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Review

Biodiversity Offsets and the Challenge of Achieving No Net Loss

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Abstract: *Businesses, governments, and financial institutions are increasingly adopting a policy of no net loss of biodiversity for development activities. The goal of no net loss is intended to help relieve tension between conservation and development by enabling economic gains to be achieved without concomitant biodiversity losses. biodiversity offsets represent a necessary component of a much broader mitigation strategy for achieving no net loss following prior application of avoidance, minimization, and remediation measures. However, doubts have been raised about the appropriate use of biodiversity offsets. We examined what no net loss means as a desirable conservation outcome and reviewed the conditions that determine whether, and under what circumstances, biodiversity offsets can help achieve such a goal. We propose a conceptual framework to substitute the often ad hoc approaches evident in many biodiversity offset initiatives. The relevance of biodiversity offsets to no net loss rests on 2 fundamental premises. First, offsets are rarely adequate for achieving no net loss of biodiversity alone. Second, some development effects may be too difficult or risky, or even impossible, to offset. To help to deliver no net loss through biodiversity offsets, biodiversity gains must be comparable to losses, be in addition to conservation gains that may have occurred in absence of the offset, and be lasting and protected from risk of failure. Adherence to these conditions requires consideration of the wider landscape context of development and offset activities, timing of offset delivery, measurement of biodiversity, accounting procedures and rule sets used to calculate biodiversity losses and gains and guide offset design, and approaches to managing risk. Adoption of this framework will strengthen the potential for offsets to provide an ecologically defensible mechanism that can help reconcile conservation and development.*

Keywords: impact assessment, mitigation, risk

Balances de Biodiversidad y el Reto de No Obtener Pérdida Neta

Resumen: *Los negocios, gobiernos e instituciones financieras adoptan cada vez más una política de no pérdida neta de biodiversidad para el desarrollo de actividades. La meta de la no pérdida neta está enfocada en ayudar a aliviar la tensión entre la conservación y el desarrollo al permitir que se obtengan ganancias económicas sin pérdidas de biodiversidad acompañantes. Los balances de biodiversidad representan un componente necesario de una estrategia de mitigación mucho más amplia para obtener una no pérdida*

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neta siguiendo la aplicación previa de evitación, minimización y medidas de remediación. Sin embargo, han surgido dudas sobre el uso apropiado de los balances de biodiversidad. Examinamos lo que implica una no pérdida neta como un resultado de conservación deseable y revisamos las condiciones que determinan si, y bajo cuales circunstancias, los balances de biodiversidad pueden ayudar a obtener dicha meta. Propusimos un marco de trabajo conceptual para sustituir las aproximaciones seguidas y ad hoc en muchas iniciativas de balances de biodiversidad. La relevancia de los balances de biodiversidad hacia la no pérdida neta yace sobre dos premisas fundamentales. Primero, los balances rara vez son adecuados para obtener la no pérdida neta por sí sola. Segundo, algunos efectos de desarrollo pueden ser muy difíciles o riesgosos, o incluso imposibles, para el balance. Para ayudar a obtener no pérdida neta a través de los balances de biodiversidad, las ganancias de biodiversidad deben ser comparables con las pérdidas, estar sumadas a las ganancias de conservación que pueden haber ocurrido en la ausencia de los balances y ser duraderas y estar protegidas del riesgo de fracaso. La adhesión a estas condiciones requiere una consideración del contexto de paisaje más amplio de desarrollo y de las actividades del balance, la sincronización de la obtención del balance, medida de la biodiversidad, procedimientos de aseguramiento y juegos de reglas usados para calcular las pérdidas y ganancias de biodiversidad y guías en el diseño de balances, y aproximaciones al manejo de riesgo. La adopción de este marco de trabajo hará más fuerte el potencial para que los balances proporcionen un mecanismo defendible ecológicamente que pueda ayudar a reconciliar a la conservación con el desarrollo.

Palabras Clave: evaluación de impacto, mitigación, riesgo

Introduction

Global losses in biodiversity and ongoing development pressures on the environment have led an increasing number of government agencies, businesses, and financial institutions to introduce policies or voluntary commitments aimed at achieving no net loss or preferably a net gain of biodiversity across areas for which these organizations are responsible (Madsen et al. 2010; McKenney & Kiesecker 2010; BBOP 2012; IFC 2012). The goal of no net loss is intended to go beyond traditional environmental-impact mitigation measures and help relieve tension between conservation and development by enabling economic gains to be achieved without concomitant biodiversity losses.

