Before a panel appointed under the
Fast-track Approvals Act 2024 **FTAA-2504-1046**

UNDER	the Fast-track Approvals Act 2024 (**Act**)
IN THE MATTER	an application for approvals for the Waihi North Project (**WNP**) – a listed project described in Schedule 2 of the Act
BY	**OCEANA GOLD (NEW ZEALAND) LIMITED** **Applicant**

STATEMENT OF EVIDENCE BY DR GRAHAM USSHER ON BEHALF OF OCEANA GOLD (NEW ZEALAND) LIMITED

Ecology – Effects Management

Dated 1 September 2025

Counsel acting:
Stephen Christensen
Project Barrister
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Introduction

1. My full name is Graham Thomas Ussher. My qualifications and experience, and my role in the Waihi North Project (**WNP**), are set out in my statement of evidence dated 10 January 2025 included in Part G of the substantive application document for the WNP.

2. I have been asked by OceanaGold (New Zealand) Limited (**OceanaGold**) to provide a response to the specific matters contained in written comments on the WNP application from the following persons invited by the Panel to comment under section 53 of the Act:

   a. Coromandel Watchdog of Hauraki Inc (Appendices A and B);
   b. Hauraki District Council feedback; Section 14 (Memorandum (final) Terrestrial Ecology, and Section16 HDC Conditions – Tracked version (final);
   c. Thames-Coromandel District Council;
   d. Waikato Regional Council Memorandum and Appendices, and Waikato Regional Council conditions;
   e. Royal Forest and Bird Protection Society of New Zealand Incorporated;
   f. Iwi; and
   g. Department of Conservation:
      i. Appendix D Wildlife Approval report;
      ii. Access arrangement report;
      iii. Section 51 covering report; and
      iv. Comments on a fast-track consenting application.

3. I have prepared this statement within the limited time available to me. Consequently, it is necessarily at a high level. I am able to provide a more fulsome response to the issues covered in this statement if the Panel requires further assistance from me.

Coromandel Watchdog

4. In Appendix B.01 paragraph 10, Ms Macassey-Pickard states that '*There has been no further consideration of the ecological effects of subsidence on the forest*…' after raising a concern that there could be total settlement in the WUG forest area of up to 300 mm up to 1,000 mm (paragraph 9). This is the range of subsidence estimated by EGL for the underground mine area in their ground settlement report[1]. The EGL report notes that the scale of potential subsidence of this magnitude would be unnoticeable in the hilly terrain of the site and would have no effect on streams or forest areas. As such I have not included an assessment of risk of subsidence to native frogs or frog habitat as the nature and magnitude of potential subsidence in the WUG forest area would be, in my opinion, inconsequential to the integrity of frog habitats or frog populations in the WUG forest area.

5. Coromandel Watchdog states that modelling undertaken by OceanaGold excludes dewatering effects on the habitat of Archey's and Hochstetter's frogs.[2] I disagree, as the report that I prepared which assessed risks to Archey's and Hochstetter's frogs[3] included the risk of dewatering on stream flows and dewatering of forest in Table 1 of that report. I noted in that report that the analyses undertaken by OceanaGold on groundwater, interflow, and stream flows indicates that it is highly unlikely that any significant impacts on the resident frogs above the WUG will result from potential reductions in wetted stream width or dewatering of the regolith. I scored the magnitude of potential effect as 'negligible' and the level of potential effect as 'very low' because of the highly unlikely nature of the effect occurring.

6. Mr Conland says at paragraphs 27 - 30 of his evidence that offsetting has been prioritised ahead of avoidance and that this 'undermines ecological integrity'. I disagree, as the ecology team (including myself) worked with the engineering design team for the project to avoid or minimise the effects of

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1 Appendix B.13. Ground settlement report. EGL, and also *paragraph 26 onwards, Appendix S –Statement of Evidence Trevor Matuschka*.

2 Initial Submissions for Coromandel Watchdog, page 9.

3 B.38. *Wharekirauponga mine: Assessment of effects on native frogs*.

placement of above ground infrastructure within the Coromandel Forest Park area and to limit the areas of vegetation clearance required. Offsetting has been applied as the last step of an exhaustive and iterative process of avoidance and minimisation. In my opinion, the project design process for this project has robustly applied each step of the effects management hierarchy.

