Improving averted loss estimates for better biodiversity outcomes from offset exchanges

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Abstract

Biodiversity offsetting aims to achieve at least ‘no net loss’ of biodiversity by fully compensating for residual development-induced biodiversity losses after the mitigation hierarchy (avoid, minimise, remediate) has been applied. Actions used to generate offsets can include securing protection, maintaining condition, or enhancing condition of targeted biodiversity at an offset site. Protection and maintenance actions aim to prevent future loss of biodiversity, so such offsets are referred to as ‘averted loss’ offsets. However, the benefits of such approaches can be highly uncertain and opaque, because assumptions about the change in likelihood of loss due to the offset are often implicit. As a result, the gain generated by averting losses can be intentionally or inadvertently overestimated, leading to offset outcomes that are insufficient for achieving no net loss of biodiversity. We present a method and decision tree to guide consistent and credible estimation of the likelihood of loss of a proposed offset site with and without protection, for use when calculating the amount of benefit associated with the ‘protection’ component of averted loss offsets. In circumstances such as when a jurisdictional offset policy applies to most impacts, plausible estimates of averted loss can be very low. Averting further loss of biodiversity is desirable, and averted loss offsets can be a valid approach for generating tangible gains. However, overestimation of averted loss benefits poses a major risk to biodiversity.

Key words: averted loss offsets, biodiversity offset, counterfactual scenarios, habitat protection, mitigation, restoration

Introduction

Biodiversity offset actions aim to generate biodiversity gains of adequate magnitude to counterbalance development-induced biodiversity losses. The aim is to achieve ‘no net loss’ (NNL) of biodiversity (IUCN, 2016). Best practice dictates that the use of offsets should only occur once all attempts to avoid, minimise, or remediate biodiversity losses have been exhausted (in line with the 'mitigation hierarchy' Arlidge et al., 2018). Nevertheless, the use of biodiversity offsets has become increasingly common around the world (Maron et al., 2016) and it is therefore critical that anticipated gains generated from offset actions are estimated as accurately as possible.

Many offset policies and projects rely wholly or partly on generating a ‘gain’ by protecting existing biodiversity which, in the absence of the offset, is anticipated to be lost in the future. These are known as ‘averted loss’ or ‘avoided loss’ offsets. Processes resulting in the loss of biodiversity manifest in two general ways: 1) complete loss of area, such as that caused by deforestation or permanent draining of wetland habitat; and 2) loss of condition (quality), as caused by factors such as impacts from surrounding land use, invasive species, climatic events, and development-induced shifts in ecological processes that result in degradation. Thus, biodiversity area, biodiversity condition, or both, can be impacted by threatening processes, and the loss of both can be averted in order to generate biodiversity gains within an offset exchange.

Averting the loss of an area that is valuable for biodiversity is typically achieved through actions that increase the legal protection of biodiversity at a site (protection actions; see Box 1), while averting loss of condition more typically involves actions implementing management actions (maintenance actions; see Box 1). The types of actions undertaken to maintain condition are often similar to those done as enhancement actions, which are those used to improve the biodiversity at a site above its current value, or even to shift an anticipated upward trajectory onto a steeper positive curve (see Box 1). Relying solely on a single action (e.g. protection) is unlikely to generate gains sufficient to offsets losses, either at the project or policy level (Maron et al., 2018). In reality, offset proposals often rely on a combination of offset actions that target preserving both the area (via protection actions) and the condition (via maintenance or enhancement actions) of a site in order to generate biodiversity benefits adequate to counterbalance losses. However, the anticipated gains from all proposed actions need to be accurately estimated, or the total offset package risks under-delivering biodiversity gains (Figure 1).

Biodiversity gain can only be generated by averting loss if there is genuinely some threat (not related to the original development project) that can be averted at the proposed offset site (Gordon et al., 2011; Maron et al., 2013). Identifying these threats and estimating the likelihood they would lead to the site being lost (the ‘likelihood of loss in the future’) is essential for estimating the expected amount of averted loss secured by an offset proposal (Maron et al., 2013). However, this may be challenging as not only do many offset polices lack explicit assumptions about counterfactual scenarios, there is also a lack of empirical data to support estimation of the likelihood of loss, and also a lack of guidance on how to use such data to construct plausible and robust scenarios of loss in the absence of the offset protection (Bull et al., 2015). Further, lack of data to estimate likelihood of losses means the use of expert judgement may need to be relied upon in many cases, but this process is subject to the influence of a range of cognitive biases. Where the likelihood of loss is overestimated this artificially inflates the 'gain' from protection, resulting in the offset exchange delivering insufficient gains to balance the losses (Maron et al., 2015).