Biodiversity offsets, also known as compensatory mitigation (e.g., in the United States, where no net loss has its origins as a project level policy goal under the 1977 Clean Water Act), have emerged as an important mechanism in efforts to achieve no net loss of biodiversity as part of implementing specific development projects. Offsets are intended to ensure compensation for residual negative effects following the rigorous, prior application of the mitigation hierarchy (i.e., avoidance measures, minimization of onsite effects, and restoration measures) (BBOP 2012; IFC 2012). Substantial concerns have, however, been raised about the use of biodiversity offsets and hence the achievability of no net loss as a practical conservation goal (Bull et al. 2013). These concerns include the absence of clear definitions and adequate biodiversity accounting frameworks (Gardner 2007), lack of evidence of actual effectiveness (Gibbons & Lindenmayer 2007), potential for offsets to undermine crucial prior steps in the mitigation hierarchy (Clare et al. 2011), and risk of biodiversity offset policies serving a largely symbolic purpose by neutralizing environmental concerns regarding development effects while providing little real protection for biodiversity (Salzman & Ruhl 2000; Walker et al. 2009).

We assessed what is necessary to achieve no net loss of biodiversity from an ecological perspective. We considered what no net loss means as a desirable conservation outcome and the ways in which the goal of no net loss is operationalized in practice. We reviewed the set of conditions and considerations that determine whether, and under what circumstances, biodiversity offsets could help to achieve the goals of no net loss or net gain of biodiversity. A critical first step in this process is the identification of situations where, a priori, offsets are likely to be inappropriate or unfeasible (Pilgrim et al. 2013). For situations where offsets may be appropriate and feasible, we propose a formal conceptual framework and decision making process (Fig. 1) as a substitute for the often ad hoc approaches in many biodiversity offset initiatives. We focused primarily on what constitutes best practice in planning for no net loss of biodiversity in the context of individual development projects, but we also considered the crucial importance of setting offset policy in an appropriate landscape and regional context. Although we acknowledge the importance of legal, financial, institutional, and political considerations in determining the success of a biodiversity offset (e.g., BBOP 2009*a*) and hence in achieving no net loss (Robertson 2004; Walker et al. 2009; Clare et al. 2011), we focused on ecological factors. biodiversity offsets are still in their infancy and until more evidence becomes available from actual field projects, controversy on whether, and under what circumstances, no net loss can be achieved will persist. Nevertheless, interest in biodiversity offsets and the concept of no net loss in both private and public sectors has increased rapidly in recent years. Our overarching aim was to inform a more robust, science-based