7. Mr Conland says at paragraphs 31-33 of his evidence that the delay in providing benefits after impacts undermines the credibility of a 'net gain' position. I disagree. Biodiversity offsetting as a tool is fundamentally built around time lags, risk and uncertainty on the basis that, in most situations, biodiversity benefits will be delivered in the future. Time lags are therefore not a weakness of the biodiversity offsetting or of the offset models used for this project, but rather are a fundamental part of them.

8. I believe I have applied these have been applied correctly in my calculations and modelling, and in a precautionary manner. The strength of the models applied to this project are that they can be used to assess the merits of the proposed pest control management programme in terms of the effectiveness of the area proposed under management, the timescale, and intensiveness of the pest control proposed. The results of the modelling show the benefits of the programme to native frogs will greatly outweigh the low risk of impacts, such that a net-gain outcome is likely and will be great.

9. In his evidence, Mr Kendal raises or infers apparent issues with how net-gain is communicated or calculated (see paragraphs 17 and 31), and whether parts of the pest management programme are additional or not. I have been unable to follow exactly what is meant by these statements, and so cannot provide a clear response. However, I emphasise that the analysis in the frog effects assessment report that I authored, and the summary statements regarding net-gain and positive effects summarised in the overall summary report of ecology matters that I authored were comprehensively assessed, are based on extensive technical work by other experts, and are robust with regard to the finding over a hugely beneficial programme of ecology works that will achieve a clear net-gain that

substantially exceed the value and extent of areas modified or removed by the project.

Hauraki District Council

10. I have read the review report prepared by Alliance Ecology Ltd and note its agreement with the fundamental elements of the body of ecology work provided by OceanaGold, including the underlying site investigations, effects assessment, effects management programme, and overall conclusion of a net positive outcome for indigenous terrestrial biodiversity.

11. The Alliance Ecology review notes inconsistencies between technical reporting and notes areas of disagreement with OceanaGold (pages 7 – 8), although concludes that these areas of disagreement are minor in the context of expected positive outcomes (page 2, para 1). The review concludes that revision to the draft management plans and revision of the draft conditions can provide assurance of the management of potential adverse effects on ecology values.

12. Alliance Ecology provides a list of recommended changes to the conditions (page 3-4 of the review report) and to the management plans (pages 5-6). I agree with the suggested changes made in the review report to Hauraki District Council conditions 1, 111, 112, 171B, 175, 176, 185, 195, 200, and 205, and to the Waikato Regional Council/ Hauraki District Council common conditions C47A, C47B, C49, and C52.

13. I do not agree with the changes suggested by Alliance Ecology to condition 171C, new condition (k) and (l), which seek to set targets of increase of Archey's frog population abundance at 2.3 times the current population and for Hochstetter's frog 4 times the current population within 5 years of implementation of the animal, pest control programme. The numbers cited by Alliance Ecology are from the Boffa Miskell effects assessment report; however, those numbers are not used as the basis for ecological offset

modelling. The ecological offset report[4] provides the basis on which targets for frog population improvements should be assessed.

14. Those targets have been conservatively (precautionarily) set at achieving 3 times the current population level for Archey's and Hochstetter's frogs after 15 years of animal pest control. I support the addition of new Condition 171C (k) and (l) if the level of population increase of each frog species is set at 3 times the current population abundance after 15 years of animal pest control. Doing so would align the anticipated benefits from the pest animal control programme for native frogs with the anticipated benefits calculated in the biodiversity offset modelling, which is the basis for the overall net-gain conclusion for native frog for this project.

Thames-Coromandel District Council

15. I have read the submission provided by the Thames-Coromandel District Council. There are no matters that address the effects assessment on native frogs or the overall ecology summary reports that I have prepared for OceanaGold. Therefore, I have no comments on the submission by Thames-Coromandel District Council.

Waikato Regional Council

16. I have read the submission provided by the Waikato Regional Council. There are no matters that address the effects assessment on native frogs or the overall ecology summary reports that I have prepared for OceanaGold. Therefore, I have no comments on the submission by the Waikato Regional Council.

Forest and Bird Protection Society

17. I have read the submission provided by the Forest & Bird.

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4 B.38. *Wharekirauponga mine: Assessment of effects on native frogs*.

