NEW ZEALAND JOURNAL OF ECOLOGY

FORUM

The Biodiversity Compensation Model: a framework to facilitate better ecological outcomes

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Published online: 26 March 2025

Abstract: Two biodiversity models are commonly used by Aotearoa's terrestrial ecologists to guide habitat restoration and enhancement activities required to offset or compensate for development project impacts. The Biodiversity Offset Accounting Model can be used to assess the adequacy of an offset proposal. A more recent Biodiversity Compensation Model can be used to complement ecologists' professional judgement on the compensation required. The latter is increasingly used when relevant biodiversity offsetting principles cannot be met with confidence. This paper responds to a Forum article by Corkery et al. (2023) which claims that the Biodiversity Compensation Model facilitates biodiversity loss. We contest this claim and review the diverse range of cases in which the model has been applied and would be expected to generate better ecological outcomes than alternative compensation approaches. As practitioners using both the Biodiversity Compensation Model and the Biodiversity Offset Accounting Model, we assert that each has valid applications and limitations. Advancing this field requires independent evaluation of the models, and a collaborative approach to improvement which leverages all available expertise.

Keywords: biodiversity compensation, biodiversity model, offsets, Resource Management Act (RMA)

Introduction

In the face of Aotearoa's alarming rate of biodiversity loss, effective management of the ecological impacts of development is crucial. Project applicants must adhere strictly to an effects management hierarchy, which has been most recently defined in the National Policy Statement for Indigenous Biodiversity (NPSIB; Ministry for the Environment 2024a) and National Policy Statement for Freshwater Management (NPSFM; Ministry for the Environment 2024b). The effects management hierarchy prioritises the avoidance of adverse effects on ecological values, followed by minimisation or remediation. If residual adverse effects remain, these must be offset, which requires a calculated net gain in biodiversity compared to that lost. When offsetting is not feasible, biodiversity compensation is considered as a last resort, beyond the option of not undertaking the proposed activity at all.

Both offsets and compensation typically involve project-specific ecological restoration and enhancement activities. A key difference between offsets and compensation is that offsets must be demonstrated via a like-for-like quantitative loss/gain calculation. In contrast, compensation does not require this calculation, but indigenous biodiversity values lost must be addressed by positive effects that outweigh the adverse effects. These requirements are outlined in the offsetting and compensation principles of statutory planning documents such as the NPSIB and NPSFM. Such principles include recognition of limits to offsetting and adherence to the effects management hierarchy.

In this paper, we explore the tools used by terrestrial

DOI: https://doi.org/10.20417/nzjecol.49.3591

ecologists to assess the adequacy of offset and compensation measures. We respond to Corkery et al. (2023) who claim, as implied by their paper's title, that relatively simplistic models like the Biodiversity Compensation Model (BCM) contribute to biodiversity loss. Their conclusions are based on a single case study; however, a broader evaluation is needed to fully assess the model's effectiveness. We present a more nuanced perspective by evaluating the BCM's application across a wide range of projects, thereby contributing to a deeper understanding of its effectiveness and limitations. We also consider the merits of both the BCM and the Biodiversity Offset Accounting Model (BOAM; Maseyk et al. 2015) in guiding the type and amount of habitat restoration and enhancement measures in response to unavoidable development impacts.

Background to offsets and compensation

A background to biodiversity offsetting and compensation in Aotearoa can be found in Corkery et al. (2023), including the following definitions:

(1) offsetting - "a measurable outcome resulting from actions designed to compensate for residual adverse biodiversity effects arising from activities after appropriate avoidance, minimisation, and remediation measures have been subsequently applied and that achieves No Net Loss or preferably a Net Gain."

(2) compensation - "actions (excluding biodiversity offsets) to compensate for residual adverse biodiversity effects arising from activities after all appropriate avoidance, minimisation, remediation, and biodiversity offset measures have been applied. Gains generated by compensation actions must be additional to those that would have occurred anyway in the absence of those actions."

There is presently no statutory mandate under the Resource Management Act (1991), or the Conservation Act (1987) and associated policy documents to apply a particular loss/ gain method for demonstrating offsetting, nor a particular approach for compensation when offsetting cannot be demonstrated.

Anticipated changes to New Zealand's resource management legislation are expected to reduce the statutory weight of policy provisions regarding offsetting and compensation, in favour of expediting infrastructure and development. Nonetheless, it remains crucial for ecologists to apply the effects management hierarchy and ensure transparency in their assessments of offsetting and compensation.

Offsetting and compensation methods

We agree with Corkery et al. (2023) that biodiversity offset models that account for losses and gains are a necessary tool for determining the adequacy of an offset proposal. The Biodiversity Offset Accounting Model (BOAM) was developed as a quantitative approach to help determine the type and amount of biodiversity offset required to achieve No Net Loss or Net Gain (NNL/NG) outcomes (Maseyk et al. 2015). In summary, the BOAM: accounts for only like-for-like biodiversity trades aimed at demonstrating NNL and uses Net Present Biodiversity Value (NPBV) to estimate whether NNL is achieved; incorporates the use of a discount rate to account for the time lag between impacts associated with project activities and the gain at a proposed offset site; and allows adjustment to account for the likelihood of success regarding the proposed offset actions.