Here, we present a method and decision tree to guide consistent and credible estimation of the amount of benefit generated by averting the loss of biodiversity at a proposed offset site. We first review high profile examples of existing approaches used in offset policies and projects internationally to estimate the amount of offset benefit generated by improving formal or legal protection of biodiversity. Next, we formally describe the calculation of the averted loss component of a biodiversity offset, and provide clear guidance for determining which additional drivers of biodiversity loss, under which situations, are appropriate to incorporate into estimates of future biodiversity loss. To reduce the influence of cognitive biases, we propose that estimates of likelihood of loss should be derived primarily from recent average 'background' rates of loss – typical recent rates of loss at similar sites (i.e. sites in the same region, comprised of comparable habitat or species assemblage, and subject to similar anthropogenic influences) sites. To illustrate our method and decision tree, we focus on averted loss of area specifically, thus herein 'likelihood of loss' refers to the probability of the complete loss of an area of biodiversity at some point in the future and not degradation of its condition, unless explicitly stated. Nevertheless, a similar logic could also be adapted to estimated averted loss of condition. We conclude by describing some limitations of our approach and some recommendations for future research.

Accounting for likelihood of loss in international offset policies and projects

Any offset policy that allows offset benefits to be generated from protection of existing biodiversity involves an assumption about future decline in biodiversity with and without the presence of the offset (Maron et al., 2015; Maron et al., 2018). These assumptions are frequently implicit. Sometimes, they are captured in ‘multipliers’ (Bull et al., 2017). However, this can be problematic when the magnitude of the multiplier stipulated by offset policies implies implausibly high ‘background’ rates of loss (Maron et al., 2015), or fails to account for factors such as time lags and uncertainty (Miller et al., 2015).

A wide range of approaches is currently used (with varying degrees of rigour) to estimate likelihood of loss under biodiversity offset policies and projects internationally (Table 1). Many biodiversity offset and related policies with NNL goals include an assumption of ongoing background loss (and thus allow ‘gains’ to be generated by averting some of this loss) (Maron et al., 2018), yet the rate of the assumed decline is often not explicitly described (Maron et al., 2013; Maron et al., 2015) (Table 1).

For offset projects that do make explicit their assumptions about the background rate of loss of biodiversity, various methods may be used to derive these estimates including expert judgement, empirical data, or a combination thereof. The offset proposal for the Rio Tinto QMM ilmenite mine in the Anosy Region, Madagascar (Table 1) provides an illustrative example, wherein defensible future scenarios were informed by recent rates of loss of biodiversity in the region to evaluate the benefit of the offset actions (Temple et al., 2012). Another example is offset strategy proposed for the Rio Tinto Oyu Tolgoi copper mine in the Southern Gobi Region, Mongolia, which included offset actions to reduce illegal hunting, improve rangeland management, strengthen protection and management of current protected areas, and improve the long-term security of tenure within the offset landscape (The Biodiversity Consultancy & Fauna & Flora International 2012). In this offset strategy, strengthening tenure was proposed as a mechanism to prevent both loss of area (complete conversion of a site) and condition, and the amount of loss averted was based on expert judgement of anticipated future loss in the absence of protection.

Decision-support tools and calculators can also be used to specify background rates of loss and estimate the amount of loss averted through protection actions on a case-by-case basis. For example, the offsets assessment guide used to calculate offset requirements under the Australian environmental offsets policy (Miller et al., 2015; Australian Government, 2018) explicitly requires a user-input estimation of the likelihood of loss (the 'risk of loss' score) which is used to calculate the amount of loss averted through protection of the proposed offset site (Table 1). This decision-support calculator is applied on a project by project basis, but this value is not dictated nor is a specific method prescribed for deriving it. This has resulted in inconsistencies in determining the offset actions required to counterbalance a given impact (Maseyk et al. 2017). In contrast, the biodiversity offset accounting system developed for the New Zealand Department of Conservation (Maseyk et al. 2016), which is a decision-support tool independent of a policy, explicitly adopts a static baseline, such that no biodiversity gain can be generated by averting future loss. This approach was adopted in recognition of the difficulty in making accurate predictions about future loss, and the high cost for biodiversity if these estimates are artificially inflated, but does not account for the benefits of protection where a genuine threat is averted. Using a static baseline is also a common approach in other jurisdictions, for example, within the European Union (Wende et al., 2018)

We suggest that the potential for overestimation of averted loss, and thus the gain derived from securing protection of biodiversity area, is elevated when methods used to estimate likelihood of loss values are opaque, arbitrary, subject to bias, perception-based, and/or are inconsistent with jurisdictional offset requirements.

Estimating gains from averted loss offsets

Evaluating the amount of biodiversity benefit that is attributable to a specific action is critical for determining the amount of gain generated (Ferraro & Pattanayak, 2006; Ferraro, 2009; Gibbons et al., 2016). This evaluation requires two future scenarios to be described: a) the estimated biodiversity values at a specified time horizon after the action has been implemented (the 'with action' scenario), and b) the estimated biodiversity values in the absence of the action occurring (the 'without action' scenario – also known as the counterfactual). The difference between the two scenarios determines the amount of biodiversity gain attributable to the specific offset action (Maron et al., 2013; Miller et al., 2015; Gibbons et al., 2016). When evaluating biodiversity offset proposals, it is particularly critical that the size of the biodiversity gain due to an offset action is estimated in a defensible way based on plausible assumptions. Not achieving anticipated goals can be disappointing for any biodiversity project, but when the actions are tied to a 'no net loss' goal, any failures or short-falls are especially disastrous for biodiversity outcomes, as losses that have already occurred remain uncompensated and unaccounted for. We pay for the error with permanent, uncompensated biodiversity loss, and hence averted loss offsets are a high-stakes endeavour that require robust evaluation predicated on explicit, defensible assumptions.

