Currencies and accounting systems

Introduction

The concept of no net loss lies at the heart of biodiversity offsets (BBOP 2012a). No net loss refers to the point where biodiversity gains from targeted conservation activities match biodiversity losses due to the impact of a specific development project so that there is no net reduction in the type, amount and condition (quality) of biodiversity over space and time (BBOP 2012a). A net gain occurs when biodiversity exceeds the point of no let loss.

Biodiversity is complex and exists over the dimensions of type, space and time (Salzman & Ruhl 2000), rendering it almost impossible to fully measure and account for in an offset design (Walker et al. 2009; Gardner et al 2013). This has implications for the design of equitable offsets, because the differences in the dimensions of type, space and time are not equivalent or exchangeable (e.g. threatened snails for threatened orchids, contiguous habitat for fragmented vegetation patches, or early seral for late seral vegetation). It is therefore critical to identify and measure important or valued biodiversity components (i.e. what we care about) using the same currency or metric for impact and offset sites, because no net loss can only be demonstrated for measured values balanced at both impact and offset sites (BBOP 2012a).

What to measure requires careful thought, because no net loss means different things to different stakeholders (BBOP 2012a; Gardner 2013), rendering stakeholder participation (BBOP Principle 6) important when identifying the biodiversity values we value and care about so that they can be measured, converted to a tradable currency and no net loss estimated in an accounting system, or model. As such, the currency and model form the basis for quantifying a balanced outcome to estimate no net loss and the choice of model type and currency is critical to the ability of a biodiversity offset to demonstrate no net loss.

Balancing losses and gains

Because biodiversity offsets are based on the explicit calculation of biodiversity losses and gains at matched impact and offset sites, it is not possible to demonstrate that gains match (i.e. no net loss can be achieved) or exceed losses without this explicit calculation. *This means that a good practice biodiversity offset must demonstrate a transparent accounting process reasonably supporting a no net loss or net gain outcome.* A good accounting process or model is transparent and facilitates retrospective interrogation by stakeholders and decision makers.

What is needed to make the calculation?

Most environmental compensation approaches in New Zealand have not objectively quantified biodiversity gains relative to losses (Brown et al. 2014). Because the quantification and transparent calculation of losses and gains is a cornerstone of the biodiversity offset design process, it is critically important that defensible approaches to measuring biodiversity losses and gains are selected that consider the following key issues (BBOP 2012a):

- The choice of biodiversity types, components and attributes;
- The choice of a currency to quantify biodiversity exchanges (e.g. area of vegetation type x measures of ecological condition); and

- The choice of an accounting system or model based on the chosen currencies and integrating benchmarks, management actions and various other considerations in order to define an offset specification.

Quantifying biodiversity in New Zealand for the purposes of developing a good practice biodiversity offset requires addressing the following three levels:

Type
Biodiversity types are the key biodiversity features found at a site, (e.g. indigenous vegetation or habitat types, threatened indigenous species, and special features of the site). These are the essential values that a good practice biodiversity offset design should match between impact and offset sites in a like for like (see Box 1) manner to demonstrate no net loss. Biodiversity types generally include vegetation communities (e.g. forest types), Threatened and At Risk (or iconic) species and other valued ecological features (e.g. karst). Because biodiversity type is incorporated into offset accounting models, they should include all aspects of the site that are valued, (e.g. old growth rimu-beech forest, coal measures vegetation, limestone vegetation, peat bog, bird sanctuary, kea habitat, *Powelliphanta* snail habitat). Because societal values differ, stakeholder participation (BBOP Principle 6) is important when identifying types to be addressed by an biodiversity offset design.

Components
Biodiversity components are the structural and functional components that describe the biodiversity type or, in the case of an iconic species, describe the important aspects of the life-cycle or population. They should be matched between impact and offset sites in a like-for-like manner, i.e. no high-value indigenous components should be substituted for other components to demonstrate no net loss. Components can include vegetation tiers (e.g. ground, understorey, canopy, epiphyte, climber), habitat types (e.g. lizard habitat, inanga spawning areas, forest), related groups of indigenous species (e.g. vertebrate, invertebrate, bird, bat, lizard), or functional roles (insectivore/predator, nectarivore/pollinator and frugivore/seed disperser). Threatened species and other high-value components should be addressed separately within an offset design for transparency. Demonstrating no net loss for individual high-value components can ease the resource consenting process by providing stakeholders and decision makers with added confidence that high-value biodiversity has been adequately addressed in an offset design.

Attributes
Biodiversity attributes are the elements of biodiversity components that are, preferably, measured or defensibly estimated (e.g. gained from measurements at a nearby similar site or by robust expert elicitation, if possible, and, in the absence of obtainable data, entered as explicit numerical quantities in an accounting model). Examples include number of trees per tier, number of individuals in a size class per plot, number of birds detected per hour. There must be at least one attribute (and preferably several) for each component in order to estimate no net loss for that component. There are no limits to the number of attributes that can be used to describe the condition of a component, but the attributes chosen should be sufficient to 'capture what we care about' because no net loss can only be estimated for those attributes entered into an accounting model.

Examples of biodiversity types, components, and attributes and how they could be measured to obtain data for a biodiversity offsetting model is presented in Appendix 1.

Box 1: The like for like concept (after BBOP 2012a)

The biodiversity offset process needs to ensure that biodiversity gains are comparable (in ecological terms, from a conservation priority perspective, and to local stakeholders) with losses that occur as a result of the development project. This is captured in the ‘like for like’ concept and reflects the fact that different components of biodiversity cannot be viewed as substitutes (i.e. traded) for each other when seeking to secure no net loss (BBOP 2012a).

This means that a good practice offset consistent with the New Zealand Guidance should demonstrate that *no high-value indigenous components and no indigenous types should be substituted for other components or types*. The like for like concept is inseparably linked to no net loss and requires careful selection of biodiversity currencies or metrics used in accounting systems to minimise concealed losses and other perverse outcomes.

