up to now, biodiversity offsets have operated locally or regionally, often on a case-by-case basis. Therefore each offset scheme has developed its own methodology, taking into account its particular context and compensation goals. This *modus operandi* makes it difficult to measure and compare the performance of the different projects in relation to each other, as well as to assess best practices [1]. A recent study by Bull *et al.* [45••] compared different methodologies and metrics used in biodiversity offset schemes, using gas extraction projects in Uzbekistan as a case study. They found that different methodologies resulted in different requirements to achieve no net loss. They argued that transferability of offsets across schemes or jurisdictions is limited.

Equivalence between credits generated in different schemes could be assessed if standard methodologies were adopted [2••,46•]. However, due to the complex nature of biodiversity, standardization across the different schemes in operation, or under development, may effectively be possible only to a certain degree.

Location: the choice of place for offsets delivery

Offset site selection and how selected sites sit within the broader landscape is another important aspect of offset design [3]. The choice of site has important ecological implications and is intrinsically dependent on the choice of metric used. Biodiversity offsets can be delivered in the vicinity of the area impacted [18]. The logic behind delivering offsets at close proximity to the lost habitat is that it increases the chances of contributing to the conservation and integrity of the same ecosystem as well as the needs of local people. When both proximity and social–ecological equivalence are met, offsets are classified as 'in-kind' — for quality — and 'on-site' — for spatial location [8,47]. On-site and in-kind offsets promote transparency of the offset delivery and render the demonstration of no net loss easier.

However the literature on systematic conservation planning suggests that, in certain circumstances greater environmental benefits result when offsets can be aligned with landscape or regional conservation goals, which may be 'out-of-kind' and 'off-site' [48,49,50••]. Advantages of off-site offsets also include their potential to secure protection of non-statutory sites of local biodiversity importance, to incorporate landscape aspects of population dynamics of threatened species, or as a source of conservation funding for biodiversity conservation initiatives. A preference for 'on-site' delivery of offsets has been increasingly loosened by several schemes in favor of better alignment with conservation goals at broader scales [18,29]. However, this trend in favor of 'off-site' and 'out-kind' type of offsets, is not always desirable and presents some philosophical challenges associated with the comparability of biodiversity values and the spatial distribution of impacts and benefits to local human communities.

Harmonizing metrics for biodiversity offsets: the EBV framework

The next decade will be crucial for biodiversity offsets and conservation. As more schemes emerge it is important to assure they deliver the promised biodiversity conservation benefits [51,52•]. Our analysis suggests that two of the most pressing conceptual issues associated with implementation of biodiversity offsets are the choice of metric and location. Their choice, and especially the choice of metric will cascade down affecting all other offset challenges. Therefore, it is essential that the research community contribute to establish a sound theoretical framework on how to measure biodiversity offsets and where to locate them.

Recently, Pereira *et al.* [53] suggested that monitoring programs should be based on a set of harmonized Essential Biodiversity Variables (EBVs) organized into six classes: genetic composition, species populations, species traits, community composition, ecosystem function and ecosystem structure. An EBV is defined as a measurement required for study, reporting and management of biodiversity change, and should exhibit certain characteristics, namely, scalability, temporal sensitivity, feasibility and relevance [53]. Monitoring programs based on EBVs would use a minimum set of essential measurements that capture major dimensions of biodiversity change [53]. EBVs can enable the harmonization between metrics and methodologies behind biodiversity offsets, allowing for comparison of outcomes and performance of biodiversity offsets across locations. Given that biodiversity values are context dependent, EBVs need to be adapted locally to reflect how human communities use ecosystem services delivered by biodiversity, particularly cultural benefits.

Table 2

Metrics used by biodiversity-offset studies, published between 1999 and 2014, mapped to classes of Essential Biodiversity Variables

Essential Biodiversity Variable class	Examples of metrics used in biodiversity offsets projects
Ecosystem structure (38 studies)	Habitat area, fragmentation
Ecosystem function (11 studies)	Net primary production; nitrogen content; soil pH
Species traits (7 studies)	Survival rate; emigration rate; dispersal distance
Species populations (38 studies)	Vegetation percent cover; number of trees per sizes/age class
Community composition (10 studies)	Species diversity

In order to assess the feasibility of the application of the EBVs framework to biodiversity offsets, we mapped the metrics used in the studies of offsets to EBVs classes (see Supplementary information). Our results show that the main EBV classes used in biodiversity offsetting schemes are species populations and ecosystem structure (Table 2). In the majority of studies, more than one EBV class was used in order to measure biodiversity losses and gains. This suggests that metrics in these classes are receiving more attention either because stakeholders feel they capture important aspects of biodiversity or because they allow for comparability of biodiversity values between impacts and conservation offsets.

Currently, the Group on Earth Observation Biodiversity Observation Network (GEO BON) is leading the development of EBVs for biodiversity monitoring, and a list of candidate EBVs is already available (http://www.geobon.org). Such timing, together with the increasing interest on offsetting provides a unique opportunity for cooperation between the biodiversity offsets research community and the monitoring community that should not be missed. From this cooperation a set of EBVs tailored for biodiversity offsets could be established, and biodiversity offset locations could contribute towards a global network of biodiversity monitoring sites.

Acknowledgements

This research was supported by the Fundação para a Ciência e Tecnologia (SFRH/BD/51438/2011) and by the MoBia project (Biodiversity Monitoring in Environmental Assessment, FCT no. PTDC/AAC-AMB/114522/2009). We thank L Borda-de-Água and S Ceauşu for their comments to this manuscript, as well as Dr G Grant from Ecoschemes and The Environment Bank for their time and availability.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cosust.2015.03.008.

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