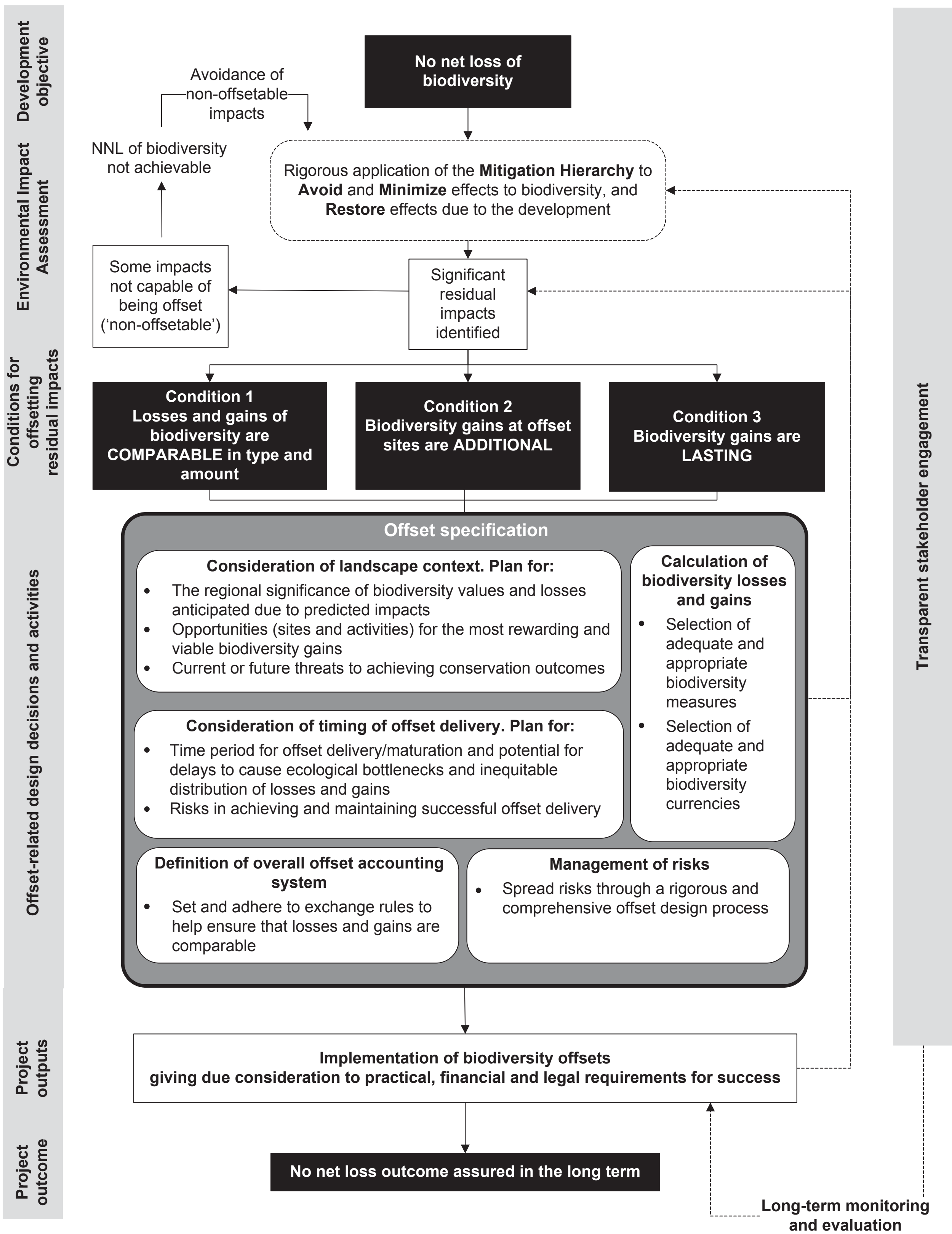

Figure 1. A generalized conceptual framework of the offset-related conditions and design activities necessary to evaluate efforts to achieve a no net loss (NNL) conservation outcome.

understanding of the conditions and precautionary standards of practice that are necessary for offsets to provide an ecologically defensible mechanism to help reconcile conservation and development.

Meaning of No Net Loss as a Desired Conservation Outcome

Concerns regarding the potential and limitations of biodiversity offsets can be partly understood in light of differing interpretations of what no net loss means. Interpretations of no net loss often vary according to the perspective and values of different stakeholders; hence, different components of biodiversity are emphasized. The interpretation of no net loss is then further affected by decisions regarding how one measures and interprets biodiversity and biodiversity changes, the scope of development effects considered, and the temporal and spatial scale at which the goal of no net loss is applied.

Defining Biodiversity

From a conservation perspective that affords intrinsic value to all components of biodiversity as defined by the Convention on Biodiversity, the goal of achieving a no net loss biodiversity outcome for a given set of development effects means no net reduction in the diversity within and among species and vegetation types; long-term viability of species and vegetation types (i.e., ensuring minimum population sizes and areas of occupation); and functioning of species assemblages and ecosystems (including ecological and evolutionary processes). Operationally, this high standard is almost impossible to guarantee because the interpretation and measurement of biodiversity are always limited by the amount of information available on the populations, species, and ecosystems involved and practical difficulties in collecting new data (Caro 2010; Gardner 2010).

A critical task, therefore, is to determine how biodiversity can best be described and measured to adequately assess effects and gauge the extent to which they can be offset. This knowledge can then guide appropriate application of the mitigation hierarchy and overall offset design, including the calculation of biodiversity losses and gains.

Best practice guidelines for achieving no net loss require developers to account for effects in at least 2 ways when designing and implementing an offset (BBOP 2012). Developers should preserve biodiversity components that are particularly valued by people (locally or elsewhere) or are of particular functional importance, which may include culturally important sites, species of high economic value, rare or threatened ecosystems, species and their habitats, and associated ecological processes and should, through the use of surrogate metrics (e.g., measures of landscape structure, condition, and fragmentation), attempt to represent and thus account for the loss of unmeasured biodiversity.

One way of ensuring the rigorous selection of particularly valued and ecologically important biodiversity components is to explicitly identify a set of affected key biodiversity components on the basis of a comprehensive assessment of potential effects and dialogue with stakeholders (BBOP 2012). Apart from helping to inform what should be the basis of loss–gain calculations, this subset of key components helps in understanding the kinds of effects a development project will have; whether effects can be offset; equivalence of affected and offset areas; and kinds of activities needed to deliver gains to offset substantial residual effects. In selecting key biodiversity components for a specific project, careful attention should be placed on biodiversity patterns (i.e., compositional and structural elements such as populations, species, and vegetation types) and ecological and evolutionary processes (e.g., plant–animal interactions and ecological connectivity). The complexity and limited understanding of biodiversity means it is always necessary to spread risk and use a diverse set of biodiversity measures that represent different levels and scales of biological organization (including species, communities, and ecosystems) and goes beyond the limited set of species and vegetation types that may have some form of legal protection in a given country or region (Lindenmayer et al. 2007; Gardner 2010). It is the selection of such key biodiversity components and associated surrogate metrics that together comprise the operational definition of biodiversity that underpins the assessment of no net loss.

Interpreting Losses and Gains in Biodiversity

The *net* in *no net loss* is indicative of the fact that some losses at the development site are inevitable and that exchanges may not be perfectly balanced—whether in time (e.g., where losses precede gains), space (no place is exactly the same as another), or type of biodiversity involved. Thus, in addition to the choices made in selecting the biodiversity components deemed at risk, subjective and legal judgments are also made regarding the acceptability of different kinds of exchanges, depending on the societal values of the stakeholders. It may, for example, be argued that it is defensible to accept the loss of a type of common biodiversity component in exchange for enhanced protection of another component that is severely threatened and rare (often called trading-up offsets).