In financial terms, biodiversity is perhaps the ultimate non-fungible asset, because it can vary so markedly between different locations and over time. Conservation activities that provide additional on-the-ground protection or benefits to the same and/or comparable habitats, species and populations can ensure that biodiversity gains match or exceed observed losses. Demonstrating that biodiversity offsets represent like for like exchanges requires careful selection of the biodiversity currency used in loss-gain calculations (see below). The only exception to the like for like condition is where development activities can be shown to impact low-conservation-priority components of biodiversity and where areas of high conservation priority can be improved through an offset (e.g. through enhanced protection or restoration activities). This kind of exchange is termed ‘out of kind’ to reflect the change in type of biodiversity that is being offset and is only viable when clear improvements (‘trading up’) in conservation outcomes are demonstrably possible. Trading up for biodiversity of higher conservation value (e.g. 50 ha of mature lowland podocarp forest exchanged for 50 ha of beech forest, or coal measures vegetation exchanged for kiwi management elsewhere) does not meet the requirements for a good practice offset because, currently, there are no robust methods that can be implemented in New Zealand for comparing and equitably exchanging different types of biodiversity.

In practice, this means that in order to demonstrate no net loss, a good practice offset needs to incorporate the like for like concept, and should be based on the evaluation and comparison of the same environments and the same ecosystems, vegetation, and habitats, and species represented within them.

Currencies

Calculating no net loss requires a currency, or metric. Currencies are a critical part of calculating losses and gains because they show how much of what is exchanged and define what is meant by no net loss. They are the units used in an accounting model to calculate losses and gains and provide the basis for quantifying residual impacts and the nature and size of the offset (BBOP 2009; BBOP 2012a; Gardner et al. 2013).

It is important to recognise that no single currency can adequately account for all affected biodiversity (Salzman & Ruhl 2000) and that careful thought must be given to the selection of any surrogates (i.e. a measurable and practical parameter that can be used as a substitute for a parameter that cannot be measured directly) to minimise the risk of unacceptable concealed losses, which can occur when one or more types or components of biodiversity are unknowingly exchanged for others (McCarthy et al 2004; BBOP 2012a; Maron et al. 2012). What is not captured by a currency relies on the adequacy of any surrogate. It is, therefore, good practice to understand the implications of using a given surrogate and to consider the use of exchange restrictions (i.e. a set of rules to define which components of biodiversity can and cannot be substituted for others) to guard against concealed loss. Ultimately, and because currencies form the basis for exchange, the choice of a good currency is essential to guard against the failure of an offset to meet no net loss (Walker et al. 2009).

A good currency is one that captures the important values exchanged (i.e. type, amount and condition), without leaving important features external to the trade (Salzman & Ruhl 2000). Accordingly, biodiversity offsets are improved when multiple attributes of the biodiversity values exchanged are measured (Maron et al. 2012), the selection of attributes is informed by adequate knowledge of the biodiversity involved and exchange restrictions are incorporated where necessary (BBOP 2012a; see below [accounting for equity in offset design]).

Minimising risk of concealed loss
Simple currencies, such as exchanges based on area of vegetation alone or an inadequate number of measures, risk concealed loss of biodiversity if values present (e.g. threatened species) within a certain vegetation type at an impact site are not present in the same type at an offset site. In such cases, any biodiversity not measured is protected only by chance (Walker et al. 2009), necessitating the use of exchange restrictions to guard against loss (Salzman & Ruhl 2000; BBOP 2012a). Exchange restrictions may include explicit decisions that prevent exchanges of different biodiversity types (e.g. kiwi for kaka, or secondary vegetation for emergent trees).

Because biodiversity is spatially and temporally heterogeneous, the risk of concealed loss when using area only and other simple aggregated currencies (e.g. habitat hectares—see McCarthy et al. 2004) is higher relative to the use of disaggregated currencies that capture more information by measuring multiple attributes and their condition. However, in the absence of appropriate attribute weighting (e.g. by threat classification level or rare ecosystems type), condition area models (i.e. those that combine area with multiple measures of condition) also risk inequitable trades because non-weighted attributes are valued equally if combined additively. Explicitly and transparently demonstrating no net loss for individual high value components eliminates this risk (NZBOP 2012).

Area only currencies cannot account for within-type variation (e.g. presence of a threatened species, quality, condition or function), because attributes other than aerial extent (often reported as hectares) are not measured. This can result in 'trading down' which undermines the ability to achieve no net loss (BBOP 2012b).

Factors to consider when choosing a currency

Key factors in the choice of a currency include transparency, robustness and the degree to which it is fit for purpose (including cost-effectiveness—although this should not compromise an equitable outcome). The choice includes consideration of the applicability of direct or surrogate (proxy) measures, aggregated or disaggregated currencies and site-specific and context-dependent currencies. The following guiding questions, suggested by BBOP (2012a), can help to distinguish between different types of currencies representing biodiversity type, amount and condition, and can be used to guide a developer in designing an offset that meets no net loss requirements for their specific project (see Table 1 for further explanation).

- Is the currency composed of direct or surrogate (proxy) measures of biodiversity?
- Does the currency include aggregated or disaggregated information on biodiversity?
- Is it based on site-specific or context-dependent measures?

Table 1: A typology of currencies (after BBOP 2012a).

Direct or surrogate measures?	In situations where a single species is affected by a development—such as bird collision mortality through wind turbine strike—direct counts or measures (e.g. number of individuals of a particular species) may represent a suitable currency. Direct measures or counts are advantageous in that they ensure that losses and gains are not masked or concealed by changes in other variables, as can occur when basing a currency on indirect or surrogate (proxy) measures. Guarding against concealed loss is particularly important when addressing significant components of biodiversity, such as threatened species. Because direct measures of biodiversity have a specific focus, they are necessarily disaggregated, but depending on how the biodiversity is measured, they can be either site specific or context specific. Because biodiversity is a multi-faceted and multi-scale phenomenon, currencies based on indirect or surrogate biodiversity measures (such as habitat complexity, vegetation type, certain condition and habitat suitability measures, area) designed to simultaneously account for multiple biodiversity components have seen popular application in offset design. To reduce problems associated with concealed loss, surrogates need to be carefully designed and *validated* based on adequate knowledge of the underlying biodiversity. It is important to consider scaling to ensure that incremental changes in surrogate values reflect comparable changes in underlying biodiversity across the full range of values, because biodiversity relationships are rarely linear. Where threatened species and complex communities are to be addressed, a combined approach using a combination of direct measures and surrogates can be useful and could be implemented.
Aggregated for disaggregated currencies?	Aggregated currencies are those that combine and generalise information on multiple biodiversity components (e.g. area x condition, broad vegetation types: forest, scrub). In the absence of differentially weighting individual components, the risk of concealed loss can be greater with aggregated currencies because individual components are treated equally (McCarthy et al. 2004). By maintaining the individual identity of individual biodiversity components (species, specific vegetation types), disaggregated currencies more transparently avoid trading between components and where no net loss is demonstrated for individual attributes, their weighting is not required (NZBOP 2012).
Site-specific or context-dependent currencies?	When an understanding of landscape-level biodiversity pattern is poor or data are limited, currencies based on site-specific information can be useful. Site-specific currencies do not include any information on relative measures such as patterns of rarity, landscape-level connectedness, levels of threat or the extent to which particular losses and gains may contribute to regional conservation priorities. Commonly employed site-level measures include area, species richness, counts of individuals, and measures of pressure. By contrast, context-dependent currencies are generally disaggregated and are able to assess the contribution of local biodiversity losses and gains to changes in conservation priorities at a regional scale (either through a contribution to the overall persistence of a given component (e.g. overall population growth rate; or to regional patterns of biodiversity). Examples include (i) the measurement of complementarity which can be used to assess dissimilarities among loss and gain sites, or identify the best combination of multiple offset sites that are necessary to achieve no net loss; and (ii) persistence or susceptibility to loss, which can be captured using a continuous measure of threat status and extinction risk.