Estimating the biodiversity gain secured by averting loss through protection of a site can be expressed as:

$$Gp = (P_{wo} - P_o)A \quad (1)$$

where *Gp* is the gain from protection alone (the offset action), P_{wo} is the probability of loss without the offset (from the counterfactual scenario) and *Po* is the probability of loss with the offset (from the offset scenario), and *A* is the area of the offset site. If there is zero probability of loss once the offset is implemented, the gain becomes expected loss without the offset: $G = P_{wo}A$. This equation assumes a relatively short time period (i.e. 5–50 years), as beyond this we can expect that the probabilities start to become equal – and equally uncertain – as the ability make defensible predictions decreases.

Sources of error when estimating likelihood of loss

Three are three main sources of error when estimating the likelihood of loss:

1. *Lack of explicit assumptions about counterfactual scenarios*

   If an offset policy provides for averted loss offsets, there is an assumption that the counterfactual scenario is one of ongoing loss (Maron et al., 2015; Maron et al., 2018). However, as we have shown above, the estimated rate of this assumed loss is often not explicitly stated. This opaqueness also allows assumptions to be influenced by socio-political factors, such setting offset ratios at thresholds deemed to be of 'reasonable' effort, rather than at levels required to achieve no net loss.

2. *Failure to distinguish drivers of loss that would trigger offset requirements and those that would not*

   For the purpose of estimating likelihood of loss, impacts on biodiversity can be categorised into two types: Type I impacts include any impact caused by an activity that itself would be subject to legislative or policy controls that (following implementation of the mitigation hierarchy) require an offset; and Type II impacts include all impacts resulting from activities that are not addressed by legislation or policy (Maron et al., 2018). When Type I impacts are captured in estimations of *P*, the amount of benefit calculated is incorrectly claimed. This is because Type I impacts are subject to policy controls such that losses would be avoided or offset, thus any loss of the site would have to be balanced elsewhere, so the gain in protecting a site from Type I impacts is zero.

3. *Cognitive biases*

   a. *The loss aversion bias.* Humans tend to be risk-averse, placing more emphasis on perceived losses than gains and focusing more on perceived consequence than likelihood of occurrence (Tversky & Kahneman, 1974; Kahneman et al., 1991). Thus, concerns over the consequence of future biodiversity loss can unduly influence the estimates of the likelihood of this loss actually occurring when the stakes are high (such as when the site contains threatened biodiversity) – because we wish to avoid it happening.

   b. *The availability heuristic*. We also tend to make assessments based on both the most recent information we have received (Tversky & Kahneman, 1974; Kahneman et al., 1991). Therefore, when recent development in a similar area has occurred, it is plausible to assume the likelihood of loss at an offset site is higher than it is.

c. *The probability neglect bias.* When uncertainty surrounding the likelihood of an anticipated event occurring in the future is high, a greater range of probabilities can appear plausible. Thus, when faced with the inherent uncertainty in decision-making which involves predictions of the future, we have a tendency to disregard probability (Sunstein, 2003).

These errors, cognitive biases, and uncertainty can influence a decision-makers ability to make an unbiased judgement of the likelihood the site will be lost, particularly when credible evidence is scarce. These factors typically work in combination, with the result typically being an overestimation of the benefit of averted loss offsets. Recognising this is particularly challenging since in many cases, protecting a site from future threats (by securing legal protection) would be considered by many as a positive thing to do. It is counterintuitive, therefore, to consider that such an action at the *site or project scale* may in fact be detrimental at the *policy or landscape scale*.

For parties with a vested interest in minimising the costs of meeting offset obligations, there exists an incentive to overestimate of the benefit of averted loss offsets (Gordon et al., 2015; Maron et al., 2016). The combination of these cognitive biases, thinking errors and asymmetric information provide considerable scope for the ‘gaming’ of likelihood of loss estimates, and thus the selection of low-quality offset sites (Ferraro, 2008; Ruhl & Salzman, 2011). Clear guidance is therefore needed to step through these issues and to reduce such influences on estimates of likelihood of loss.

Improving transparency and credibility of estimates of future biodiversity loss

To overcome the issues outlined above we propose an objective, robust, and repeatable process for calculating appropriate likelihood of loss estimates under both the offset (P_o) and the counterfactual (P_{wo}) scenarios. Our proposed method uses demonstrated *past rates of loss* to inform estimates of *future likelihood of loss* and is underpinned by five principles:

1) Where available, recent past rates of loss in similar sites are usually a sound basis for predicting future rates of loss.
2) The likelihood of loss is site-specific but estimates should be informed by landscape-scale estimates.
3) Estimates of particularly high likelihood of loss at a site must be supported by credible and robust evidence.
4) The time horizon over which likelihood of loss is estimated, and thus the time over which benefit due to averting loss is accrued, is clearly defined.
5) Type I impacts (any impact caused by an activity that itself would be subject to legislative or policy controls such as an offset requirement) are excluded from likelihood of loss estimates.