While we consider the BOAM theoretically represents best practice for offsetting, practical limitations often impede its application, as we discuss further below. When offsetting cannot be demonstrated for a particular biodiversity value, applicants must turn to compensation. Ecologists have historically relied on various approaches to determine an appropriate quantum of compensation. These include sole reliance on professional judgement, simple compensation ratios or multipliers, and negotiated outcomes: often referred to as 'horse trading' (Baber et al. 2021). These approaches have been criticised for their lack of transparency, rigour, and certainty, and for their often ad-hoc application (Wilson & Oliver 2023).

To address some of these shortcomings, the Biodiversity Compensation Model (BCM) (Baber et al. 2021; Tonkin & Taylor, 2021a, 2021b), was recently developed. The BCM offers a technically accessible tool for experienced ecologists to assess the likely adequacy of proposed compensation, following the User Guide (Tonkin & Taylor, 2021a). Drawing on established tools like the BOAM (Maseyk et al. 2015), Ecological Impact Assessment Guidelines (EcIAG; Roper-Lindsay et al. 2018), and the United Kingdom Statutory Biodiversity Metric, the BCM serves as a decision-support tool for ecologists to evaluate compensation packages across various project phases. As a compensation model, the BCM should only be applied only when offsetting is not feasible.

The practical limitations of offsetting

We agree with Corkery et al. (2023) that application of the effects management hierarchy can be undermined if models are used to support compensation proposals where offsetting is feasible.

Offsetting is typically ruled out when limitations and constraints associated with obtaining or interpreting data, and quantitatively predicting a future state, hinder the ability to 'demonstrate' an offset with adequate confidence. Moreover, offsetting is not pursued when offsetting principles, such as those of the NPSIB and NPSFM, cannot be met.

Using BOAMs to demonstrate, with confidence, net gain outcomes at the project approval stage has proved challenging. To our knowledge, BOAMs have been successfully applied at the application stage in only a few major projects, such as the proposed Auckland Regional Landfill (Te Rūnanga o Ngāti Whātua v Royal Forest and Bird Protection Society of New Zealand Incorporated [2023] NZEnvC 277 [722]), Te Ahu a Turanga Manawatū-Tararua Highway (Waka Kotahi New Zealand Transport Agency v Manawatū-Whanganui Regional Council [2020] NZEnvC 192 [168]) and Matawii Water Storage Reservoir (Te Tai Tokerau Water Trust, 23 October 2020, Expert Consenting Panel decision, Environmental Protection Authority (EPA)), and solely for impacted vegetation values.

In these instances, the BOAMs have been subjectively applied and biased towards what can be measured easily. For these projects, losses and gains in vegetation could be readily quantified with a high level of confidence. For example, native tree basal area loss can be easily measured and compared to an expected gain in basal area at revegetation sites based on existing literature. In other projects of a similar scale and magnitude where a BOAM was attempted, offsetting was rejected by appellants due to perceived uncertainties in the data, e.g. native vegetation loss at the Te Ara o Te Ata Mt Messenger Bypass (Barea 2018) and Hochstetter's frogs (*Leiopelma hochstetteri*) at the proposed Auckland Regional Landfill (Tonkin & Taylor 2022 unpubl. data).

Indeed, the BOAM's core reliance on quantitative data or quantitative proxies becomes particularly challenging for complex habitats, rare, cryptic, or highly mobile fauna, or other biodiversity values for which cause and effect is uncertain (Baber et al. 2021). Even with extensive survey effort and robust quantitative data, confidence in a particular effects management proposal does not necessarily increase, due in large part to uncertainties associated with future predictions, including those associated with climate change, and the deterministic nature of the model.

The common native passerine, tūī (*Prosthemadera novaeseelandiae*) illustrates the challenges of applying a BOAM to demonstrate offsets. Using accepted survey methods, tūī can be readily counted to help quantify relative impacts. It is known that tūī respond positively to both native revegetation and to the control of introduced mammalian predators. However, tūī show considerable variability in their response to conservation actions: across eight studies population increases ranged from 46–900% after pest control (Innes et al. 2004; Baber et al. 2009; O'Donnell et al. 2012; Ruffell & Didham 2017; Miskelly 2018; Fitzgerald et al. 2019; Fea et al. 2020; Fitzgerald et al. 2021). This variability likely reflects differences in the pest management regime, variations in detection probability, site specific habitat conditions, and landscape context including anthropogenic pressures. The wide range of observed population increases makes it difficult to choose the most appropriate model input to inform a BOAM (i.e. a defensible estimate of the increase in tūī counts at some point in future due to proposed offset actions).