Detailed currencies relying on species-level information or spatially explicit maps of biodiversity and threatening processes can be difficult to implement when such information is insufficient or not available. Consequently, calculation of losses and gains often relies on simplified and site-based currencies and, in particular, varying approaches to area x condition-based currencies, although direct species specific currencies can be appropriate on their own (or incorporated into more complex approaches) where the offset is directly relevant to individual threatened species. Area x condition currencies include habitat hectares (Parkes et al. 2003) and approaches developed by BBOP (BBOP 2012a). Area x condition currencies provide for the combination of multiple currencies based on direct measures (threatened species), aggregated (vegetation type) and disaggregated (vegetation condition measures) currencies and may incorporate time discounting or other approaches to address equity problems associated with uncertainty, including time lags (see Dealing with Uncertainty). Table 2 provides a comparison of the main advantages and disadvantages of some currently available currencies and suggestions for their most appropriate use. Although habitat hectares and area x condition currencies have often been used in New Zealand, there are more approaches to developing offset currencies and new approaches are likely to be developed as offsets become more widely adopted.

Table 2: Comparison of the main advantages and disadvantages of some currently available currencies and suggestions for their most appropriate use.

Currency	Advantages	Limitations	Conclusions
Iconic Species	• Relatively simple • Explicit accounting for individual value using direct currency	• Not a reliable measure of biodiversity beyond specific values • Requires tight exchange restrictions	• May be appropriate where an impact on a specific biodiversity feature needs to be addressed • May be useful if there are only limited biodiversity elements of value in a largely modified environment, such as seabird nesting sites on coastal farmland
Habitat hectares	• Relatively easy and simple compared with area x condition	• Not possible to estimate or model uncertainty • Use of surrogates conceals trade-offs between different elements of biodiversity • Successional and non-natural vegetation types can be difficult to model accurately • Models can allow like for unlike trades between attributes	• Can be useful for offset design where biodiversity complexity is not high and risk of concealed loss is low. Not recommended as a model for complex, high-value biodiversity, as the limitations mean that no net loss is very difficult to demonstrate.

Currency	Advantages	Limitations		Conclusions
Area x condition	• More transparent than habitat hectares • Better captures multiple biodiversity values • Outputs can be independently verified	• Requires more resources and more-expert judgement than habitat hectares • Area and condition are traded off, but this lacks a sound ecological basis and is likely to differ between attributes • Not possible to model uncertainty (but could be developed for new approaches)	• Choices of attributes are subjective, meaning that outcomes can be influenced by attribute choice • Requires accurate vegetation/habitat mapping • Requires accurate benchmarks such as baseline condition and predicted improvements in condition • Generally a new accounting model created for each offset project—creates variability and inconsistency	• Useful for moderate to high biodiversity complexity in New Zealand biodiversity offset situations, provided that a number of constraints and standards are applied, including: o Ensuring that attribute selection covers a meaningful range of biodiversity components o Ensuring that attributes capture different stages and/or ages of species o Using empirically informed parameters wherever practical. Avoid use of unverifiable parameters o Utilising counts or measures of individuals wherever practical, e.g. counts of saplings, estimation of fauna population size, measures of tree stem diameters o Transparently demonstrating that all components demonstrate no net loss, and thus overcoming issues relating to trade-offs within types

Currency	Advantages	Limitations	Conclusions
Ecological integrity	• Conceptually attractive • Uses objective measures • References national conservation goals • Could be implemented in a range of frameworks • Can provide an initial desktop scoping of offsets for further development with site data	• Currently implemented in Vital Sites and Actions framework • Data is not yet available for all aspects and components of biodiversity, but those important for a particular offset can be added if specific data collected • Currently, there is no recommended method for quantification of site condition	• Has the potential to be a comprehensive currency given sufficient investment in data collection • Further development and implementation in an appropriate frameworks would be useful • Provides an avenue by which offsetting can be done in a common currency consistent with conservation prioritisation and reporting

It is good practice to adequately understand the values and complexity of the biodiversity at impact and offset sites (ideally accomplished via the Assessment of Environmental Effects (AEE) process), and to select a currency with sufficient internal complexity to adequately reflect biodiversity complexity (i.e. as biodiversity complexity increases, the number of attributes in the currency should commensurately increase (NZBOP 2012). In doing this, it is relevant to also ensure that complex models are transparent and contribute sufficient data to adequately inform the decision-making process.

Area x condition currencies

It is good practice to consider and recognise that these currencies all risk leading to unacceptable concealed loss if they are constructed without appropriate understanding of the affected biodiversity (at both loss and gain sites) and explicit, transparent accounting for high-value components. This risk should be assessed and clearly accounted for when designing a good practice biodiversity offset. Table 3 draws from the BBOP in providing some factors to consider when using area x condition currencies—more detail can be obtained at BBOP (2012a).

Table 3: Factors to consider when using area x condition currencies (after BBOP 2012).

