Biological Conservation 224 (2018) 162–169

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

# A quantitative framework for evaluating the impact of biodiversity offset policies

I. Peterson[a,*], M. Maron[b], A. Moillanen[c], S. Bekessy[a], A. Gordon[a]

[a] School of Global Urban and Social Studies, RMIT University, GPO Box 2476, Melbourne, VIC 3001, Australia
[b] School of Earth and Environmental Sciences & Centre for Biodiversity and Conservation Science, The University of Queensland, Australia
[c] Department of Biosciences, P.O. Box 65, FI-00014, University of Helsinki, Finland

ARTICLE INFO

Keywords:
Avoided loss
Averted loss
Counterfactual
Biodiversity offset
Offset policy
Impact evaluation
Strategic assessment

ABSTRACT

We propose an impact evaluation framework for biodiversity offsetting that can be used to determine the impacts attributable to developments and their associated offsets under a range of assumptions. This framework is used in conjunction with two hypothetical models of the offsetting process to illustrate a number of issues that can arise when conducting impact evaluations of biodiversity offsetting, where the 'intervention' comprises a development and its associated offsets. We establish that including gains due to avoided losses (i.e. development that would have otherwise happened) in the intervention impact calculation results in a reduction in the offset requirements per unit of development. This occurs regardless of whether the biodiversity at the development or offset sites is declining, stable, or improving. We also show how including gains due to avoided loss requires the consideration of offsets that might otherwise have occurred. These 'avoided offsets' increase the offset requirements per unit of development regardless of the background site dynamics. Finally, we examine offsetting as part of a larger, spatially strategic scheme and show that when the development and offset regions are separated, including avoided loss in the impact calculations can result in a situation where the development impact goes to zero and a system that attains 'net gain' regardless of the development and offsetting activities. The proposed framework can be used to inform offset policy by providing a transparent and logical methodology for the determining the offset requirements for the impacts attributed to development.

## 1. Introduction

Over the past decade, biodiversity offset policies have emerged as an important tool for dealing with development impacts on biodiversity (Madsen et al., 2011). They aim to balance the negative biodiversity impacts of development with conservation gains elsewhere, and have been rapidly adopted in an increasing number of nations worldwide (Brownlie and Botha, 2009; Ives and Bekessy, 2015; Madsen et al., 2011; Saenz et al., 2013). In addition, a range of industries have adopted informal voluntary offsetting, in part as a social license to operate (Benabou, 2014; Madsen et al., 2011; Rainey et al., 2015).

Biodiversity offsets are unique among conservation interventions as the biodiversity gains attributed to a set of conservation actions are tied directly to biodiversity losses. Offsets involve counterbalancing a specified biodiversity loss after appropriate avoidance measures for the loss of biodiversity have been considered. When the gains attributed to the offset fully mitigate the losses attributed to the development, the offset is considered to have achieved "no net loss" (NNL) of biodiversity (Bull et al., 2014; Gibbons and Lindenmayer, 2007). A "net gain" or "net positive impact" are also commonly cited as offset policy objectives (Bull and Brownlie, 2015; Gibbons and Lindenmayer, 2007; Mckenney and Kiesecker, 2009). However, the effectiveness of offset policies remains unclear as there have been few formal impact assessments undertaken, in part due to the time and expense of these assessments, and in addition, a lack of political will to enforce them (Gordon et al., 2015).

To understand if and when a biodiversity offset achieves NNL, a net gain, or fails in these objectives, it is necessary to measure and compare the change attributable to the development actions with the change attributable to the offset actions associated with that development. We refer to this change as the "impact" (which can be negative or positive) and apply this term to the measurement of both the development and offset interventions. An impact evaluation aims to measure the difference between what happened subsequent to the intervention (the 'outcome'), and what was likely to occur in the absence of the intervention (a 'counterfactual') (Baylis et al., 2016; Ferraro, 2009). Counterfactuals therefore play a critical role in the impact calculations as they provide the baselines that are used to quantify the change

* Corresponding author.
E-mail address: isaacrussell.peterson@rmit.edu.au (I. Peterson).

https://doi.org/10.1016/j.biocon.2018.05.005
Received 23 October 2017; Received in revised form 18 April 2018; Accepted 11 May 2018

attributable to an intervention.

A meaningful impact calculation requires that the outcome and the counterfactual used in the impact calculation are both measured using the same metric. The specification of the metric is particularly important in offsets as the development and offset impacts need to be commensurate in order to calculate the net impact (Bull et al., 2014; Bull et al., 2013). There is therefore an implicit requirement that in order to determine the net impact, the outcomes of the development and offset sites, as well as their respective counterfactuals, are all measured according to the same metric. If this condition is not met, the development and offset impacts are assessed under a different set of assumptions and any subsequent evaluation of no net loss is invalidated.

A sound impact evaluation requires that the chosen counterfactual adequately capture the processes and events that are likely to influence the site in the absence of the intervention. For example, in the offsets policy used in New South Wales, Australia, if the biodiversity of a site is in decline due to background pressures such as invasive species or climate change, the counterfactual needs to capture this decline, yielding gains due to avoided declines when that site is appropriately managed (Office of Environment and Heritage for the NSW Government, 2017). Additional gains can be obtained if the site is protected using a 'security benefit score' for vegetation in good condition and without any existing conservation obligations. In this case there are effectively two distinct processes that need to be accounted for in the impact calculations, namely large scale background condition decline, and local scale processes such as vegetation clearing that are associated with the avoided clearing gains.