18. At paragraph 95 of the submission, Forest & Bird discusses their concern that there are no stated implications if monitoring shows an effect of surface vibrations or dewatering on native frogs, including requirements in the conditions to take action to reduce effects. I note that conditions recommended by Hauraki District Council (new conditions 171C (h), (i) and (l)) provide assurance that monitoring of pest control programmes and frog populations will be assessed against thresholds and triggers for undertaking actions to increase management areas and/or actions to benefit frogs, and to trigger mitigation actions (in the case of evidence of dewatering[5]). I also note that the pest control programme proposed by the Applicant[6] is anticipated to provide a net-benefit outcome for frog populations even if all frogs within the >2 mm / sec vibration footprint die in some modelled scenarios[7].

19. Death of 75% of native frogs within the vibration footprint still results in a substantial net-gain for frogs under all modelled scenarios[8], mainly because the substantial anticipated benefits of pest control in adjoining areas outside of the vibration footprint. Although I have modelled frog losses up to 100% within the vibration footprint, I reiterate the point made in my technical report that I do not regard it as likely that any frog deaths will result from vibration, and certainly not the high levels that I used in the precautionary offset modelling that I have undertaken.

20. At paragraphs 205 - 207, Forest & Bird refers to the principles of offsetting in the National Policy Statement for Indigenous Biodiversity (**NPSIB**) and states that:

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5 H.07; Section 7 of the Wharekirauponga Underground Mine water management plan prepared by OGNZL dated March 2025

6 B.40. *Pest Animal Management Plan*.

7 B.38. *Wharekirauponga mine: Assessment of effects on native frogs*.

8 B.38 *Wharekirauponga mine: Assessment of effects on native frogs,* Tables 6-8.

> Given that the effects on frogs are so uncertain an offsetting and compensation approach does not meet the requirements of the NPS IB. As such, the proposal is contrary to Clause 3.11 of the NPSIB.

21. While I acknowledge uncertainty in relation to potential effects on native frogs, I reiterate my opinion that the level of uncertainty is low and that even if adverse effects were to occur across the vibration footprint of the underground mine, and on the majority of the native frog population at the site, the proposed pest control programme would still result in a considerable net-gain outcome for frogs.

22. The biodiversity offset models used to evaluate potential outcomes (the Biodiversity Offset Accounting Model (**BOAM**) and Biodiversity Compensation Model (**BCM**)) require that the level of uncertainty of effects or outcomes is not great, as offsetting should not be undertaken where uncertainty is high (for example, the BCM model does not work where uncertainty is high).

23. Uncertainty is a feature of all forecast events that are subject to environmental variation, especially so in ecology where multiple variables may dictate variation from expected outcomes (in a positive or negative way). In the case of this project, and where there is the potential for mining effects on native frogs, I do not consider that the level of uncertainty around effects or pest management outcomes to be so sufficiently great so as to violate the uncertainty principle of the NPS-IB or similar principles of accepted offsetting practice.

Iwi

24. I understand that iwi consulted by OceanaGold have expressed in their comments significant concerns regarding frogs, including the effects of dewatering, vibration, and the proposed salvage translocation approach. They note that protocols for translocation have not been adequately informed by tikanga and Mātauranga Māori. Ngāti Pū, in particular, are

concerned that the proposed translocation site is of lower ecological quality than the existing habitat.

25. I leave comment on translocation protocols and quality of the proposed release site to other experts.

26. I note that the topic of frogs has been considered in significant detail, with a comprehensive suite of assessments on potential effects and proposed management measures. I elaborate on this throughout this evidence and within the specific expert reports that RMA Ecology has produced on this matter, being those reports within Appendices B.35 and B.38 of the substantive application materials.

Department of Conservation

27. At paragraphs 64 – 66, the Department of Conservation (**DOC**) states that a 3-fold increase in the numbers of Archey's frog as assumed in the offset modelling by OceanaGold is unrealistic and not ecological feasible over the timeframe considered, and that the overall outcome from actions to avoid, remedy, mitigate, offset and compensate will likely not result in a net-gain for native frogs. DOC's position is further elaborated on in paragraphs 69 – 70 and 74-79.