Area alone is not generally an adequate currency.	Area alone (e.g. 1 ha of mixed podocarp / broadleaf forest) is a surrogate for the amount of biodiversity within the affected area. However, it does not account for internal variation in condition (i.e. vegetation, species present and their abundance or function). It also lacks any information on the context of the biodiversity in the wider landscape. Because potential offset sites vary in their condition and few are likely to be pristine, using area alone currencies risks 'trading down', where a higher-quality impact area is offset by a substantially lower-quality area of the same vegetation type, thus resulting in a biodiversity net loss. Multipliers (often used to attempt to account for uncertainty in surrogate use) can be appealingly simple, but are of limited utility because a larger amount of common and lower-quality biodiversity is not the same thing as a smaller amount of rare and high-quality biodiversity. Ensuring equality in condition is important in delivering like for like trades resulting in no net loss.
Assessment of ecological condition requires a benchmark.	Measurements of ecological 'condition' or 'quality' can only be made with reference to a benchmark state that reflects a 'natural' or 'pristine' or other desirable condition relating to, for example, accepted conservation goals (Noss 2004; Gardner 2010; NZBOP 2011a, b). The benchmark provides an objective framework, and a common reference point, for evaluating biodiversity losses and gains across impact and offset sites. To maximise the potential for a genuine like for like exchange it may be necessary to employ multiple benchmarks relevant to different biodiversity components that make up an overall offset package. Despite it seeming like a simple process, the establishment of appropriate reference conditions as a basis for judging offset performance and measuring biodiversity gains is challenging and has confounded scientists working in natural resource management systems for decades. To assist with this, Gardner (2010) proposed five considerations that can help when establishing a suitable reference condition for biodiversity assessment: 1. *Identify reference sites based on an independent understanding of prior human impacts.* The selection process should include an agreed set of disturbance criteria relevant to the specific regional and ecological context. 2. *Accept the problem of shifting benchmarks.* For much of New Zealand, 'natural, pristine ecosystems' have been lost, yet this should not necessarily impede an ability to measure losses and gains in biodiversity. 3. *Match impact sites to the most appropriate benchmark when selecting amongst offset candidates.* It can be useful to collect data on a variety of potential benchmark conditions and then compare each candidate reference site against the characteristics of the impact site in order to find the most appropriate match for evaluating like for like exchanges. 4. *Recognise that ecosystems are highly dynamic.* Ecosystems are in a constant state of natural flux as they undertake cycles of disturbance and recovery. This will confound attempts to define benchmark conditions robustly using data from a single time period. 5. *Include information on landscape context.* Long-term viability of biodiversity at any given site critically depends on its interaction with other components of the wider landscape, and consideration of this context dependency is necessary when determining reference conditions.

Surrogate-based currencies need to be carefully scaled against changes in the underlying biodiversity components of conservation concern.	Biodiversity rarely varies along linear scales. Accordingly, it is vital that currencies based on surrogates of biodiversity (e.g. area of a particular vegetation type x condition) are consistently scaled against changes in biodiversity values so that an incremental change in the currency reflects the same change in constituent biodiversity values at both high and low ends of its range. The most famous type of scaling factor is found in the use of the species-area exponent z to adjust for the fact that a doubling of habitat area is unlikely to be associated with double the number of species (i.e. area and species are not linearly scaled). Similarly, changes in condition are also unlikely to have a linear relationship with changes in biodiversity, and may need to be scaled. Ideally, this scaling factor would be calibrated using direct observations of (multiple) species across different impact and benchmark sites, or would otherwise need to be developed based on expert opinion, for example.
Context-dependent information that provides information on rarity or irreplaceability should be included in the currency where possible.	Unless currencies include some measure of irreplaceability (e.g. from national conservation planning processes), there is a danger of allocating low values to degraded yet highly irreplaceable and/or threatened biodiversity (Bekessy et al. 2010). This is problematic as many of the world’s most important (for conservation) ecosystems are in a degraded state.

Constructing model parameters

The explicit measurement of attributes followed by balancing losses and gains distinguishes biodiversity offsets from other forms of environmental impact management (BBOP 2012a). Consequently, without attribute measurements (parameters) to inform a loss-gain accounting system, no net loss can’t be quantitatively demonstrated, in which case a biodiversity offset consistent with the guidance cannot be developed.

This means that it is good practice to plan for the data needs of an offset design early in the project development phase, preferably during the AEE study. However, where reliable, verifiable field-based parameter values are reasonably unobtainable, appropriate parameters might be carefully developed with adequate supporting knowledge via one or more of the following two approaches:

- Structured expert elicitation (see Kuhnert et al. 2010 for review) to synthesise a range of plausible values generated by informed expert knowledge (if available) and preferably modelled as an appropriate probabilistic distribution accounting for variation and uncertainty.
- Informed expert opinion in scenarios where it is possible to produce informative values that are ecologically plausible, defensible and testable.

If either approach is adopted, the reasons why verifiable field data cannot practically be obtained should be explicit, and the steps required to test the veracity of the estimate used should be described. *It is good practice to use parameter values that are testable to avoid the risk of biodiversity loss if untestable and incorrect parameters are used.*

If expert elicitation or informed expert opinion is used to develop parameters, it is important that experts can demonstrate that they are competent experts in the relevant field (preferably quantitative ecologists) and that uncertainty is adequately accounted for to avoid perverse outcomes based on values that are not plausible. Guidance on eliciting and using expert knowledge is provided in the literature (e.g. Kuhnert et al. 2010 and Speirs-Bridge et al. 2010), including use of the Delphi process, which offers potential for reaching consensus on model parameters in data-poor environments (e.g. MacMillan & Marshall 2006), when available expert knowledge is adequate. A key core element of the Delphi process is a consensus-building stage involving the dissemination of expert informed opinion (primary results), followed by communication between the experts allowing for adjustment of prior views—thus minimising over-confidence in initial responses (Speirs-Bridge et al. 2010; McBride et al. 2012)—and to bring about convergence towards an overall solution (MacMillan & Marshall 2006). A strength of the Delphi approach is that it provides for open dialogue and shared intellectual space for developers and conservation interests. Such a process has synergies with the RMA process and is consistent with the intent of BBOP Principle 6—Stakeholder participation.