Even greater challenges arise for threatened species offsets, since these species are typically more difficult to count, data are often harder to interpret, robust evidence on the magnitude of response to conservation actions is often lacking, and there can be significant differences between project specifics and referenced studies. Although the BOAM allows for use of surrogates and proxies in specific situations and subject to constraints (Maseyk et al. 2015), it still requires that the attribute values and losses are quantifiable and the outcome verifiable. The paradox is that in practice, a BOAM often cannot be populated with the data required to demonstrate an offset with sufficient certainty to satisfy stakeholder ecologists, until that offset has occurred. In turn, this illustrates the importance of post-consent monitoring to verify that predicted outcomes have occurred or guide adaptive management or contingency measures, if required.

Biodiversity compensation in practice

The quality of compensation occurs on a continuum, ranging from proposals that align closely to offsetting, to those that do not. Decision makers and regulatory agencies must consider whether compensation offered by an applicant is acceptable: Have the residual effects been adequately quantified? Has biodiversity offsetting been attempted and justifiably ruled out in the first instance? Have all biodiversity compensation principles been adhered to? Is the type and quantum of biodiversity compensation expected to generate biodiversity gains that outweigh residual adverse impacts? Is the approach to compensation as transparent and robust as possible? Will expected gains at proposed compensation site(s) be verified through biodiversity outcome monitoring, and is this feasible? And finally, will robust adaptive management/contingency measures be enacted where required?

Challenges of non-modelling based approaches

In the absence of models, methods for determining an appropriate residual effects management package have been widely criticised. For example, in opposing the Notice of Requirement applications for the Te Ahu a Turanga Manawatū-Tararua Highway, the Director-General of Conservation and others questioned "whether the offsetting/compensation predictions [which at the time were multipliers] could be confidently relied upon to ensure a Net Gain or even a No Net Loss", based on the applicant's use of environmental compensation ratios (unqualified multipliers) at the hearing stage of the resource consent application. Similar concerns were raised regarding use of multipliers for the Ara Tūhono Warkworth to Wellsford Road construction project (Waka Kotahi New Zealand Transport Agency v Auckland Council [2023] NZEnvC 242 [10]).

Likewise, while conceptually appealing, negotiated outcomes can take significant time investment from parties and experts, lack transparency, may lead to ecological outcomes disconnected from impacts, and necessitate a high degree of stakeholder engagement and willingness to compromise. This approach also raises concerns about stakeholder exclusion for those with limited advocacy capacity or resources, particularly mana whenua (Business and Biodiversity Offsets Programme, 2009a; Jenner & Howard 2015).

Biodiversity compensation models

The BCM was developed to address some of the constraints associated with biodiversity offsetting and the current suite of approaches to compensation (Baber et al. 2021, Tonkin & Taylor 2021a, 2021b).

Without wanting to oversimplify each of the models, the key features of the BOAM and BCM are compared in Table 1. Like the BOAM (Maseyk et al. 2015), the BCM helps determine the habitat restoration and enhancement measures required. However, the BCM serves a distinct role as a compensation model compared to the BOAM which is an offset model. Specifically, the BCM functions as a validation tool to complement professional judgement, rather than a predictive model used to demonstrate or claim an offset as per the NPSIB stated offset requirement. Nonetheless, the BCM builds on the BOAM by sharing several key features including:

The mathematical foundation

A discount rate to account for time lags between impacts and gains. Contingency for the level of confidence that stated biodiversity gains will be achieved via the proposed restoration and enhancement measures. The BCM is intended to bring the ecological outcomes achieved by compensation closer to those of an offset. It is designed for use in accordance with the user guide (Tonkin & Taylor 2021a). Importantly, this user guide requires adherence to biodiversity offsetting or compensation principles and the need for appropriate levels of evidence and science-based information.

The BCM uses a qualitative biodiversity value score based on area and habitat value for a given biodiversity feature, such as a particular species or habitat type. Specifically, a relative value for the modelled biodiversity feature is determined at the impact site(s) before and after impacts to provide an impact (loss) score, and at the compensation site(s) before and after compensation actions to provide a compensation (gain) score. Ideally, these assessments and the corresponding biodiversity value scores are based on field data and include inputs from other appropriately qualified and experienced ecologists, mana whenua representatives, submitters, or regulatory authorities. Such was the case for Te Ahu a Turanga Manawatū-Tararua

Table 1. Key high-level comparisons of the Biodiversity Offset Accounting Model and Biodiversity Compensation Model modelling approaches.

Attribute	BOAM (Offsetting)	BCM (Compensation)
Purpose		
Meets statutory requirements for quantitative assessment for biodiversity offsetting	✓	X
Biodiversity outcome target/contingency		
No Net Loss/Net Gain target	✓	X
Net Gain target (arbitrarily set at 10%)[1]	X	✓
Biodiversity measures		
Explicit quantitative measures (e.g. tree Diameter at Breast Height which can readily be quantified)	✓	X
Qualitative measures based on EcIAG ecological value assessment (including desktop and field investigations) (e.g. for cryptic or rare fauna that can't readily be quantified)	X	✓
Explicit like-for-like exchanges (biodiversity type, component and attributes)	✓	X
Typically like for like but allowing for like for unlike habitat trade-up scenarios	X	✓
Contingency to reduce risk of erroneous predictions		
To address biodiversity risk for threatened biodiversity values	X	✓
To address impact uncertainty	X	✓
To address confidence in proposed conservation actions	✓	✓
Discount rate (3%)	✓	✓
Relative information and computational requirements		
Relatively high resource intensity	✓	X
Relatively low to moderate resource intensity	X	✓