Despite the importance of counterfactuals in biodiversity offsets, guidance on the specification of the counterfactuals used in the impact calculations is often limited or lacking (Maron et al., 2016b). In the limited number of cases where counterfactuals are mentioned, the assumptions used in the specification of the counterfactual are rarely quantified and made explicit, and in some cases are demonstrably incorrect (Maron, 2015; Maron et al., 2013). While impact assessments using counterfactuals that change through time have been previously discussed in the context of biodiversity offsetting (Bull et al., 2014, Bull et al., 2013; Gordon et al., 2015; Maron et al., 2015; Sonter et al., 2017, p. 2; Virah-Sawmy et al., 2014), these publications consider only a single counterfactual in a particular impact calculation. In real-world applications, there is nearly always uncertainty regarding what counterfactuals could or should be used in the impact calculations and many counterfactuals can be plausible choices. These cases require a systematic framework that can incorporate multiple processes and uncertainties in the impact calculations.

To address these issues, we present a quantitative framework that allows the impact of the development and offset to be calculated relative to particular counterfactuals, or relative to an aggregated set of counterfactuals via a 'weighted counterfactual'. Using this framework in conjunction with two hypothetical offsetting models we examine the components of potential loss and potential gain in both the development and offset sites. We determine the subsequent effect of including gains due to avoided loss in the offset and development impacts over a range of declining, stable and improving ecological states where consistent counterfactuals are enforced in both the development and offset impact calculations. We examine these impacts at the scale pertaining to a single development-offset pair, and compare these impacts to those obtained at the scale pertaining to larger offset schemes where multiple development impacts are offset in a spatially strategic manner.

## 2. Methods

Determining the impact of a development or offset requires the specification of a metric that is used to quantify both the absolute state of the site(s) and the impact(s) relative to a counterfactual. Throughout this paper it is assumed that the states and impacts of all sites and interventions are assessed using the same metric, i.e. the development and offsets are assessed on a like-for-like basis. For simplicity we present the results in this paper under the assumption that the biodiversity value can be quantified by a single component biodiversity surrogate that the offset intervention targets (Bull et al., 2016; Bull et al., 2013; Maron et al., 2012; Quétier and Lavorel, 2011). This metric can represent a quantity such as vegetation cover and condition, or a species-based metric such as species occupancy or abundance. We derive a set of results using equations with a general, analytic form, applicable to any function that can be used to describe a time-evolving ecological state, as well as presenting a set of examples that use the logistic function (Mace et al., 2008) to model the changing ecological state of the development and offset sites.

### 2.1. The state of the development and offset

The biodiversity state of the development site is assumed to initially evolve according to an arbitrary function, $C_D(t)$, that represents the condition change over time. We assume, for simplicity, that the development of a site immediately results in a complete and permanent loss of the biodiversity at that site. The biodiversity state, $B_D(t)$, of a site that is developed at time, $t_1$, can then be written as:

$$B_D(t) = \begin{cases} C_D(t) & (t \le t_1) \\ 0 & (t > t_1) \end{cases}. \tag{1}$$

To compensate for the loss of biodiversity attributed to the development, an offset is implemented at an alternate site. We assume that the offset involves a restoration, with a resulting state that is described by a function, $R(t)$. For simplicity, it is assumed the offset is also implemented at time $t_1$. The biodiversity state of the offset site, $B_O(t)$, can be written as:

$$B_O(t) = \begin{cases} C_O(t) & (t \le t_1) \\ R(t) & (t > t_1) \end{cases}. \tag{2}$$

In the absence of the development and offset, if it is assumed that the development and offset sites would continue to evolve according to $C_D(t)$ and $C_O(t)$ respectively, for the period defined by $t > t_1$, then these functions describe counterfactual states of the sites and can be used in the development and offset impact calculations.

Throughout this paper we present a series of time evolving states and impacts that are modeled using a logistic function, widely accepted to model ecological processes such as non-linear population dynamics, with the form:

$$C(t) = \frac{K}{1 + Ae^{-\alpha(t-t_0)}}. \tag{3}$$

The maximal, minimal, and initial states are determined by the parameters $K$ and $A$. The parameter, $\alpha$, governs the rate of change, and setting $\alpha$ to $\alpha < 0$, $\alpha = 0$, and $\alpha > 0$ results in a monotonically decreasing, stable, and monotonically increasing state respectively. A time-shift, $t_0$, can be included to ensure a continuous ecological state under the change of a management regime. In the examples presented here, the biodiversity state of each site prior to either an offset or development intervention is assumed to be in decline (i.e. $\alpha < 0$ for all sites) although the results are generalizable to include improving and stable states (see Supplementary Information). Example development and offset states, described by Eqs. (1) and (2) respectively, and where $C_D(t)$ and $C_O(t)$ have the form in Eq. (3) are shown in Fig. 1(a) and (b).

### 2.2. Calculating impacts

The impact of an intervention is defined as the difference between the state, $B(t)$, subsequent to the intervention and a counterfactual for the site, $C(t)$, i.e.

$$I(t) = B(t) - C(t). \tag{4}$$