Defining the Scope of Effects on Biodiversity

Beyond limitations in how one interprets and measures changes in biodiversity, the meaning of no net loss as a conservation outcome also depends critically on defining the scope of effects for which a given project should be held accountable. Current best practice focuses on substantial direct, indirect, and cumulative (where feasible and appropriate) project effects by the project proponent and contractors or subcontractors. These effects include those associated with access and delivery infrastructure but do not include effects on biodiversity from third-party suppliers or delivery to end users (BBOP 2012; IFC 2012). We focused on these development site-level effects, rather than on the much more challenging goal of achieving no net loss for a given end product at point of use. We also recognize the importance of wider concerns for regional biodiversity losses due to cumulative effects on biodiversity from multiple developments and the need to take such changes into account when designing offsets for individual projects (Brownlie & Botha 2009). Achieving no net loss at wider landscape or regional scales fundamentally requires governing authorities to provide enabling conditions such as imposing limits on other development effects and offset activity (Pilgrim et al. 2013) or establishing minimum targets for the protection of key areas and species, which can be used to guide offset objectives in situations where such key biodiversity components are under increasing threat (e.g., Brownlie & Botha 2009).

Balancing Aspirations and Practical Constraints

Minimizing the discrepancy between the aspirations and practical constraints of attaining no net loss of biodiversity requires acceptance of a high-level conservation goal as the basis for selecting measured biodiversity components and strict adherence to a set of necessary conditions and transparent accounting procedures. The no-net-loss concept then legitimizes the exchange of biodiversity across types of biodiversity, locations, and time, subject to this set of constraining conditions and design procedures.

Conditions under Which Offsets Help to Achieve No Net Loss of Biodiversity

Biodiversity offsets are limited in their ability to mitigate against development effects. Perhaps most importantly, offsets are rarely, if ever, adequate for achieving no net loss of biodiversity alone. Rather, the appropriateness and potential success of an offset depend on the extent to which prior steps in the mitigation hierarchy (avoidance, minimization, and remediation of effects) are applied. Some effects (e.g., on highly threatened biodiversity) may be too difficult or impossible to offset and have to be avoided. Other residual effects need to be limited (e.g., through onsite mitigation and restoration measures) to increase the chance that they could be offset entirely (BBOP 2012) (Fig. 1). Although some effects, such as species extinction, are obviously irreversible, clearly defining a comprehensive and regionally appropriate set of limits to the kinds of effects on biodiversity that are possible to offset is difficult. To help overcome this difficulty, Pilgrim et al. (2013) devised a generic burden-of-proof framework that can be used as a starting point to assess the appropriateness and achievability of offsets, given differing levels of concern for affected biodiversity, magnitude of residual effects, opportunity for suitable offsets, and feasibility of offset implementation in practice.

The combination of these limitations demonstrates that offsets cannot be seen as the only solution to balancing all forms of development effects on biodiversity. The types of effects for which offsets, as part of the broader mitigation hierarchy, can make an appropriate contribution toward the delivery of a no-net-loss outcome is challenging to define on the basis of the limited evidence available. Although the conditions and considerations we outline can be applied generally, successful outcomes are more likely for localized, spatially limited projects such as mining, building, and infrastructure development (which comprise the majority of offset initiatives to date) that do not affect more vulnerable and spatially restricted (and hence irreplaceable) components of biodiversity. As currently conceived offsets are unlikely to be appropriate for mitigating the effects of large-scale clearing of land for agriculture.

In situations where offsets are being appropriately applied in the context of the mitigation hierarchy, and there is no clear evidence that an offset would be inappropriate due to unacceptable effects on biodiversity of high conservation concern or a lack of opportunity for concomitant biodiversity gains (e.g., as outlined by Pilgrim et al. 2013), no net loss can be achieved theoretically by satisfying 3 main conditions: biodiversity gains are comparable to losses from residual effects insofar as they are both appropriate (similar in kind or type) and adequate (of an amount greater than or equal to the losses); biodiversity gains are additional to outcomes that would have resulted in the absence of an offset; and biodiversity gains are lasting and protected from risk of failure (Fig. 1). Demonstrating that these 3 conditions have been met and a no net loss outcome achieved is only possible if sufficient ecological data exist to account for biodiversity changes that result from the development and mitigation efforts.

Condition 1: Biodiversity Losses and Gains are Comparable in Type and Amount

An explicit biodiversity loss and gain calculation is required to ensure that, with a reasonable degree of confidence, gains are comparable to losses (and hence ensure that biodiversity is not lost) and to track delivery of gains due to the offset activities. Calculation of biodiversity losses and gains requires selection of appropriate and representative biodiversity components and metrics to measure changes and definition of biodiversity currencies and an associated offset accounting system to help ensure equity in the type, distribution, and temporal delivery of biodiversity gains compared with losses and to adjust offsets to guard against underperformance or failure (Salzman & Ruhl 2000; BBOP 2009*b*; Quétier & Lavorel 2011; Overton et al. 2012).