[1]The BCM User Guide is being updated at the time of writing to use the term Net Positive, rather than Net Gain.

highway (Waka Kotahi New Zealand Transport Agency v Manawatū-Whanganui Regional Council [2020] NZEnvC 192) and for the proposed Auckland Regional Landfill (Te Rūnanga o Ngāti Whātua v Royal Forest and Bird Protection Society of New Zealand Incorporated [2023] NZEnvC 277) (ecologists representing applicants and regulatory authorities only). Additionally, for both projects, biodiversity outcome monitoring is required to verify that stated outcomes are achieved or to guide adaptive management or contingency measures if required.

To ensure the effectiveness of these measures, robust consent conditions with stringent performance measures should be established, including comprehensive review and redress clauses to assess progress against ecological enhancement targets. These conditions should also encompass biodiversity outcome monitoring and reporting requirements, including verification and contingency actions, and must remain in effect for the duration of the modelled term.

Does the BCM facilitate biodiversity loss?

Using the BCM as an illustrative example, Corkery et al. (2023) contend that certain loss-gain models facilitate biodiversity loss. While we acknowledge the limitations of BCMs as discussed in the user guide and further elaborated upon below, we maintain that the implication that BCMs themselves facilitate biodiversity loss is unfounded.

Comparing the quantum of effects management measures from BCM and BOAM

In instances where direct comparisons have been made, BCMs indicated more habitat enhancement and restoration was necessary to achieve Net Positive outcomes compared to BOAMs. This contrast was evident in both Te Ahu a Turanga Manawatū-Tararua Highway project and the proposed Auckland Regional Landfill, primarily due to additional contingency multipliers and/or conservatism in BCM application that account for uncertainties.

For Te Ahu a Turanga, the BOAM recommended 45.6 hectares of native revegetation to offset 11.8 hectares of forest habitat loss. However, the BCMs indicated that this was insufficient to achieve a likely net positive outcome (or benefits that outweigh the impacts). Instead, the BCM deemed additional measures necessary including:

(1) 48.3 hectares of livestock exclusion from existing forest to prevent further degradation.

(2) intensive mammalian pest control over 393.9 ha, for up to 25 years, to bolster biodiversity values in the short to medium term.

Likewise, for the Auckland Regional Landfill project, while a Hochstetter's frog BOAM demonstrated a substantial NG outcome (1182% by year 22), the BCM indicated a more conservative 48% NG by year 35. This discrepancy stems from the differing approaches of each method. Unlike BOAMs, BCMs explicitly incorporate impact risk and uncertainty, leading to more cautious estimations of biodiversity gain. Additionally, the BCM inputs reflected more conservative expectations of the benefits of pest management than suggested by peer-reviewed scientific research (Baber et al. 2009; Longson et al. 2017, Crossland et al. 2023).

Further examples of biodiversity values for which BCMs would be expected to generate better ecological outcomes relate to the BCM's enabling of trade-up scenarios, for example, impacts on exotic forest habitat that are addressed through native revegetation and mammalian pest eradication or control within high-value native habitats. This scenario exemplifies that in certain instances, like-for-unlike biodiversity compensation may surpass offsetting in achieving ecological outcomes.

Application of BCMs on major infrastructure projects

As set out in Table 2, the application of BCMs to infrastructure projects that have recently been consented or proposed generally results in a proposed quantum of restoration and enhancement actions that is unlikely to facilitate biodiversity loss.

BCMs are not just used by ecologists working for applicants. For instance, submitter ecologists in the Huia Water Treatment Plant mediation proceedings used BCMs to successfully bolster their arguments for the need to increase the duration of the proposed mammalian pest control programme. Furthermore, during project optioneering and early design phases, ecologists have used BCMs to guide developers. By providing a readily understandable tool for helping to evaluate proposed measures, we have found that preliminary BCMs can facilitate client buy-in for impact avoidance or improved compensation packages. This makes it easier for developers to grasp the rationale behind ecological recommendations and navigate project adjustments, rather than relying on a "because I say so" multiplier which may be challenged through the process. In many cases, BCMs have helped communicate risk and cost to developers, leading to project redesign and a greater level of avoidance of effects on ecological values.