These principles underpin our proposed method for estimating likelihood of loss under both with and without scenarios as illustrated in Figure 2 (estimating likelihood of loss under a counterfactual scenario', P_{wo}) and Figure 3 (estimating likelihood of loss under the offset scenario, P_w) and detailed below.

Estimating likelihood of loss under a counterfactual scenario

There are three important factors to guide estimation of the likelihood of loss of a proposed offset site under a counterfactual scenario: 1) recent rates of loss of similar sites; b) policy and legislative requirements likely to be triggered by any impact to the site; and c) site-specific influences on likelihood of loss. The pathways in Figure 2 help determine how these factors should guide estimates.

Pathway A illustrates that even where the loss of a site is highly likely, but those losses are due to Type I impacts, the relevant likelihood of loss is negligible (0% in Figure 2). This is because, assuming compliance with policy, any losses at the site would themselves have to be offset.

Pathway B describes situations where development impacts would not be sufficient to trigger offset requirements, for example, the magnitude of the impact might fall below policy thresholds that trigger a need for an offset. In such situations, the likelihood of loss at the proposed offset site is considered to be greater than the calculated recent rates of loss. However, in the absence of credible evidence that development will occur specifically at the proposed offset site, it can be assumed that the site is subject to the same level of threat as other sites in the landscape. Therefore, the likelihood of loss can be calculated using the calculated recent rates of loss without any adjustment.

Estimating likelihood of loss under the offset scenario

The pathways in Figure 3 describe factors to take into account when estimating the likelihood of loss of a proposed offset site under an offset scenario—the scenario in which the site receives additional protection. In addition to the factors that need to be considered under the counterfactual scenario, a further important consideration is the strength of protection (through for example, change in tenure) that will be placed on the site to avert future losses as the offset action.

Pathway A describes situations where the proposed protection is insufficient to entirely prevent the loss of the site, such as where certain use rights override the protection mechanism. However, if the impacts caused by any such activity would themselves require an offset, the likelihood of loss is not elevated, and thus remains negligible (0% in Figure 3). For example, exploration for and extraction of mineral resources is permitted under several forms of legal protection of land in Australia, but its impacts on listed threatened species are often required to be avoided or offset. We note that the assumption that impacted offset projects will themselves be offset, in compliance with policy, may not be true in all jurisdictions (see for example the impacted Kalagala offset for the Bujagali hydropower project in Uganda, Esmail, 2017).

Pathway B describes situations where the proposed form of protection is sufficient to prevent loss of the site. In these cases, the proposed offset action (protecting the site) is sufficient to effectively reduce the likelihood of loss (the magnitude of which is determined under the counterfactual scenario') to a negligible level.

Finally, Pathway C describes situations where loss of the site would be neither prevented by the proposed protected tenure status nor likely to be subject to an offset requirement. In these situations, an appropriate likelihood of loss assumption would be significantly greater than zero, but less than the calculated recent rates of loss at similar (unprotected) sites. This acknowledges that the protection conferred on the site by the offset will reduce the likelihood of loss, but some residual risk remains.

In order to progress through the decision tree, our method requires landscape-scale assessment of recent rates of loss, and then site-scale evaluation of additional, localised influences on likelihood of loss.

Step 1: Describing recent rates of loss at a landscape scale

In the absence of other data, recent rates of loss calculated at a landscape scale can provide a plausible and independently-verifiable input to predicting of future rates of loss at a proposed offset site located within that same landscape (Maseyk et al., 2017). This assumption is made on the basis that sites within the same landscape are subject to similar anthropogenic influences. Although this may not hold true in certain circumstances, such as a change of regulations affecting vegetation removal (Evans, 2016; Rhodes et al., 2017; Simmons et al., 2018) it provides a useful starting point to estimating P_{wo}, with additional evidence should be required if the estimate is to deviate from P_{wo}. Recent work in Australia provides an illustrative example of the implementation of this method, where it was used to estimate ‘risk of loss’ (equivalent to likelihood of loss) of forest across Australia by measuring change in forest extent due to human intervention within a recent ten-year period (2005 and 2014) using forest extent and change imagery (Maseyk et al., 2017).The change in forest extent was then used to calculate the annual rate of primary deforestation within Local Government Areas (LGA) across Australia, expressed as a proportion of the remaining forest extent. Finally, the average annual rate of deforestation between 2005 and 2014 for each LGA was calculated (Figure 4). These rates were multiplied by 20 (the Australian policy requires risk of loss to be calculated within a 20 year 'foreseeable future' time horizon) to estimate the risk of loss for each LGA. These risk of loss figures have been recommended as a basis for estimates required by the Australian offsets assessment guide (Miller et al., 2015; Maseyk et al., 2017).