Condition 2: Biodiversity Gains are Additional

Biodiversity gains from conservation activities undertaken as part of an offset project need to be additional to those that would have occurred in the absence of the project (thereby ensuring that an offset has actually occurred due to conservation activities of the developer). It is also necessary to ensure that offset activities do not lead to the displacement or leakage of harmful activities and damage elsewhere and that offset activities do not result in negative effects on biodiversity that is not the focus of the offset. biodiversity offset gains can be achieved through 2 broad kinds of intervention.

First, gains can be achieved by averting the loss and degradation of biodiversity by removing or reducing threats. Offset activities could include promoting more responsible natural resource management and alternative livelihoods for people who undertake unsustainable levels of resource extraction (e.g., providing alternative protein sources to substitute for wild game) and creating, expanding, or strengthening protected areas to guard against current or future risks to affected biodiversity (e.g., through mechanisms such as land purchase, contractual agreements, and conservation easements that limit legal rights to clear vegetation or to mine). For averted-loss offsets to be defensible, it must be shown that ongoing or impending threats are both imminent and will have substantial effects on biodiversity. It is also essential that an offset results in measurable conservation outcomes. General structural investments in local capacity building, research, and environmental education may be important, particularly in establishing enabling conditions for offset success. Yet to qualify as part of an offset they need to produce relevant and measurable biodiversity gains that are comparable to the residual effects of development.

Second, biodiversity gains can be achieved through positive management actions to improve biodiversity condition through habitat restoration. Restoration refers to activities that endeavor to return some features and processes in an area to their ecological condition prior to some anthropogenic effect, for example by stabilizing soil erosion, reintroducing native species, removing and controlling invasive species, or accelerating natural regeneration processes (e.g., inclusion of bird perches to encourage seed dispersal) (Harper & Quigley 2005; Gibbons & Lindenmayer 2007). There is considerable skepticism in the scientific community that the current science and practice of restoration ecology is, for the majority of ecosystems, capable of delivering biodiversity gains that are sufficient to achieve no net loss (e.g., Palmer & Filoso 2009; Maron et al. 2012).

Lasting Nature of Biodiversity Gains

Biodiversity gains from an offset need to last at least as long as the residual effects, which may well be permanent for many development projects. This requirement to assume long-term responsibility for residual effects is a key aspect that differentiates no-net-loss offsets from other weaker and less rigorous forms of compensatory conservation. In ensuring that gains are lasting, 2 sources of uncertainty and risk need to be considered (Fig. 1). First, offset activities may underperform or fail, either because of management failure or due to an external threat (e.g., other development or climate change) that jeopardizes the long-term integrity of the offset. Second, unless offset gains are fully secured prior to effects, time lags in achieving an offset may lead to ecological bottlenecks that threaten long-term biodiversity persistence (Bendor 2009; Bekessy et al. 2010).

Offset-Related Design Decisions and Activities for Achieving No Net Loss

Designing a biodiversity offset to help ensure no net loss—and therefore meet the 3 conditions outlined earlier—requires consideration of the wider landscape context of development effects and associated offset activities, the timing of offset delivery, the approach taken for calculating biodiversity losses and gains, and the definition of the overall offset accounting system and approaches to managing risk.

Importance of Considering Landscape Context

It is essential that the design and implementation of project-level offsets account for the wider landscape context (Fig. 1) for at least 3 reasons. First, estimates of biodiversity losses and gains need to ensure comparability in the regional significance of biodiversity on the basis of patterns of irreplaceability and vulnerability and socioeconomic and cultural biodiversity values (Walker et al. 2008, 2009; Gibbons et al. 2009; Underwood 2011). Second, a landscape understanding of the distribution of biodiversity and development activities is needed to identify opportunities for securing additional and ecologically viable biodiversity gains and hence to determine the most appropriate set of offset activities and locations (Kiesecker et al. 2009; Pouzols et al. 2012) and identify areas where effects should be avoided altogether because they cannot be offset (Kiesecker et al. 2009). Third, a landscape perspective is necessary to identify and address risks to the long-term maintenance of biodiversity gains (e.g., due to other development projects, encroachment by invasive species, and informal settlements) in offset design and implementation.

Importance of Considering Timing of Offset Delivery

The timing of offset delivery affects the temporal distribution of biodiversity losses and gains, the durability of conservation outcomes, and the size of the offset (Fig. 1). Unless all the biodiversity gains from an offset are delivered before development occurs, losses due to project effects will exceed, at least temporarily, any biodiversity gains from the offset (Bendor 2009; Bekessy et al. 2010). Such delays in compensating for losses can result in bottlenecks in ecological resources and time-delayed cascade effects, such as the delayed recovery of key species' resources (e.g., tree hollows, large tree boughs, and fallen timber that characterize mature forest habitats [Vesk et al. 2008; Bedward et al. 2009]), that may threaten the persistence of certain species, especially those vulnerable to extinction (Maron et al. 2010). In such cases, it is not possible to achieve offset gains comparable to residual losses.