Critique of Te Kuha BCM application

Corkery et al. (2023) use the Te Kuha mine case (Royal Forest and Bird Protection Society of New Zealand Inc. v West Coast Regional Council and Buller District Council [2023] NZEnvC 68) to exemplify how certain models can facilitate biodiversity loss. However, we disagree, for the following reasons. The BCM did not guide the compensation package, as stated by Corkery et al. (2023) as it was determined prior to the application of the BCMs. Rather, in the limited instances where the BCMs were applied, they were simply used as a supplementary check to reinforce professional judgement, specifically the applicant ecologists' view of the likelihood that compensation benefits outweighed losses for the modelled biodiversity feature. BCMs were only applied for those limited instances in which available data and information was deemed adequate, i.e. for several avifauna species where impacts could be adequately assessed and there was demonstrable evidence that these species respond to pest control (see Table 3 for an example). The Te Kuha mine consent application was declined, so there was no facilitation of biodiversity loss. We consider that basing their critique on a single case without comparison to a wider range of cases introduces considerable bias. Their critique ignores all other instances in which BCMs were used to guide the adequacy of the compensation package and where decision-makers and other ecologists party to the consenting process have accepted the approach. Their critique also lacks specific comparison to alternative compensation methods, which is a crucial element for robust assertions, given that the BCM is not an offset model. Benchmarking the BCM against perfect-world principles in the absence of this relative assessment again introduces bias. For instance, we note that benchmarking the application of multipliers, professional judgement or negotiated outcomes and even the BOAM against these same stringent principles would also reveal an array of shortcomings, such as a lack of transparency, insufficient disclosure of limitations, or difficulties in practical application.

Finally, the material inaccuracies and notable omissions in the Corkery et al. (2023) critique collectively misrepresent the application of the BCMs in the Te Kuha Mine case. It is well beyond the scope of this paper to detail all inaccuracies or notable omissions, but those most material are provided in Table 4. Further to this, Table 3 summarises the data inputs and justification that went into the BCM for roroa (great spotted kiwi, *Apteryx maxima*). The BCM was applied by applicant ecologists as a supplementary check of proposed habitat restoration and enhancement, designed to achieve net positive outcomes for this species.

Council hearing and Environment Court decisions

In respect of measures to address residual adverse effects, the task of the Environment Court or Council hearings panel is to consider the applicant's approach (and criticisms of the approach from regulatory authorities and appellants) based on merit and the weight of evidence before them. Corkery et al. (2023) do not mention the available Environment Court or Council hearing decisions in which BCMs have been accepted as an appropriate approach, despite the full suite of criticisms set out in the evidence of appellant ecologists. Corkery et al. (2023) instead confine their arguments to the Te Kuha case. However, the authors do not mention that in this instance, the Court directed further mediation in relation to the BCMs but only excluded the BCM from consideration due to the disagreement among ecologists involved in the proceedings. We note that this end position may also have been reached if the parties had instead relied on negotiated outcomes, which also require agreement to be gained.

Alignment with international approaches

Despite criticisms by Corkery et al. (2023) about the use of qualitative data in BCMs, this approach reflects current international practice (Borges-Matos et al. 2023). While recognised limitations exist in capturing all facets of biodiversity through proxies, their workability and practicality are demonstrable advantages. As the biodiversity offset implementation handbook (Business and Biodiversity Offsets Programme 2009b) emphasises, finding a balance between exhaustive, often impractical quantification and simplistic approaches lacking scientific rigour is crucial.

This balance is exemplified by the UK Statutory Biodiversity Net Gain Metric, the culmination of more than 14-years' research, which become mandatory in February 2024 and offers a practical tool to measure biodiversity gains and losses in the United Kingdom. The metric uses habitats as a proxy for biodiversity and calculates biodiversity value for the purposes of biodiversity net gain (BNG) which is set at a minimum of 10%. Biodiversity value is calculated in standardised biodiversity units. The metric is designed to inform decisions in conjunction with locally relevant evidence, expert input, or guidance (Department for Environment, Food and Rural Affairs, 2024). The BCM intentionally adopted key elements of earlier iterations of this model, including the use of qualitative biodiversity value scores derived from real data and expert-based contingency multipliers to account for impact uncertainty and risk.

Table 2. Summary of impacted biodiversity values and proposed compensation gains for selected recent large infrastructure projects, as guided by Biodiversity Compensation Models.