Using remotely sensed land cover data is an accepted and repeatable method by which to determine land cover change in forest and woodland ecosystems. However, it has some limitations, including being less reliable at higher resolutions (e.g. property scale) and not sensitive enough to capture patterns of loss at too fine a resolution (e.g. country scale), and being less reliable for non-forest habitat types. Additional research should focus on understanding the spatial and temporal scales most useful for using past biodiversity losses for estimating future likelihood of loss, including where assessment at a larger scale (e.g. political boundary) may obscure heterogeneity within the area due to non-random patterns of loss due to biophysical or geographical factors such as soil type, production potential, or proximity to existing settlements or desirable areas for residential expansion. Future assessment of data on past loss rates should also be refined to exclude loss driven by development that would have triggered an offset requirement; which will also improve the accuracy of likelihood of loss estimates, particularly where concentrated activities such as urbanisation can skew data when evaluated at larger scales.

We also suggest that methods for identifying change in over habitat types for which remotely sensed data is less readily available or accurate (e.g. non-woody or short-stature habitat types) are needed to improve this approach.

Step 2: Consider any additional site-specific factors influencing likelihood of loss

Once recent rates of loss at similar sites have been described, a site-specific assessment of likelihood of loss is required to ascertain 1) whether any additional factors that influence likelihood of loss are at play; and 2) whether the activities occurring in the wider landscape that contribute to loss are, or are likely to, occur at the proposed offset site. Where there is no evidence to suggest otherwise, it is possible to assume that a given offset site will be subject to the same rate of loss as other similar rates of loss in the landscape; however, there may be good reasons why such an assumption does not hold. Consequently, we suggest that conclusions and assumptions regarding likelihood of loss at a proposed offset site need to be supported with site-specific, credible, and robust evidence that is documented and made publicly available. In particular, where it has been determined that the likelihood of loss for a proposed offset site is greater than the background rate of loss, the evidence needs to support the likelihood that the proposed offset site would be lost, and not just that it may occur (e.g. under current planning legislation and policy), or that it is known to occur at other sites.

Discussion

Biodiversity conservation will require the long-term maintenance and enhancement of both habitat extent and quality and this will require a combination of actions that avert loss of area; increase quality of existing biodiversity; and reinstate lost biodiversity. The greatest offset gains will be secured by averting loss in circumstances where future threat is high, and defensibly estimated, and by increasing quality of existing biodiversity through both protection and management of habitat in accordance with clearly stated objectives for offset policies and conservation outcomes. It must also be acknowledged that obtaining no net loss outcomes by averting loss is relative to a baseline of decline (Maron et al., 2018), and real conservation gains can only be achieved through policies that are targeted at protection and restoration (Arlidge et al., 2018).

In this paper, we propose a transparent, robust, and consistent method to improve estimation of likelihood of future loss of biodiversity at a site, which in turn will improve the accuracy of the amount of biodiversity gain generated by an averted loss offset. We focus only on averting loss of area and only one offset action—protection of the site—for simplicity. However, the basic logic presented here is also applicable to evaluating biodiversity gain by averting loss of condition also. In particular, the emphasis on explicitly separating estimations for offset and counterfactual scenarios and differentiating between Type I and Type II impacts is universally relevant.

We also show that observed background rates of loss in forest extent in Australia between 2005 and 2014 are lower than rates being used to estimate future risk of loss (Maseyk et al., 2017), or assumed within Australian biodiversity offset policies (Maron et al., 2015). This is a key finding as Gibbons et al. (2016) demonstrate that averted loss offsets that achieve a no net loss are only feasible where offset ratios can sit at a practical and socially acceptable threshold of ≤10:1; which would equate to a counterfactual annual rate of biodiversity loss are ≥6%. These combined findings underscore that the scope for no net loss to be achieved using only averted loss offsets is in reality extremely limited.

Limitations of relying on protection actions to achieve biodiversity gains

The use of protection actions to generate biodiversity gains as an offset for development impacts is common practice in some regions around the world. Changing land tenure, in many places, may be perceived to be relatively straightforward, inexpensive, and quick compared to the complexities, uncertainties, expense, and long timeframes associated with maintenance or enhancement activities. Further, May et al. (2016) conclude that protection offsets (land acquisition) compared favourably to other offset types in terms of environmental outcomes in Western Australia. However, the amount of gain that can be credited to the offset action can only be calculated if likelihood of loss in absence of protection has also been estimated. The protection of 100 ha of land only equates to 100 ha of offset gain if it would otherwise have been cleared immediately. While the *action* of protecting the site can carry greater certainty, and greater ease of implementation monitoring (land protected or not protected), the uncertainty associated with the outcome remains very high, because the counterfactual is highly uncertain. This illustrates the critical difference between an action occurring (e.g. was the land procured? Were the trees planted?) and whether the chosen offset action is likely to generate the amount of gain anticipated (e.g. was as much future loss as estimated actually averted?) (Ferraro, 2009; Maron et al., 2013; Gibbons et al., 2016). While the former is straightforward to measure, the latter can only ever be estimated, such as by examining trends in the surrounding landscape and extrapolating these trends to the site in question.