Two approaches have been proposed for addressing the potential problem of time lags in biodiversity offsets. One approach is to demonstrate that the requisite biodiversity gains have been secured before development begins. For example, gains can be demonstrated through the use of a biodiversity banking system in which a developer can buy credits in the form of mature offsets to license planned operations (Bekessy et al. 2010). Although this approach unquestionably improves the probability that no net loss is achieved, its success depends on a wide range of biodiversity credits being available to ensure ecological comparability between gains and losses (Bekessy et al. 2010). In addition, most existing conservation-banking schemes allow credits to be released over a limited period (often <20 years) prior to full maturation of target biodiversity to incentivize landowners to create conservation credits as opposed to pursuing other potential land uses.

An alternative approach to compensate for delays in offset maturity is to increase the size of the offset through a so-called multiplier or mitigation ratio (Bendor 2009). This ratio may be calculated in proportion to the expected delay (e.g., Hruby 2012) or by applying a discount rate over a specific time interval that relates to the project life span, human lifetimes, and expected biodiversity recovery rates (e.g., Moilanen et al. 2009). Overton et al. (2012) extend the use of discounting to develop the concept of net present biodiversity value (NPBV) as a measure of equity in biodiversity transactions across type of biodiversity, space, and time. The use of time discounting is advocated on the grounds that it is inherently unfair to compensate for a guaranteed immediate loss with a hypothetical and much less certain future gain (Bruggeman et al. 2005; Moilanen et al. 2009; Overton et al. 2012). Although this makes sense in terms of equity, the use of multipliers that are based on time discounting may do nothing to address the underlying problem that temporal delays can lead to critical shortages in ecological resources over time (no matter how large the offset) that then make it impossible to achieve offset gains comparable to losses from development.

Importance of Approach for Calculating Biodiversity Losses and Gains

Confidence in the integrity of a proposed offset depends foremost on a transparent process for selecting the subset of measured biodiversity components and metrics, the biodiversity currencies used to quantify residual losses and potential gains and guide offset design processes, and an appropriate offset accounting system.

The selection of biodiversity components and surrogate metrics is central to our interpretation of what no net loss of biodiversity means as a conservation outcome. They should include components of biodiversity that are of particular importance to people (which should include those already afforded legal protection in the country in question), ecosystem functions, and surrogate components that represent unmeasured biodiversity (e.g., measures of habitat structure). biodiversity metrics are the specific parameters used to measure changes in biodiversity components (e.g., area, number of individuals and species, vegetation height, and canopy cover). biodiversity components can only contribute to the assessment of biodiversity losses and gains if they are measurable.

Biodiversity currencies are used to calculate losses and gains in biodiversity and to quantify residual effects of development on biodiversity and the nature and size of the offset required to achieve no net loss (BBOP 2009*b*; Norton 2009). Currencies can include direct measures of biodiversity or comprise multiple or surrogate measures, such as metrics of habitat extent and condition. No single currency can adequately account for all biodiversity affected by development (Salzman & Ruhl 2000; Gardner 2010), meaning that complementary currencies are needed to reasonably account for different components of biodiversity.

In simple offset schemes, such as early U.S. wetland mitigation efforts, offsets are determined only on the basis of area (Salzman & Ruhl 2005; Madsen et al. 2010). More tailored currencies that incorporate information on type, amount, or condition of multiple biodiversity components have accompanied the rise in popularity of biodiversity offsets. Some of these newer currencies are already well developed and established in law, such as the habitat hectares index used in the Bushbroker program in Victoria, Australia (Parkes et al. 2003) and the environmental benefits index applied in Western Australia (Hajkowicz et al. 2009). There are also a growing number of proposals in the literature, including integration of data on habitat area with data on abundance of key indicator species (e.g., biodiversity change index [Normander et al. 2012]); modeling frameworks to estimate trade-offs between changes in habitat area and population size (Tanentzap et al. 2013); intervention-specific metrics (e.g., plantation biodiversity benefits score for restoration plantings [Cawsey & Freudenberger 2008]); spatially nested metrics to assess changes in site-, landscape- and regional-level biodiversity values (e.g., Gibbons et al. 2009); economic habitat-value metrics that measure incremental progress toward landscape-scale conservation targets (Dymond et al. 2008); and multidimensional metrics that incorporate stakeholder preferences and management indicators together with information on different components of biodiversity (e.g., Hajkowicz & Collins 2009).

Preference should ideally be given to currencies that are based on direct, disaggregated, and context-dependent measures of biodiversity that provide the most unambiguous and locally relevant data (e.g., persistence probabilities of a regionally threatened species). However, in practice, a lack of relevant data (e.g., good, up-to-date, and context-dependent biodiversity data) or of adequate resources, capacity, or time to collect such data means that aggregated surrogate measures that combine the affected area of vegetation or habitat with some measure of condition (e.g., habitat hectares index) are most commonly employed. Aside from pragmatic reasons, such surrogate measures aid communication to the general public (BBOP 2009*b*). Despite the advantages of surrogate-based currencies, direct measures of specific components of high-value biodiversity (e.g., threatened and economically important species) and of components for which surrogates cannot be used (e.g., individual species targeted by hunting or disease) are invariably necessary to prevent important losses being masked in the exchange of biodiversity losses and gains.