Application and status	Impacted biodiversity	Proposed compensation as guided by BCMs
Manawatū Tararua highway (Waka Kotahi New Zealand Transport Agency v Manawatū-Whanganui Regional Council [2020] NZEnvC 192)	Loss of 11.8 ha of mostly native regenerating forest and associated impacts on At Risk bird, lizard, and invertebrate species.	45.6 ha of native revegetation of exotic pasture 48.3 ha of livestock exclusion from existing native forest 393.9 ha of mammalian pest control and weed management within native forest for up to 25 years.
Peacocke Structure Plan Area plan change (The Adare Company Limited v Hamilton City Council [2023] NZEnvC 245)	Loss of 488 ha of pasture and 34 ha of exotic vegetation and associated residual impacts on nationally threatened long-tailed bat habitat.	On-site protection and restoration of 128 ha of riparian margin that includes 62 ha of native riparian revegetation and 128 ha of mammalian pest control and weed management. Off-site riparian margin restoration including 190 ha of native riparian revegetation (47.5 km of riparian margin at 20m width) and weed and mammalian pest control, or 700 ha of mammalian pest control in high-value bat roosting habitat in perpetuity.
Auckland Regional Landfill resource consent Environment Court interim decision (Te Rūnanga o Ngāti Whātua v Royal Forest and Bird Protection Society of New Zealand Incorporated [2023] NZEnvC 277)	Loss of 150.4 ha of exotic pine forest, wattle forest and pasture vegetation, 7.2 ha of native vegetation, 1.86 ha of mostly exotic-dominated pasture wetland and 9.5 km of pine forest streams. Associated impacts on Threatened or At Risk indigenous species including long-tailed bat, birds, Hochstetter's frog, lizard species, invertebrates.	110 ha of native terrestrial revegetation and mammalian pest eradication including wasp control 215.9 ha of native habitat subject to pest animal control in perpetuity 4.42 ha of wetland restoration 15.42 ha of wetland habitat subject to mammalian pest eradication, wasp control and weed management 19.53 ha of wetland habitat subject to mammalian pest control in perpetuity and weed management. 30.7 km of mostly native forest stream habitat for Hochstetter's frog subject to pest control or pest eradication and revegetation of 1.6 ha of potential frog stream habitat.
Beachlands South private plan change (Council decision granted)	Future loss of c. 200 ha of exotic pasture grassland, 6.43 ha of exotic scrub and 0.15 ha of exotic-dominated natural inland wetland and associated impacts on species: notably copper skink and several Threatened or At Risk wetland birds.	88.7 ha of proposed protection and restoration including 32 ha of associated native revegetation to enhance ecological connectivity; and 35 years of weed and mammalian pest control.
Newcombe Road sand quarry resource consent (Council decision pending)	Loss of 4.1 ha of pasture, 3.63 ha of exotic vegetation and 0.174 ha of natural inland wetland. Associated impacts on indigenous species, notably long-tailed bat and potentially copper skink.	12 ha of riparian revegetation (c. 2 km of Karapiro stream); and 3.7 ha of wetland restoration and enhancement via native wetland revegetation, wetland margin revegetation and weed management.
Eastern Busway - Stages EB2/3R (Council decision granted)	EB2/3R - Loss of 0.43 ha of potential native lizard habitat (native and exotic vegetation), notably At Risk copper skink and ornate skink.	EB2/3R - 1.45 ha of lizard habitat restoration planting, including provision of lizard refugia such as log piles.
Eastern Busway - Stages EB3C/4L (Council decision granted)	EB3C/4L - Loss of 0.578 ha of potential native lizard habitat (native and exotic vegetation), notably At Risk copper skink and ornate skink.	EB3C/4L - 1.75 ha of lizard habitat restoration planting, including provision of lizard refugia such as log piles.

Table 3. Data inputs into the roroa (great spotted kiwi, *Apteryx maxima*) Biodiversity Compensation Model used to help assess the predicted net positive outcomes for this species.

Data input	Explanation	Te Kuha Applicant's rationale for data inputs into the roroa (great spotted kiwi) BCM
Benchmark score	The benchmark is always 5	A benchmark of 5 correlates to a call count of 3.28 per hour, which reflects the five-year average call count of the nearest managed roroa population (GB; unpubl. data). This population is in high-value habitat subject to pest control.
Net positive target	The extent to which the compensation score must exceed the impact score, to reduce the potential risk of net loss outcomes (false positives).	A net positive target of 20% was assigned, which means that the compensation score must exceed the impact score by > 20% to be considered sufficient to outweigh impacts.
Impact risk contingency	A multiplier to reflect greater risk associated with higher ecological value (see below). Ranges from 1 (negligible-very low) to 4 (very high).	An impact risk contingency of 4 was assigned, reflecting the very high ecological value of roroa as assessed using EcIAG. This contingency input applies to a nationally threatened biodiversity value and accounts for the greater biodiversity risk associated with impacts on nationally threatened species. This input automatically increases the impact score by 20% and accordingly, pushes up the level of compensation required to achieve the stated 20% net positive target.
Impact uncertainty contingency	A multiplier to account for uncertainty relating to impacts. Ranges from 1 (low) to 4 (very high).	An impact uncertainty contingency of 3 (high) was assigned. This contingency accounts for data/information uncertainty such as the potential for edge effects surrounding the project footprint. This input automatically increases the impact score by 20% and accordingly, pushes up the level of compensation required to achieve the stated 20% net positive target.
Habitat value at impact site prior to impact	Corresponds to the assessment of value in the ecological effects assessment, which follows EcIAG methodology and is based on desktop and field investigations. Ranges from 0 to 5.	A data input score of 2/5 was assigned (low end of moderate value). This score correlates with call counts on the ridge line of 1.5 calls/hour during surveys in 2013 compared to the benchmark call count of 3.28 calls/hour. As such, the assigned values were primarily informed by both site field investigations and peer-reviewed studies. Moreover, it aligns with evidence that the preferred feeding habitat for roroa includes deep soils/deep litter of tall forest, which was not present in the project footprint, and the low survival rates of chicks (zero to near zero) without continuous pest control. Notably this is a conservative score because it excludes more recent bird counts in 2020 which did not record any roroa present, i.e. counts of 0. We note that appellants considered the score should be 4.75 with no specific justification or elaboration as to why.
Extent of impact	Areal extent of impact (ha) for habitat type	Scale of footprint 144 ha (direct impacts) as proposed in the consent application. Edge effects were accounted for in the impact uncertainty contingency.
Value after impact	Ranges from 0–5. See habitat value prior to impact.	It was conservatively assumed that the roroa population would decline to zero after impact. However, the rehabilitation measures proposed would be expected to support a roroa population in the medium to long-term.
Discount rate	Accounts for time lag between the impact occurring and the biodiversity gains being generated by the conservation action(s).	The discount rate of 3% is consistent with that applied in the BOAM. This discount rate rewards benefits that are delivered quickly and conversely, requires more compensation effort when compensation gains take longer to eventuate.
Finite end point	Time period between commencement of compensation actions and assessment of their benefits.	A value of 35 years was assigned, which means that the assigned compensation value of 4 is conservatively expected to be realised by Year 35 (the duration of proposed mammalian pest and wasp control). In reality, pest control is likely to benefit roroa breeding success almost immediately. Had the finite end point been assigned a value of 5 years, then the model output would have been greater (1187% rather than 431%). This same conservatism was applied across all bird models.