Expert opinion might not be appropriate for generating model parameters for threatened or highly irreplaceable biodiversity if confidence is low (i.e. poorly informed best guesses are not appropriate model parameters because they contain little information and high uncertainty). If plausible parameters cannot be developed, or uncertainty is unacceptably high, it may not be possible to develop a biodiversity offset consistent with the guidance because explicit calculation of losses and gains are required to demonstrate no net loss (BBOP 2012a).

Biodiversity offset accounting systems

Ensuring an equitable exchange of biodiversity requires a transparent and fair accounting system or model (BBOP 2012a, Maron et al. 2013). Where currencies define what is being traded, an accounting model is the process by which biodiversity losses and gains are compared to derive the net change estimate necessary to demonstrate no net loss. This process estimates the net balance, or equity (BBOP Principle 7; BBOP 2009) in the exchange of biodiversity between an impact site and the offset site (BBOP 2012a). In doing this, the assessment of biodiversity offsets draws from the well-understood concepts associated with financial accounting and aims for a comparable level of rigour. The accounting system can only estimate no net loss when the same currency (derived from the same underlying biodiversity measurements) is used for losses and gains (BBOP 2012a).

An accounting model may need a range of elements reflecting a range of intervention activities delivering adequate biodiversity gains to limit the risk of failure and to demonstrate a no net loss target (BBOP 2012a). In practice, this may involve parameters reflecting a combination of restoration, pest control and/or other averted loss actions. The core output from the accounting model or system is the offset specification, which details the offset sites and activities that can deliver no net loss or net gain relative to predicted impacts (BBOP 2012a).

When parameterising accounting models, it is good practice to enter values so that no net loss is estimated in a forward predictive manner. Back-fitting a model from a desired point of no net loss compromises the integrity and transparency of the modelling process, which is about estimating the future behaviour of a system based on observable information (i.e. attribute measurements).

One of the main benefits in using an accounting system lies in the process by which parameters and management actions are selected and incorporated into the model. This requires an offset developer to think explicitly about impacts, losses and gains in a more structured manner than many other forms of impact management. The modelling procedure and its outputs provide a guide to the likelihood of achieving no net loss, not an absolute result. When interpreting model outputs, it is important to adequately consider sources of uncertainty and, where their magnitude is high, applying a precautionary principle can reduce the risk of an unfavourable outcome.

Several accounting systems have been investigated or used in New Zealand to balance biodiversity losses and gains to demonstrate no net loss. Several of these have been implemented in spreadsheets, e.g. habitat hectares and area x condition models. While spreadsheets can be useful, it is important to consider their limitations, including their ability to model uncertainty, and because as model complexity increases, transparency and ability to interrogate model structure decreases. Additionally, any errors contained within the spreadsheet may propagate throughout the model and remain unidentified due to difficulty in detecting them in very large spreadsheets. In very complex scenarios, implementing offset models within a programming language environment (e.g. R or RobOff) can improve the transparency, communication and robustness of estimates of no net loss.

It should be remembered that the science around demonstrating no net loss is still developing and new models or accounting systems are likely to improve on the currently available models. Notwithstanding that, Table 4 provides a comparison of the main advantages and disadvantages of some currently available accounting systems.

Some biodiversity offset accounting systems

Habitat hectares

Habitat hectares (Parkes et al. 2003) was developed for assessment of vegetation quality in Victoria, Australia and has been adopted by the Victoria State Government as a key component of their vegetation management policy framework, which includes biodiversity offsets. Habitat hectares is both a currency and accounting framework (see Tables 2 & 4), based on qualitative scores of vegetation condition to generate a 'habitat score' representing the proportion of the complete 'habitat' present. This score is determined for a stand of vegetation by recording and tallying qualitative scores for individual quality criteria and standardising the scores relative to a benchmark. The method has been criticised (McCarthy et al. 2004) for its ability to conceal trades of different types of biodiversity, necessitating careful use of exchange restrictions based on an adequate knowledge of the underlying biodiversity pattern across type, space and time (Salzman & Rhul 2000). In the absence of appropriate exchange restrictions, the use of habitat hectares for highly complex biodiversity scenarios poses a greater risk of biodiversity loss than other methods that explicitly measure biodiversity attributes.

The original paper published by Parkes et al. (2003) can be found at the following link:http://www.environment.gov.au/archive/biodiversity/toolbox/templates/pubs/habitat-hectares.pdf

Area x condition

Area x condition (sometimes called condition area or area condition or condition hectares) is also both a currency and an accounting framework (see tables 2, 4). Area x condition accounting systems incorporate the area x condition currency in an accounting framework, to explicitly estimate net change in the amount and condition of attributes (i.e. they are quantified) between impact and offset sites, after standardisation with appropriate benchmarks. Area x condition accounting systems can be designed to provide an explicit estimate of no net loss on an individual component basis, thus reducing problems associated with concealed loss when the currency adequately includes 'what we care about'. However, unless attributes are differentially weighted to reflect their value to society, all attributes are considered equal, and concealed trades may occur (e.g. early seral forest will be valued equally with mature forest). The accounting system can also incorporate the 'net present biodiversity value' concept (Overton et al. 2013) and other forms of time discounting.

RobOff—robust offsets calculator

RobOff (Pouzols et al. 2012) is a framework and software for conservation planning, including the design of biodiversity offsets (see Table 4). Its strength lies in its ability to account for both uncertainty and for time-lags between biodiversity loss and the predicted gains delivered by offsetting actions. It compares a range of possible scenarios to determine the optimal allocation of resources to ensure that offsetting gains are sufficient to balance development losses, and it therefore functions as an offset accounting system. In making these calculations, RobOff takes account of the conservation value of different biodiversity features, the negative impacts upon them of development actions and the potential gains from offsetting actions and explicitly considers the costs and feasibility of actions, budgetary constraints, time discounting and like for like requirements.

RobOff can address complex problems associated with habitat maintenance, management, restoration and offsetting by removing the spatial components of offset site selection (i.e. it does not consider the physical location of an offset site). The latter can subsequently be assessed in complementary spatial systematic conservation planning tools (e.g. Zonation (http://cbig.it.helsinki.fi/software/zonation/)

or Marxan (http://www.uq.edu.au/marxan/)) to optimise the location of the offset specification. This provides for offsets to be designed in context with national conservation goals and strategies, if so desired.