28. I reconfirm the opinion in my report regarding modelling and frog enhancement that a 3-fold increase is feasible, and that a net-gain outcome is likely over a period of 15 years, for the following reasons:

    a. The area over which pest management and frog recovery is proposed to be undertaken is 632 ha, not the 318 ha referred to in DOC's paragraph 69.

    b. DOC assumes that all frogs will die within the 314 ha >2 mm sec vibration footprint, which the ecologists advising OceanaGold regard as unrealistic and excessively cautious. This is especially so given the evidence in the frog effects assessment report[9] that Archey's frogs tolerated vibration at the Golden Cross mine, currently live within vibration areas adjoining roads in the Coromandel, and tolerate disturbance in captive rearing situations (including brooding males staying put on eggs despite regular checks by Auckland Zoo staff).

c. DOC's published works from the Archey's frog site at Whareorino showed increases of frog numbers of 2.9 times over 10 years, 3 times over 9 years, and over 3 times increase over 1 year from different studies, despite rodent densities reaching periodic high levels (i.e. less intensive and less effective pest control than is proposed for the OceanaGold pest control programme).

d. The 10 % annual population increases cited by DOC in its paragraph 79 were based solely on outcomes of rat control. The Pest Animal Management Plan proposed by OceanaGold[10] includes control of mice, rats, possums, mustelids, cats and pigs – hence the confidence in a substantially higher gain in frog numbers.

29. In addition, since the matter of sensitivity testing for the offset models was raised through earlier consultation with DOC (see paragraphs 74-76 of DOC's evidence), I have run a bootstrapping statistical analysis (**Appendix A**) using 20,000 model runs across a range of possible inputs and outcomes for model variables (instead of the limited scenarios of single variables presented in the frog ecology effects report by RMA Ecology). The bootstrapping exercise used a range of frog outcomes from 1.5 times to 4.5 times increases in number (that is, considerably less than the 3 times benefit that I regard as reasonable). Other variables that were entered as non-fixed parameters were proportion of frog population impacted, impact risk (ecological), impact risk (uncertainty), and offset effect confidence with input

9 B.39. *Wharekiropunga underground mine Bioresearches native frog assessment*.
10 B.40. *Boffa Miskell Pest Animal Management Plan.*

values ranging from (in my opinion) very low values (unlikely to be represented in reality; pessimistic) through to higher values (optimistic outcomes).

30. The results of the bootstrap modelling are that:

a. For the BOAM offset model, the pessimistic approach resulted in net-gain outcomes 84 % of the time (i.e. 16.4 % were loss outcomes), and for the optimistic model 99.6 % were net-gain outcomes (i.e. 0.4 % were loss outcomes)

b. For the BMC model, the outcomes were similar with the pessimistic approach resulting in net-gain outcomes 75.3 % of the time, and the optimistic approach resulting in net-gain outcomes 98.3 % of the time.

c. The threshold for the level of impact on Archey's frogs when the amount of impact pushed the model into net-loss was (for the BOAM model) 98 % for the pessimistic approach and 99 % for the optimistic approach, meaning that at least 98 % of frogs would have to perish within the surface vibration footprint to result in a net-loss offset outcome with pest control across the 632 ha of managed area. I regard the likelihood of the loss of at least 98 % of native frogs from vibration footprint to vibration effects to be an unreasonably precautionary assumption.

31. The conclusions from the bootstrapping work were that the offset model analyses indicate that although the chances are not zero, there is a very low chance that there will be a net loss outcome for Archey's frogs that results from the proposed mine programme, and from the proposed frog population enhancement pest animal control programme.

32. Consequently, I have a very high level of confidence in the outcomes of the models. The sensitivity analyses demonstrate that to produce net loss outcomes requires that implausible assumptions about both impacts on

frogs from mine development and failure of predator control to increase frog numbers need to be made.

33. Coupled with the assurance provided in the Pest Management Plan that pest control will be undertaken to a more comprehensive and robust design than has been undertaken by DOC on its Archey's frog sites to date, I disagree with the statements made in paragraphs 64-79 of DOC's comment.

34. Overall, I stand by the statements made in the reports authored by RMA Ecology that the results of the mine development will be minor (if any) on native frogs, that the benefits will be significant, and that the overall result will be a clear net-benefit outcome for native frogs.

Dated: 1 September 2025

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Graham Thomas Ussher

Appendix A – simulation analysis of Archey's frog value outcomes from pest control at Wharekirauponga underground mine site.