Table 3. Continued.

Data input	Explanation	Te Kuha Applicant's rationale for data inputs into the roroa (great spotted kiwi) BCM
Compensation contingency	Level of confidence in the likely success of the proposed compensation measures and methodology, ranging from 1 (very high) down to 4 (low).	A value of 3 was conservatively assigned, reflecting moderate confidence in the compensation outcome. This contingency reduces the compensation score (calculated biodiversity gain is multiplied by 0.625), thereby requiring more effort to meet or exceed the 20% net positive target. The score was not lower because there is considerable evidence that intensive pest control operations generate considerable increases in roroa numbers. The score was not higher due to the uncertainties around the relative benefits of pest control operations proposed for this consent and the pulsed 1080 drops that the Department of Conservation (DOC) had subsequently proposed.
Habitat value at compensation site before compensation	Assessed using EcIAG methodology. Ranges from 0 to 5.	A habitat value score of 2 was assigned, reflecting the quality and amount of habitat currently available to roroa at the compensation site. The site was not subject to continuous mammalian pest control or wasp control. However, DOC completed a 1080 aerial drop in 2020 and two further drops were anticipated at three-year intervals.
Habitat value at compensation site after compensation	Habitat value after compensation at the assigned finite end point. Ranges from 0 to 5.	A habitat value score of 4 was assigned reflecting relatively very high value habitat (low end). This constitutes a 40% lift in Kiwi numbers/counts relative to the benchmark after 35 years of intensive pest control. Although we would expect a 60% lift in the population, pulsed aerial 1080 drops planned by DOC are considered non additional and are therefore not counted. We consider this conservative because peer-reviewed studies demonstrate rapid recovery of kiwi under intensive pest control regimes. We factored in a 10% increase to proposed pulsed 1080 drops by DOC noting that there is mixed evidence on the efficacy of pulsed 1080 drops on roroa and no certainty they would be undertaken.

Table 4. Technical corrections to Corkery et al.'s (2023) critique of Biodiversity Compensation Model application at Te Kuha.

Statement in Corkery et al. (2023)	Technical corrections/response
"*The applicant proposed compensating for these difficult-to-offset losses through an out-of-kind exchange…*"	BCMs were used only as a supplementary check on the likelihood of predicted net positive outcomes for the final subset of avian species to which a BCM was applied. The outcomes for any other biodiversity values to which a BCM was not applied were assessed based on professional opinion alone and sat outside the model.
The "*BCM output is a unitless percentage…*"	The use of a unitless percentage is in fact derived from the BOAM (Maseyk et al. 2015) and is a relative percentage of loss or gain based on the absolute percentage of the compensation score in relation to the impact score (e.g. a compensation score that is 20% larger than the absolute impact score equates to a 20% net positive outcome).
"*Subsequent sensitivity analyses showed that the calculated NG outcomes for all bird species were sensitive to minor fluctuations in inputs (e.g. ± 10% of the input data)*"	This statement is inaccurate and lacks context. By assuming 10% negative variation across multiple data inputs, the sensitivity analysis mentioned by Corkery et al. (2023) was cumulative. This meant for the applied models that an assumed 10% error percentage for individual inputs equates to an error that is equal to or upwards of 50%. As such, the only conclusion that can be drawn from this sensitivity analysis is that when the data inputs are altered considerably and only negatively, so are the data outputs.
"*…back calculations were used to convert unitless percentages to estimated 5-Minute Bird Count (5MBC) measures. Estimates of "real-world" numbers were less impressive than model outputs…*"	Real world numeric gains predicted in the model were small because they were conservatively assigned (e.g. a fernbird increase from 0.75 to 0.85 per bird count was predicted). However, this constitutes a large predicted gain given that the proposed mammalian pest control encompassed an area of 6000 ha and was proposed for a term of 35 years. The magnitude of gain is based on both the relative increase and the scale across which the increase is expected. To discount the scale of offset as Corkery et al. (2023) have done is erroneous.
"*…the BCM did not address the uncertainty associated with biased data; likely to be an issue when relying on subjective, poorly corroborated data.*"	This was addressed in the BCM via several contingencies that elevate the impact score, e.g. impact uncertainty and biodiversity risk. We note that the BOAM does not include such contingencies despite the potential for quantitative inaccuracies or bias in quantitative data.