Further, protection actions aimed at averting loss of area are often perceived to secure existing biodiversity values immediately (from the point at which the area is protected), apparently avoiding uncertainties associated with time-lags between losses occurring and gains being generated. Thus, where there is a tangible threat to the persistence of that biodiversity into the future, averting loss can be seen as a more socially acceptable offset option than restoration offsets, where there is greater uncertainty that the anticipated gains will be achieved. However, immediate biodiversity gains are only generated where the likelihood of loss is high and imminent. Typically, the likelihood that a site might be lost accrues gradually with time, and so the gains secured by a protection offset will also gradually accrue over time (Sonter et al., 2016). Further, prediction becomes progressively more difficult as the time horizon increases (e.g. 10 years versus 50 years). Thus, defining a time horizon is important and needs to be both realistic in terms of capturing future likelihood of loss, yet relevant to policy timeframes, and meaningful for monitoring ecological change in response to offset actions.

Our methodology does not attempt to account for non-compliance with protection agreements or the likelihood of illegal activities, and also assumes that offset sites would be protected in perpetuity (i.e. protection status would not be downgraded or removed in the future). Assumptions about anticipated non-compliance could feasibly be built into estimates of likelihood of future loss, or when accounting for uncertainty in evaluating an offset proposal. We suggest that any such assumptions would need to be supported with defensible evidence to avoid unduly overinflating estimates of future loss and thereby reducing the offset requirement. However, it would be more appropriate to reconsider site selection if the likelihood of illegal activity at a potential offset site was considered a strong possibility.

Although we focus on likelihood of complete loss of a proposed offset site, the same logic can be applied to other situations (such as future loss of condition) by substituting protection actions for alternative actions targeted to prevent further habitat degradation. This will pose the same practical challenges mentioned here (determining the appropriate scale at which to calculate past loss and the inherent difficulties in predicting the future). However, biodiversity condition data are often lacking and trends in change in condition are often difficult to determine. This can be resolved to some degree by predictive modelling, or informed by structured expert judgement.

Using recent background rates of loss to inform future estimates

In many situations, relying on past background rates of loss (e.g. past 10 years) can be a plausible predictor of future rates of loss—or at least, a good starting point. This method introduces consistency and transparency, and is less open to gaming than unguided site-by-site estimates. However, in cases of marked changes in rates of loss over time, such guidance is less useful. In such cases, a more relevant time period might be used as a baseline, or a selection of plausible trends could be specified (e.g. see Bull et al., 2015) and a conservative assumption made—although this carries risks that estimates of gain will be artificially inflated. Although we used a linear mean calculation in our case study, a geometric mean may be more appropriate to reflect the non-linear nature of ecological dynamics (Buschke, 2017).

Therefore, any assumptions made in using past rates of loss should be explicit, and if these assumptions are proven incorrect with time, the loss-gain calculations underpinning the offset design need to be revisited. This highlights the important need for ongoing outcome monitoring of both offset sites and other sites in the landscape that act as controls, so that the impact of averted loss measures can be estimated, and the counterfactual assumptions evaluated over time.

Incorporating site-specific influences on likelihood of loss estimates

Allowing site-specific considerations to affect estimates of likelihood of loss can risk undesirable socio-political influences. There is also a risk that a requirement for site-specific evidence at a particular offset site can create an incentive to generate threats in order to claim a greater amount of biodiversity gain using averted loss offsets. This would create perverse outcomes (over inflating likelihood of loss) and set precedents for unrealistic likelihood of loss estimates (Maseyk et al., 2017). To prevent this, declarations of intended development should be subject to adequate scrutiny to ensure they are genuine, and not merely obtained to inflate likelihood of loss.

Conclusion

The ability and likelihood of offset actions to successfully deliver biodiversity gains are shrouded in uncertainty, and failures are common (Quigley & Harper, 2006; Burgin, 2010; May et al., 2016). Quantifying the gain generated by averted loss offsets is reliant on the accuracy of assumptions about likelihood of loss, the uncertainty of which cannot be resolved in most cases. This inherent uncertainty in predicting the future is common to all offset actions, but is exacerbated in averted loss offsets as the variation in gain estimates is most affected by the counterfactual scenario, which is never observed and therefore can never be proven. However, improving the reasoning process for arriving at estimates of benefit from offsets, and making assumptions transparent are critical for ensuring averted loss offsets do not in fact, entrench and accelerate biodiversity losses (Maron et al., 2015).

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Conflicts of interest None

Ethical standards This research complies with Oryx's Code of Conduct for authors submitting research.

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Box 1: Categories of actions to achieve biodiversity gains within offset exchanges

Protection actions are designed to generate offset gains by avoiding or reducing the likelihood of the loss of extent (area) of biodiversity at a site. Protection is typically achieved by changing the legal status of the land (or sea) in order to restrict use rights.

Maintenance actions are designed to prevent declines in biodiversity condition from occurring, and thus maintain biodiversity in the condition it was in at the time of the offset commencing. Maintenance actions include actions targeted at specific processes placing pressure on the condition of a site, or compromising the viability of species (e.g. exclusion of livestock that are causing the ongoing degradation of a wetland or control of an invasive plant species that is spreading).