In RobOff, offset management actions produce different, uncertain responses for biodiversity components in different biodiversity types through time. RobOff analyses are intended to answer questions about how much of what kinds of (conservation) measures should be allocated to which biodiversity type.

RobOff is publicly available software located at http://cbig.it.helsinki.fi/software/roboff/

Vital Sites
Vital Sites is an accounting framework that utilises the ecological integrity currency as a biodiversity goal (see Table 2 in Overton & Price 2011). Vital Sites uses the concept of ecological integrity (Lee at al. 2005) defined by:

- Species occupancy—the extent to which species fill their natural ranges;
- Environmental representation—the entire range of ecosystems are represented; and
- Native dominance—species composition and ecosystem processes are dominated by native species.

The Vital Sites model uses a broad range of biodiversity information on species and environments, and threats on biodiversity, such as project-related vegetation clearance and animal and plant pests. The model uses two computation strands to address the three components of ecological integrity: 1) species occupancy, and 2) environmental representation and native dominance, combined. For each strand, the significance of an impact and offset site is evaluated as its marginal contribution to national ecological integrity. In addition, the model uses information on development impacts, pest and other pressures at a site to estimate the vulnerability or expected loss of biodiversity at the site. Significance of a site is calculated for each computational strand as the marginal loss of national ecological integrity that would occur if the species was lost from the site. With full development, Vital Sites offers the ability to evaluate both like for like and out of kind offsets and can be used as an initial scoping exercise for impact assessment and to guide the selection of potential offsets to address residual impacts. The output includes offset density maps showing the locations of offset opportunities at a national scale.

Table 4: Comparison of the main advantages and disadvantages of some currently available accounting systems (models) and suggestions for their most appropriate use.

Accounting system/model	Advantages	Limitations
Habitat hectares	• Simpler to use • More cost effective for small projects	• Limited transparency when implemented in Excel and errors can propagate through spreadsheet • Concealed loss or like for unlike trades not apparent in spreadsheet unless attributes are weighted and explicitly accounted • Does not internalise exchange restrictions • Not well suited to highly complex biodiversity • Does not account for uncertainty
Area x condition	• Uses quantitative attribute measures • Can be designed to explicitly account for no net loss on individual component and attribute basis • Reduced risk of concealed like for unlike trades • Computationally flexible	• When implemented in Excel can be complex, lacking in transparency and errors can propagate through spreadsheet • Concealed loss or like for unlike trades not apparent in spreadsheet unless attributes are weighted and explicitly accounted • Does not internalise exchange restrictions • Does not account for uncertainty
RobOff	• Explicit accounting for uncertainty • Flexible handling of time lags • Objective simultaneous analyses of a range of actions • Considers management costs • With further development, potential for out of kind exchanges • Complements spatial planning tools • Can be used to assess adequacy of a proposed offset • Can handle complex analyses in multiple environments	• High level of conceptual understanding of offsets and technical expertise required to run software • Does not account for costs that vary over time • Software is under ongoing development, requiring ongoing user support and up-skilling • Binary treatment of like for like or like for unlike does not consider biodiversity similarity/dissimilarity spectrum • Requires use of exchange restrictions

Accounting system/model	Advantages	Limitations
Vital Sites	• Uses currency of marginal contribution to national conservation goals (e.g. ecological integrity) • Can incorporate a range of biodiversity goals, including ecological integrity • Provides means for out of kind exchanges based on chosen currency, with current recommendation that such exchanges are constrained • Objective simultaneous analyses of a range of actions • Can handle complex analyses in multiple environments • Provides desktop evaluation of impacts and spatial identification of diverse offsetting options	• Use is limited by national-scale data availability • No current methods to use plot-based field data to validate results • Does not explicitly consider uncertainty • Still under development • Operates at coarse spatial scale • Requires use of exchange restrictions

Accounting for equity in offset design

Equity is a BBOP principle (BBOP Principle 7). Salzman & Ruhl (2000) point out that equity in biodiversity accounting varies according to type, time and space, whereas financial accounting is only concerned with equity in time (discounting) as dollars have a set and consistent value across space. An offset accounting model would, ideally, account for changes in all three dimensions (type, time, space) to ensure the delivery of no net loss. The majority of existing methods account in some way for exchanges in type and across space between impact and offset sites, but few deal with time. Exception to this are models incorporating the concept of net present biodiversity value that incorporate specified time intervals and a discount rate with a currency (Overton et al 2013; BBOP 2012a). The use of discount rates in biodiversity offsetting is controversial because there is some disagreement about the appropriateness of drawing concepts from economic principles and applying them to biodiversity, as this assumes that society values biodiversity and money in a similar way. If offset developers apply discount rates to their offset designs, it is important that the discount rates used are justified and the implications of their use understood.

Although it is impossible to guarantee that a biodiversity offset delivers truly like for like biodiversity benefits, several considerations important to addressing problems of equity are presented in Table 4.

Table 5: Consideration for addressing equity in using a biodiversity offset accounting system (after Salzman & Ruhl 2000; BBOP 2012a).

Equity in the type of biodiversity	Because biodiversity is heterogeneous, demonstrating like for like exchanges is challenging, requiring that rigorous offset design pays careful attention to choosing biodiversity currencies that adequately capture any significant changes in valued biodiversity components. Restrictions (exchange rules) are needed to limit exchanges that would undermine the delivery of no net loss. A variety of exchange rules can be used to improve equivalence of biodiversity exchange includes: **1. Limits on exchanges that involve biodiversity components of known conservation importance (e.g. of high irreplaceability or vulnerability).** This highlights the point that there are limits to what can be offset (BBOP Principle 2—Limits to what can be offset (BBOP 2012b; Pilgrim et al. 2013)). Rules can be set that prevent the exchange of irreplaceable, or threatened biodiversity for components of lower irreplaceability or threat status – i.e., 'trading down'. Biodiversity components of particular conservation importance should be dealt with individually in the biodiversity accounting process to ensure that any changes and the ability to achieve their no net loss can be easily assessed. **2. Limits on declines in ecological condition between impact and offset sites.** One problem with some currencies based on area x condition is that increases in area may be allowed to compensate for decreases in condition (i.e. to the extent that the currency rules allow area and condition to be exchangeable). This could easily result in a significant drop in biodiversity conservation value if a large area of very low condition was offered in exchange for a smaller area of excellent ecological condition. Such risks may be limited by applying an exchange rule which requires that key indicators of ecological condition either do not change significantly or can only increase between impact and offset sites (i.e. insisting on like for like or trading up and not allowing 'trading down'). Such an exchange rule could be implemented in an accounting model that individually quantifies losses and gains and estimates no net loss for specified attributes. **3. Limits on what is considered substitutable within aggregated surrogate currencies.** McCarthy et al. (2004) highlights the importance of this by identifying possible weaknesses in the habitat hectares currency (Parkes et al. 2003); for example, in situations where increases in some attributes (such as volume of dead wood) mask negative changes in others (such as loss of live trees). This kind of problem can be solved, at least in part, by establishing exchange rules that set minimum values (and, possibly, upper limits) to key components that make up any aggregated currency. Where possible, such threshold values should be justified through validation against actual biodiversity data in reference sites.