Estimates of biodiversity condition are an important component of most biodiversity currencies. Measurements of ecological condition or quality can only be made with reference to some independently assessed benchmark state(s) (whether theoretical or measured) that provides a common reference point for evaluating biodiversity losses and gains across development and offset sites (Gibbons & Freudenberger 2006; Gardner 2010). Despite its intuitive appeal, estimating changes in ecological condition is not easy and requires local and regional ecological knowledge and expert experience.

Defining an Overall Offset Accounting System

A number of generalized offset accounting systems or decision frameworks have been proposed to integrate considerations of landscape context, timing of offset delivery, selection of biodiversity measures and currencies, and integration of regional conservation planning considerations in offset design (Kiesecker et al. 2009, 2010; Underwood 2011); integrated assessment methods to improve or maintain environmental outcomes following land clearing (Gibbons et al. 2009); landscape equivalency analyses that account for metapopulation persistence across entire landscapes and incorporate societal time preferences (Bruggeman et al. 2005); and the offset design process in Business and Biodiversity Offset Program Standard (BBOP 2012). Pouzols et al. (2012) propose an integrated offsets calculator (with accompanying software, RobOff) that allows a systematic comparison of the biodiversity benefits of alternative conservation actions and their uncertain effects on biodiversity components in different environments through consideration of time, costs, and feasibility of actions. The calculator does not, however, explicitly account for landscape context due to computational limitations.

Accounting procedures are used to estimate the net balance, or equity, of exchanges. Limits in the fungibility of biodiversity across space, time, and type of biodiversity mean that in addition to the careful selection of appropriate and adequate biodiversity currencies, the specification of offsets to achieve no net loss of biodiversity also requires a set of restrictions or exchange rules.

The most important restriction to recognize prior to considering the application of a biodiversity offset is the existence of limits to the application of offsets. These limits are based on the irreplaceability and vulnerability of the biodiversity in question and on the feasibility of possible offsets (Pilgrim et al. 2013). In situations where development may affect highly vulnerable or irreplaceable biodiversity, or where offset options are extremely limited, achieving no net loss may only be possible through avoidance of effects (e.g., by redesigning parts of the development project itself). Where an offset is deemed possible, a number of exchange rules are necessary to help ensure biodiversity losses and gains are comparable: limits on biodiversity components that are substitutable, guidelines on the acceptability and desirability of trading up, limits on declines in area or ecological condition between development and offset sites, and integration of project-level offsets into a wider conservation planning framework.

Limits need to be established regarding the biodiversity metrics that can be considered substitutable within aggregated, surrogate currencies. McCarthy et al. (2004) highlight the importance of this rule by identifying possible weaknesses in the habitat hectares method (Parkes et al. 2003). For example, in some situations increases in a biodiversity component (e.g., volume of dead wood) can mask negative changes in other biodiversity components (e.g., loss of live trees). This kind of problem can be solved through use of disaggregated currencies or, at least in part, by establishing exchange rules that set minimum values (and possibly upper limits) to which the individual components that make up an aggregated currency can be substituted.

Clear guidelines are needed on the acceptability and desirability of trading up. Although like-for-like exchanges (i.e., adherence to condition 1 in Figure 1, that losses and gains are comparable in type and amount) should be the default approach to all offsets, there are occasions where trading-up (or out-of-kind) offsets may be desirable. Trading up is the process by which loss of more common and widespread biodiversity is offset with enhanced protection or restoration of rarer or more threatened biodiversity. Although such exchanges can represent valuable conservation opportunities, clear guidelines are needed to prevent the exchange (possibly inadvertent) of highly irreplaceable or threatened biodiversity for components of lower irreplaceability or threat status (e.g., Walker et al. 2008; Pilgrim et al. 2013).

Limits need to be established regarding acceptable declines in area or ecological condition between development and offset sites. A fundamental problem with simple area × condition currencies is that increases in the spatial extent of an offset may be allowed to compensate for decreases in its condition or similarly that improvements in condition are allowed to compensate for decreases in extent. Such risks may be limited by applying an exchange rule that requires estimates of habitat extent and ecological condition either do not change substantially or can only increase between development and offset sites (e.g., Kiesecker et al. 2009).