Enhancement actions aim to restore biodiversity values where declines have already occurred and are designed to increase the condition of targeted biodiversity above its condition at the start of the offset activity. Enhancement actions are similar to maintenance actions, but generally need to be applied at a greater intensity to not only halt, but reverse, declines. Enhancement actions may also include the creation of biodiversity values in places where these values have been lost, such as through translocations of threatened species, or habitat creation.

Although protection, maintenance, or enhancement actions can in theory occur completely independently, they are often implemented together. Maintenance and enhancement actions can be similar, and both can occur at offset sites that have been protected.

TABLE 1: A sample of international offset policies, schemes, or decision-support tools illustrating the varied approach to estimating the likelihood of loss. Further detail is provided in other reviews on the use of multipliers (Bull et al., 2017) and no net loss policies (Maron et al., 2018)

Policy/scheme/project name Jurisdiction/location	**Type**	**Generalised description of approach to estimating threat of loss / or rate of value accrued from an averted loss offset under a counterfactual scenario**	**Source**
Rio Tinto QMM llmenite mine Anosy Region, Madagascar	Project	Used explicitly stated counterfactual scenarios which incorporated quantitative analysis to estimate background annual rates of loss.	Temple et al. (2012)
Rio Tinto Oyu Tolgoi copper mine Southern Gobi Region, Mongolia	Project	Future likelihood of loss within proposed offset site determined using expert evaluation of likely pressures (due to poverty and increasing importance of mineral extraction for economic development)	TBC & FFI (2012)
BioBanking Assessment Methodology New South Wales, Australia	State-level policy	Uses a generic multiplier based on assumptions of 'high' or 'low' likelihood of decline within a 20-year time horizon. Assumptions of high or low risk of decline are derived from categorisation of land based on land-use zones.	The State of New South Wales and the Office of Environment and Heritage (2014)
Native Vegetation Permitted Clearing Regulations, Victoria, Australia	State-level policy	Assumes a likelihood of loss of vegetation extent of 10% over ten years (plus 10% for 'prior management' and approximately 10% for condition maintenance).	Department of Environment Land Water and Planning (2017)
Queensland Environmental Offsets Policy Queensland, Australia	State-level policy	Uses a generic ratio of exchange that implicitly assumes decline (of condition and area) of 18% over 20 years, but does not explicitly state the rate of decline.	The State of Queensland (2014)

Environment Protection and Biodiversity Conservation Act environmental offsets policy Australia	Country-level policy	Explicitly incorporates case-by-case ‘risk of loss’ estimates within the *Offsets assessment guide* calculator. Guidance on good practice for estimating risk of loss in the context of the EPBC offsets policy has recently been produced.	Miller et al. (2015); Maseyk et al. (2017)
Offsets for Loss of Biodiversity Colombia	Country-level policy	Assumes a decline in biodiversity but does not specify the rate of this decline.	Montenegro et al. (2012)
Biodiversity Offsets Accounting Model New Zealand	Policy independent decision-support tool	Explicitly assumes a static baseline (no change in biodiversity value over time) thus no net loss is compared to before the impact and not a counterfactual scenario. Users of the model can implicitly incorporate rates of loss into estimated future biodiversity values, but the model gives no direction on how to derive estimates of future loss.	Maseyk et al. (2016)

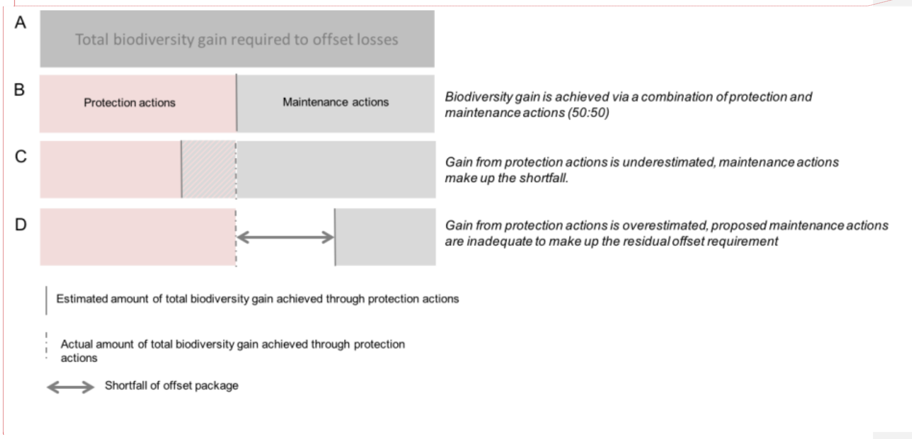

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FIG. 1**:** A conceptual illustration of the influence of miscalculating gains from offset actions on the adequacy of a total offset package using protection estimates as an example.