	4. Requirements for minimum landscape context conditions at offset sites. Offset sites that have not been designed to account for composition and structure of the wider landscape may not prove ecologically viable in the long term. Rules can be set that require offset sites to be of a minimum size, and be characterised by a minimum level of connectivity with neighbouring patches of the same vegetation type (Gibbons et al. 2009).
Equity in space	Biodiversity is spatially heterogeneous due to variability in biogeography and the type and intensity of human activities. Heterogeneity in biodiversity can be envisaged as a continuum along which greater distances between two points represent increasing dissimilarities. This means that units of biodiversity that are geographically close tend to be more similar than those that are geographically more distant. Accordingly, geographic distance is often used as a relatively useful proxy of ecological equivalence. Spatial exchange restrictions that take the broader regional context into account and/or which limit the distance over which impact and offset sites can be separated (e.g. catchments or ecological districts) can be used to help ensure that an offset is more likely to achieve the goal of no net loss. Accounting systems that integrate measures of biodiversity at a variety of scales (e.g. at site level or landscape level—to capture habitat connectivity, for example—and regionally) provide a means of integrating spatial equity in biodiversity exchanges.
Equity in time	Unless the biodiversity gains from an offset are delivered before the development impact occurs, it is inevitable that losses at the impact site will exceed any biodiversity gains from offset activity at least for a period of time (Bekessy et al. 2010; Overton et al. 2013). Any temporal mismatch or lag between losses and gains increases the risk that certain biodiversity components cannot be maintained at all. This may be due to the failure in the offset activity (e.g. restoration is unsuccessful), or as a result of the nonlinear nature of biodiversity and time-delayed ecological cascade effects (e.g. loss of key ecological processes such as seed dispersal or nutrient cycling, degradation or loss of habitat and critical resources needed for the persistence of certain species) or due to the impact of unexpected hazards such as fire, flooding and pest invasion for which provision has not been made. A common approach to addressing certain aspects of equity over time is the use of simple multipliers (see also section 3.2 in BBOP 2012a for further guidance): these are applied to assess the required 'gains' to be delivered by a specific offset, with the size of the multiplier varying according to the length of the time lag between losses and gains. However, the size of time-discounting-based multipliers can be enormous when dealing with offset activities that take a long time to deliver biodiversity gains (e.g. replacing old growth forest (Moilanen et al. 2009)). Use of multipliers does not, however, address the problem where temporal delays lead to critical resource shortages over time that may result in irreversible biodiversity loss (e.g. loss of large roost trees use by long-tailed bats) or for scenarios where uncertainty around the technical ability to deliver an offset is high (e.g. re-establishing coal measures vegetation). Problems around the use of multipliers are best addressed by providing a successful offset ahead of any impacts taking place (Bekessy et al. 2010).

Further detail on calculating losses and gains and the selection of currencies can be obtained in BBOP (2012a) from the BBOP website http://www.forest-trends.org/

References

BBOP (Business and Biodiversity Offsets Programme) 2009. Resource Paper: Biodiversity offset design handbook. BBOP, Washington, D.C. http://bbop.forest-trends.org/pages/guidelines

BBOP (Business and Biodiversity Offsets Programme) 2012a. Resource Paper: No net loss and loss-gain calculations in biodiversity offsets. BBOP, Washington, D.C. http://bbop.forest-trends.org/pages/guidelines

BBOP (Business and Biodiversity Offsets Programme) 2012b. Resource Paper: Limits to what can be offset. BBOP, Washington, D.C. http://bbop.forest-trends.org/pages/guidelines

Bekessy, S.A.; Wintle, B.A.; Lindenmayer, B.D.; McCarthy, M.A.; Colyvan, M.; Burgman, M.A.; Possingham, H.P. 2010. The biodiversity bank cannot be a lending bank. *Conservation Letters 3*: 151–158.

Brown, M.A.; Clarkson, B.D.; Stephens, R.T.T.; Barton, B. 2014. Compensating for ecological harm—the state of play in New Zealand. *New Zealand Journal of Ecology 38(1): 139–146.*

Gardner, T.A. 2010. Monitoring forest biodiversity: improving conservation through ecologically responsible management. Earthscan, London.

Gardner, T.A.; von Hase, A.; Brownlie, S.; Ekstrom, J.M.M.; Pilgrim, J.D.; Savy, C.E.; Stephens, R.T.T.; Treweek, J.; Ussher, G.T.; Ward, G.; ten Kate, K. 2013. Biodiversity offsets and the challenge of achieving no net loss. *Conservation Biology published online: 23 AUG 2013. DOI: 10.1111/cobi.12118*

Gibbons, P.; Briggs, S.; Ayers, D.; Seddon, J.; Doyle, S.; Cosier, P.; McElhinny, C.; Pelly, V.; Roberts, K. 2009. An operational method to assess impacts of land clearing on terrestrial biodiversity. *Ecological Indicators 9*: 26–40.

Kuhnert, P.M.; Martin, T.G.; Griffiths, S.P. 2010. A guide to eliciting and using expert knowledge in Bayesian ecological models. *Ecology Letters 13*: 900–914.

Lee, W.; McGlone, M.; Wright, E. 2005. Biodiversity inventory and monitoring: a review of national and international systems and a proposed framework for future biodiversity monitoring by the Department of Conservation. Landcare Research Contract Report: LC0405/122.