Limitations of the BCM

Corkery et al. (2023) contend that relying on a qualitative value score rather than focusing on quantitative data is a key limitation of the BCM. Yet all value scores are based on the established Ecological Impact Assessment Guidelines (EcIAG; Roper-Lindsay et al. 2018), in which the determination of values employs a combination of literature and database review, site-specific field assessments (including gathering quantitative data) and the professional judgement of suitably qualified and experienced ecologists. These EcIAG assessments are intended to be comprehensive and provide the basis and justification for each model input.

In our view, employing expert judgement alongside desktop and field investigations in a BCM does not render an assessment somehow arbitrary, as suggested by Corkery et al. (2023). To suggest the qualitative value score applied is arbitrary undermines the role of the professional ecologist more broadly than just in relation to BCMs. The same could be said, for instance, regarding the outcomes agreed through expert conferencing, which equally rely on professional ecological input. This approach also overplays the role of quantitative-focused models such as the BOAM, which also rely heavily on expert judgement to determine a predicted future state, are strongly influenced by the quality and relevance of input data, and are equally affected by future uncertainties.

The limitations and constraints of the BCM are acknowledged in the User Guide on pages 4–5 (Tonkin & Taylor 2021a), and they are not repeated here. They can be managed via the following approaches:

(1) being implemented by suitably qualified and experienced practitioners

(2) using robust and reliable data from a range of sources

(3) conservatism in selecting a net positive target; application of an impact risk contingency to account for the greater risk to more threatened indigenous biodiversity, and application of an impact uncertainty contingency

(4) applying models only when the level of data is adequate

(5) limiting the degree of aggregation in the model, e.g. using separate models for different ecological features such as vegetation types or different bird species

(6) undertaking manual sensitivity analyses that involve recalculating predicted outcomes for each affected biodiversity value, under alternative assumptions or data inputs

(7) involving all ecologists and other informed stakeholders in the development of the BCM (noting that this depends on willingness to engage)

(8) requiring biodiversity outcome monitoring to verify intended benefits once biodiversity impacts and gains can be quantified using real data and to guide adaptive management and or contingency measures as required. This includes the need for additional or alternative management of sites, or additional sites where enhancement trajectories underperform.

Conclusion

In conclusion, we agree that the use of models for offsetting or compensation can result in more confidence being placed in predictions than is warranted (Corkery et al. 2023), a concern also raised by the Environment Court. We also concur that models should not be seen as a pathway to rely on compensation without first testing the feasibility of offsetting. However, we do not agree with the implication by Corkery et al. (2023) that use of the BCM facilitates biodiversity loss in Aotearoa. Conversely, we argue that the BCM can generate better ecological outcomes than alternative compensation approaches and even the BOAM, based on direct comparisons to date. Application of any biodiversity model must be underpinned by robust ecological assessment. As users of the BOAM and BCM, we contend that each model has merits and limitations, and in practice, they can be effectively used in a complementary manner on projects.

Suggested way forward

Calculating the quantum of biodiversity loss associated with a proposal and the commensurate quantity of offsetting or compensation is a multi-faceted challenge and such decision-support tools are essential to avoid sole reliance on expert judgement.

We agree that further work is necessary. Offsetting and compensation are developing fields in Aotearoa and their use and application continues to improve and evolve. The BCM for instance was released as Version 1 and was intended to be updated in response to user feedback and learnings (Tonkin & Taylor 2021a), such as refining terminology to reference net positive targets. This approach aligns with ongoing refinements to ecological models like the Stream Ecological Valuation (refined in 2010), which is expected to adapt further (Price et al. 2022) to Aotearoa's evolving scientific understanding of offset and compensation applications. Accordingly, we consider that these models would benefit from further development to refine terms and strengthen the statistical validity and sophistication of inputs. We advocate for independent evaluation of these processes and models to advance their effectiveness. Importantly, the testing, development, and improvement of these tools relies on engagement with experts and collaborative efforts. Certainly, both decision-makers and the calibre of offset/compensation packages [for assessing residual adverse ecological effects] would benefit considerably if ecologists could reach agreement on which models were appropriate for use and confine their disagreements to model inputs.

On final note, and in accordance with the NPSIB and NPSFM, we reiterate the importance of adhering to the effects management hierarchy and the need for concerted efforts to avoid, minimise or remedy adverse ecological effects before offsetting, and lastly compensation, are considered.

Additional information and declarations

Author contributions: All authors were involved in conceptualising, writing, and editing; MB prepared the original draft of the manuscript.

Funding: Not applicable.

Data and code availability: There is no data or code associated with this work.

Ethics: Not applicable.

Conflicts of interest: The authors use both the BCM and BOAM in their business activities. Several authors (MB, JQ, DM and JM) were involved in developing the BCM which is a publicly accessible model, available to all ecologists without any licensing fees or restrictions.

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Received: 22 July 2024; accepted: 17 October 2024
Editorial board member: Peter Bellingham