Memo

To:	Cassie McArthur, Oceana Gold	Job No:	2034
From:	Graham Ussher, RMA Ecology Ltd	Date:	21 July 2025
cc:	Kerry Watson, Oceana Gold		
Subject:	OGNZL Wharekirauponga mine: simulation analysis of Archey's frog value outcomes: cover letter		

Dear Cassie,

As part of the consultation being undertaken by OceanaGold (NZ) Ltd (OGNZL) with the Department of Conservation (DOC) for the Wharekirauponga underground mine in the southern Coromandel, we have prepared a report that assesses the potential risk of the mine on native frogs. Included in that report is a summary of the biodiversity offset modelling approach used to assess the potential state of frog populations should the mine proceed, and with the extensive planned pest control programme in place.

The results of that analysis indicated that, across three different offset models applied, and under scenarios that are regarded by frog experts for OGNZL to be reasonable, the probable outcome will be a large net-gain to frog populations.

DOC has requested additional information regarding the biodiversity offset modelling, in particular that the modelling explore a greater range of potential input values into the models used, including a broader range of values for potential uplift and certainty linked to outcomes, and how these are reflected in the model outputs in terms of loss, no-net-loss and net-gain. In effect, DOC's request is for a sensitivity analysis of the models, including where inputs may have a combined effects that leads to a less beneficial outcome.

Attachment A to this letter provides the sensitivity analysis.

The result of this sensitivity analysis is that the offset models indicate that although the chances are not zero, there is a very low chance that there will be a net loss outcome that results from the proposed mine programme, and from the proposed frog population enhancement pest animal control programme.

In fact, the sensitivity analysis undertaken allows us to reiterate statements that we made in our original report that plausible scenarios of adverse effect on frogs, combined with probable benefits from the extensive pest control programme, will lead to overwhelming benefits for the local frog populations.

In addition, the sensitivity analysis reinforces the robustness of the offset calculations presented in the original report by RMA Ecology, and shows that the conclusions from that work are robust.

Graham Ussher

Principal Ecologist

21-Jul-25

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Attachment A

RMA Ecology Ltd. 2025. OGNZL Wharekirauponga mine: simulation analysis of Archey's frog value outcomes. Report prepared by RMA Ecology Ltd dated 9 July 2025. 20 pp.

To:	Cassie McArthur, Oceana Gold	Job No:	2034
From:	Duncan Nicol, RMA Ecology Ltd Graham Ussher, RMA Ecology Ltd	Date:	21 July 2025
cc:	Kerry Watson, Oceana Gold		
Subject:	OGNZL Wharekirauponga mine: simulation analysis of Archey's frog value outcomes		

Memo

Dear Cassie,

As part of the consultation being undertaken by OceanaGold (NZ) Ltd (OGNZL) with the Department of Conservation (DOC) for the Wharekirauponga underground mine in the southern Coromandel, DOC has requested additional information regarding the modelling of biodiversity losses and gains for Archey's frogs.

The information that we have prepared to date[1] for OGNZL in this regard has included an effects assessment of the type, likelihood and scale of potential adverse effects on Archey's frogs form surface vibrations, and an analysis of the potential benefits to frog populations of a proposed wide-scale predator control programme within and surrounding the mine site.

DOC has requested that our offset modelling explore a greater range of potential input values into the models used, including a broader range of values for potential uplift and certainty linked to outcomes, and how these are reflected in the model outputs in terms of net-loss, no-let loss and net-gain.

This memorandum provides the results of an examination of the models and presents the outputs from using a broader range of inputs than assumed by us in our original modelling. This examination is essentially a sensitivity test of the offset models, and the results confirm the ability of the proposed pest control programme at the site to provide net benefits that exceed potential impacts on Archey's frogs.

We have not modelled the potential impacts or benefits on Hochstetter's frogs in a similar manner; however, given that there are a greater number of studies elsewhere that show benefits for Hochstetter's frogs from pest control, and because Hochstetter frog habitat is present in only a small part of the site, it is likely that a positive result obtained for Archey's frogs will also infer a positive result for Hochstetter's frog.