MacMillan, D.C.; Marshall, K. 2006. The Delphi process—an expert-based process to ecological modelling in data-poor environments. *Animal Conservation 9*: 11–19.

Maron, M.; Hobbs, R.J.; Moilanen, A.; Matthews, J.W.; Christie, K.; Gardner, T.A.; Keith, D.A.; Lindenmayer, D.B.; McAlpine, C.A. 2012. Faustian bargains? Restoration realities in the context of biodiversity offset policies. *Biological Conservation 155*: 141–148.

Maron, M.; Rhodes, J.R.; Gibbons, P. 2013. Calculating the benefit of conservation actions. *Conservation Letters 6(5)*: 359–367.

McBride, M.F.; Fidler, F.; Burgman, M.A. 2012. Evaluating the accuracy and calibration of expert predictions under uncertainty: predicting the outcomes of ecological research. *Diversity and Distributions 18*: 782–794.

McCarthy, M.A.; Parris, K.M.; Van Der Ree, R.; McDonnell, M.J.; Burgman, M.A.; Williams, N.S.G.; McLean, N.; Harper, M.J.; Meyer, R.; Hahs, A.; Coates, T. 2004. The habitat hectares approach to vegetation assessment: an evaluation and suggestions for improvement. *Ecological Management Restoration 5*: 24–27.

Moilanen, A.; van Treeffelen, A.J.A.; Ben-Haim, Y.; Ferrier, S. 2009. How much compensation is enough? A framework for incorporating uncertainty and time discounting when calculating offset ratios for impacted habitat. *Restoration Ecology 17(4)*: 470–478.

Noss, R.F. 2004. Some suggestions for keeping national wildlife refuges healthy and whole. *Natural Resources Journal 44*: 1093–1111.

NZBOP 2011a. Biodiversity offsetting models for the Escarpment Mine Project, Denniston Plateau, Westland. Contract report prepared by Wildland Consultants for New Zealand Biodiversity Offsets Programme, August 2011. New Zealand Department of Conservation, Wellington.

NZBOP 2011b. Summary report measuring impacts and defining biodiversity offset specifications for the Tahi NZ Eco-resort. Contract report prepared by Auckland University for New Zealand Biodiversity Offsets Programme, December 2011. New Zealand Department of Conservation, Wellington..

NZBOP 2012. Selection and weighting of attributes for use in biodiversity offsetting currencies. Contract report prepared by Wildland Consultants for New Zealand Biodiversity Offsets Programme, June 2012. New Zealand Department of Conservation, Wellington.

Overton, J.; Price, R. 2011. Ecological integrity and the design of biodiversity offsets. Landcare Research Contract report LC:800 prepared for the New Zealand Department of Conservation.

Overton, J. McC.; Stephens, R.T.T.; Ferrier, S. 2013. Net present biodiversity value and the design of biodiversity offsets*. Ambio 42(1)*: 100–10.

Parkes, D.; Newell, G.; Cheal, D. 2003. Assessing the quality of native vegetation: The ‘habitat hectares’ approach. *Ecological Management and Restoration 4*: S29–S38.

Pilgrim, J.D.; Brownlie, S.; Ekstrom, J.M.M.; Gardner, T.A.; von Hase, A.; ten Kate, K.; Savy, C.E.; Stephens, R.T.T.; Temple, H.J.; Treweek, J.; Ussher, G.T.; Ward, G. 2013. A framework for assessing offsetability of biodiversity impacts. *Conservation Letters* 6(5): 376–384.

Pouzols, F.M.; Burgman, M.A.; Moilanen, A. 2012. Methods for allocation of habitat management, maintenance, restoration and offsetting, when conservation actions have uncertain consequences. *Biological Conservation 153*: 41–50.

Salzman, J.; Ruhl, J.B. 2000. Currencies and the commodification of environmental law. *Stanford Law Review 53*: 607–694.

Speirs-Bridge, A.; Fidler, F.; McBride, M.; Flander, L.; Cumming, G.; Burgman, M. 2010. Reducing overconfidence in the interval judgments of experts. *Risk Analysis 30(3)*: 512–523.

Walker, S.; Brower, A.L.; Stephens, R.T.; William, G.L. 2009. Why bartering biodiversity fails. *Conservation Letters 2*: 149–157.

Appendix 1

Examples of biodiversity types, components and attributes and how they could be measured to obtain data for a biodiversity offsetting model.

Biodiversity type	Biodiversity components	Biodiversity attributes	Measurement method
Vegetation type	Community areal extent	Aerial extent	Number of hectares (ha)
	Species composition	Number of species in project area	Number of species
		Number of species per ha	Species/ha
	Vegetation tiers	Species per tier	Species/tier
		Relative diversity per tier	% of species per tier, or expected number of species per tier
	Maturity/age	Height of tiers	Use tier heights appropriate to vegetation type
		Diameter of trees	Basal area/ha
		Vegetation density	Basal area/ha
			Stems/ha
		Size of patch/individual	Area or diameter
	Condition	Presence of browsers	e.g. Foliar browse index, goat browse plots, faecal pellet counts
		Level of pest control undertaken	e.g. target or actual Residual Trap Catch
Rare species	Population size	Number of individuals	Number of individuals
		Proportion of total population	% of population
	Population distribution	Location of individuals	% of area that is suitable
		Proximity to other individuals/populations	Distance to other location
Fauna	Population size	Number of individuals	Number of individuals
		Proportion of total population	% of population
	Population density	Number of individuals per area	Number of individuals per unit area
		Habitat occupancy	% of suitable habitat occupied
	Population distribution	Location of individuals	Area occupied, size of home range
		Proximity to other individuals/populations	Distance
	Effect on population	Number of individuals affected	Number of individuals

Biodiversity type	Biodiversity components	Biodiversity attributes	Measurement method
		Total number of individuals	Number of individuals
Habitat type – wetland	Type of wetland	Area (ha) of wetland	Hectares (ha)
	Depth of water	Depth above/below soil surface	Water depth (cm)
Threats	Weed species	Presence/absence	Presence/absence
		Density	Plants/m^2
		Number of plants	Number of individuals
	Animal pests	Presence/absence	Presence/absence
		Density	Animals/m^2
		Number of animals	Number of individuals
		Index of numbers	e.g. Foliar browse index, goat browse plots, faecal pellet counts, Residual Trap Catch