The design of project-level offsets must be integrated into a wider conservation planning framework to ensure compositional similarity between losses and gains. Intrinsic human use and cultural values of biodiversity are by definition context dependent (e.g., species composition, rarity, endemism, human use), and this makes it essential that offset designers carefully assess the compositional similarity and regional significance of both expected losses and potential gains of biodiversity. Efforts to ensure compositional similarity between losses and gains for unmeasured components of biodiversity can be assisted by rule-of-thumb spatial restrictions such as the maximum distance between development and offset sites or by restricting exchanges to within the same watershed, center of endemism, environment and vegetation type, or area in which people who may be affected by the effects of development on biodiversity live (Salzman & Ruhl 2000). In addition, a number of simple index-based frameworks incorporate landscape and regional biodiversity values alongside site-based estimates derived from information on percent cover, condition of vegetation types, and rates of change in habitat area and condition (e.g., Oliver et al. 2005; Gibbons et al. 2009). More elaborate frameworks exist that incorporate spatially explicit information and modeling of biodiversity patterns and processes in landscape-scale assessments of conservation options (e.g., Ferrier & Drielsma 2010). Such frameworks have been applied recently to the specific problem of offsets (Kiesecker et al. 2010; Underwood 2011) and integration of conservation prioritization, development effects, and offset evaluation (Overton et al. 2012).

Managing Risks

In addition to the exchange rules, other safeguards are needed to maximize the probability that offsets can deliver comparable and lasting biodiversity outcomes. These safeguards include a rigorous adherence to the mitigation hierarchy, assurance that offset activities are in addition to interventions that would occur in the absence of development, selection of offset activities that are based on existing evidence of effectiveness, and a rigorous approach to selecting biodiversity measures, currencies, and accounting frameworks.

Particular emphasis needs to be placed on a precautionary approach to offset design and implementation in situations where risk and uncertainty in offset delivery are high, as is invariably the case for all but the simplest ecosystems (Maron et al. 2012). Uncertainty in the performance of offset interventions is best minimized by producing offset gains prior to losses due to development through biodiversity savings banks (Bekessy et al. 2010). Many existing offset schemes employ risk-aversion multipliers to increase the size of an offset and safeguard against uncertain outcomes (BBOP 2009*b*; Quétier & Lavorel 2011). Although intuitive, a lack of data and technical understanding means that such multipliers are often generic and determined by the conservation significance of affected biodiversity (e.g., Parkes et al. 2003) rather than being linked to specific risks and mitigation measures (e.g., probability of seedling survival in a restoration planting). As in the case of time delays and resource bottlenecks, multipliers are inappropriate for situations where there is a risk that the offset intervention may fail entirely. For restoration offsets, Moilanen et al. (2009) concluded that when multipliers are calculated appropriately (i.e., probability of failing to achieve no net loss is minimized) very high multiplier ratios may be required (e.g., >1:100). Yet in practice, offset ratios are often even lower than levels required by law (e.g., Quigley & Harper 2006).

To account for these difficulties a bet-hedging strategy (Moilanen et al. 2009) is advisable that spreads risks by combining a rigorous offset design framework with multiple offset sites and activities that seek to account for a wide range of biodiversity components.

Multipliers should not be relied on to minimize probabilities of failure, especially when there are risks of ecological bottlenecks from time delays in offset maturation, but they may be useful in compensating for discounted time preferences for low-risk (i.e., not vulnerable or threatened) biodiversity.

Future of Biodiversity Offsets and No Net Loss

Biodiversity offsets are receiving increasing interest from business, government, finance, and conservation sectors across the world, and we expect the opportunities and challenges we discussed here to become increasingly prevalent. Ambitious policy goals relating to no net loss of biodiversity and the contribution that offsets may, in some cases, make in achieving this need to be interpreted and operationalized in a defensible and transparent way.

Considerable concern about biodiversity offsets remains due to differing interpretations of no net loss and the potential for misuse of offsets (Walker et al. 2009; Clare et al. 2011). There is a lack of clear examples where best practice has, beyond reasonable doubt, delivered no-net-loss outcomes. There is also need for a greater recognition that in some situations, and despite every attempt at mitigation, no net loss of biodiversity cannot be achieved; that is, development will result in irreplaceable loss of biodiversity. Such development projects may be approved by governments because there is a clear and overriding public interest in the project. In such situations, it may be possible to achieve partial compensation for loss of biodiversity, but a claim of no net loss of biodiversity should not be made (Pilgrim et al. 2013).

Conservation outcomes from biodiversity offsets only partly depend on the scientific rigor underpinning the choices of biodiversity currencies and exchange restrictions we have discussed. Positive outcomes are also to a large extent determined by other factors that affect the appropriate application of the mitigation hierarchy and adoption of a rigorous offset design and implementation framework (Gibbons et al. 2009; Walker et al. 2009; Quétier & Lavorel 2011), such as access to adequate data and technical expertise, economic and financial safeguards and incentives, and the strength of monitoring and enforcement.

We hope our article will help to reduce confusion and improve the accountability and rigor of future projects by laying out a clear framework of the basic conditions and issues that need to considered and accounted for in any offset design process. Although considerable progress has been made in developing good practice for biodiversity offsets (e.g., BBOP 2012), more research is urgently needed to strengthen the evidence base on ways to achieve no net loss. Developers, regulators, civic groups, and scientists all have a responsibility to engage critically and constructively in this process to ensure that offset projects are given adequate scrutiny and that the promise of no net loss moves from a largely symbolic policy to an ecologically defensible mechanism for helping to reconcile conservation and development.

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