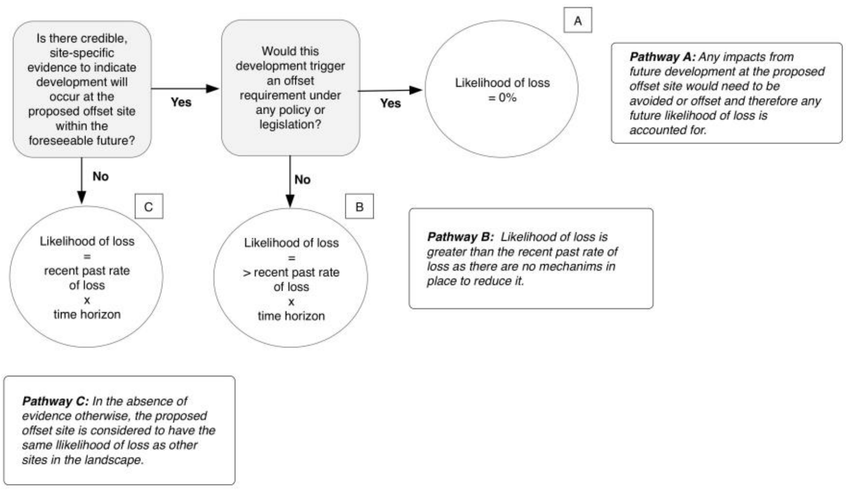

FIG. 2 A process for determining future likelihood of loss (total loss of area) under a counterfactual scenario (P_{wo}). Foreseeable future = may be defined by the relevant policy or legislation but can be considered to be the life of the offset or a generation. Time horizon = the period over which the outcome of the offset is being calculated (e.g. benefit achieved at 20 years).

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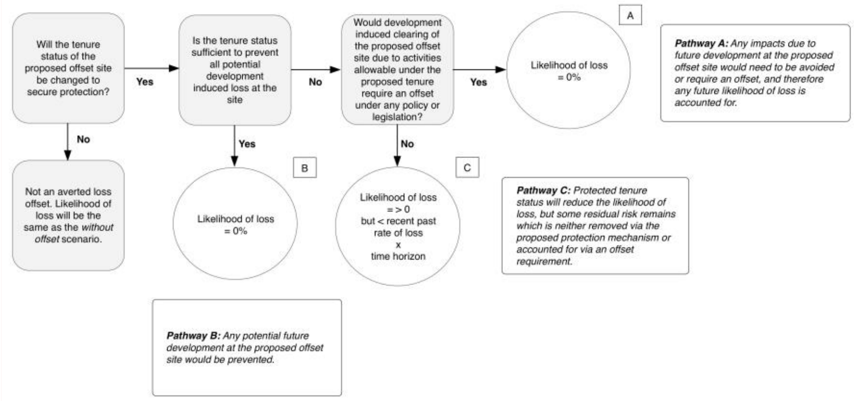

FIG. 3 A process for determining future likelihood of loss (total loss of area) under an *offset* scenario (P_o). Foreseeable future = may be defined by the relevant policy or legislation but can be considered to be the life of the offset or a generation. Time horizon = the period over which the outcome of the offset is being calculated (e.g. benefit achieved at 20 years).

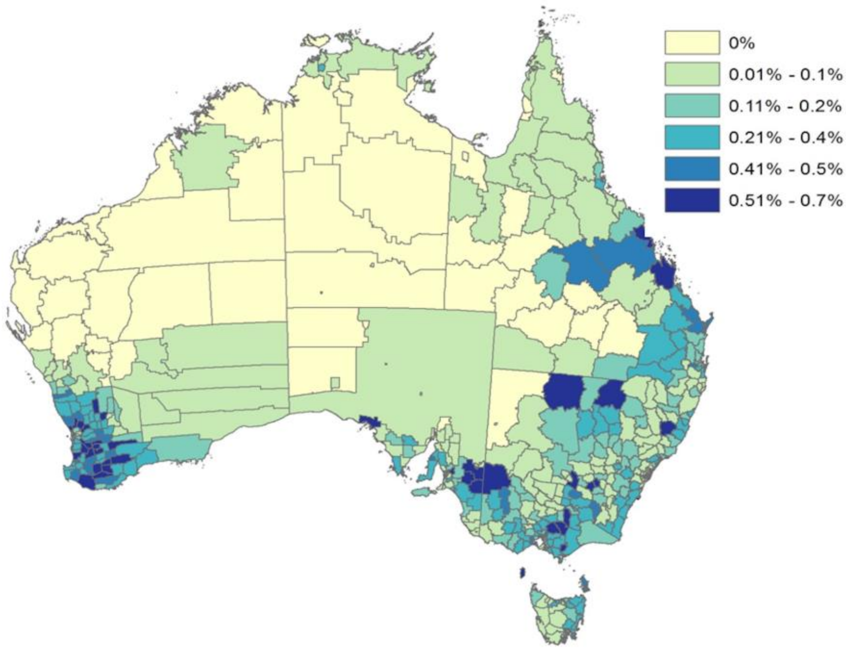

FIG. 4 Range of average annual rate of loss between 2005 and 2014 within each Local Government Area across Australia (adapted from Maseyk et al., 2017). These rates calculated from past deforestation rates are considerably lower than assumed declines within offset approaches in Australia (Maron et al., 2015).