1 Overview

A more detailed analysis was requested by DOC regarding the net value outcomes as a result of potential vibrational impacts on Archey's frog population. This study provides additional statistical rigour to the use of the Biodiversity Compensation Model (BCM) and Biodiversity Offset Accounting Model (BOAM) models, and it is a continuation of the previous report prepared by RMA Ecology (2025).

A simulation-based approach of the BCM and BOAM models was used to investigate the varying effects of non-fixed parameters on the net value outcome. Iterative sampling was used to provide the full range of possible scenarios. Several steps were taken in the sensitivity analysis to understand the impact of the non-fixed parameters from

[1] RMA Ecology Ltd. January 2025. OGNLZ Wharekirauponga mine: potential adverse effects on native frogs. Report prepared for OceanaGold (NZ) Ltd. 30 pages plus Appendices.

different perspectives. The general plan statistically assessed the outcomes of the BCM and BOAM output given two sampling methods based on informed or uninformed prior knowledge, giving four output scenarios: BCM with and without prior knowledge and BOAM with and without prior knowledge.

2 Methods

2.1 Input Parameters

Both the BCM and BOAM models have fixed and non-fixed parameters. The RMA Ecology 2025 report provides detail for all parameter decisions which are summarised in this report. The fixed parameters were based on prior research informing the model development, or they were site-specific and required values from field surveys or site studies, or they were established by expert recommendation; these fixed parameters were held constant across the modelling scenarios (Tables 1, 3).

The non-fixed parameter ranges were obtained from the model formulas or from the details within the previous report (Maseyk et al. 2015; RMA Ecology 2025; Table 2). The non-fixed parameters have a range of values and were randomly sampled from parametric distributions. However, two approaches ('Approach one' and 'Approach two') of model variability were developed alongside the two BCM and BOAM models (Tables 2, 4).

The first approach was chosen to represent sampling without prior knowledge using uniform distributions across the parameter ranges. The second approach was chosen to represent sampling with prior expert judgement and knowledge using truncated normal distributions set around likely values.

The ecological value impact (i.e. percentage of the frog population that is assumed to die) proportion range was based on a potential minimum 10 % loss to maximum 100 % loss. A 10 % loss was chosen as a nominal level of very low loss; obviously choosing 0 % loss would make the analysis unwarranted, as the project would deliver only benefits with no associated potential loses to analyse. Approach one sampled from a uniform distribution between these values, whereas Approach two set the mean of the truncated normal distribution at 25 % based on the estimate from the OGNZL expert advisory group who stated "Given that Archey's frog seems able to survive and persist in 2 mm /sec vibration environments, it is unlikely that all or most frogs will die when exposed to marginally greater vibrations" (RMA Ecology 2025).

The offset effect (pest control benefit) confidence (BOAM) and the compensation effect confidence (BCM) are key uncertainties in both models, and a confidence rate below 50 % invalidates the models. Three levels of confidence are available: moderate (50 %–70 %), high (75 %–90 %), and very high (> 90 %). Approach one sampled from a uniform distribution between 50 %–99 %, whereas Approach two set the mean of the truncated normal distribution at 75 % based on an appropriate level of confidence recommended by the OGNZL advisory group as 'moderate' or 'low' (RMA Ecology 2025).

The offset benefit multiplier which estimates the potential benefits of the animal pest control programme in terms of increasing the abundance of native frogs had a value range of 1.5 to 4.5. Approach one sampled from a uniform distribution between these values, whereas Approach two set the mean of the truncated normal distribution at 3 based on the expert estimate from the OGNZL advisory group and informed by several studies which produced estimated multiplied benefits between 2.3 and 4 (RMA Ecology 2025).

The BCM model has two impact contingency parameters which increase the impact value based on a certain percentage to account for the ecological risk and the uncertainty risk[2]. The ecological risk contingency parameter increases the impact value based on the discrete range: negligible value (+0 %), moderate value (+5 %), high value (+10 %), and very high value (+20 %). The uncertainty risk parameter increases the impact value based on the discrete range: low uncertainty (+5 %), moderate uncertainty (+10 %), high uncertainty (+20 %).

For the contingency parameters, Approach one sampled from both uniformly, whereas Approach two set the mean of the truncated normal distribution at high levels for ecological risk (+10 %) to recognise the threat status of Archey's frogs and the high-value forest ecosystem at site, and Approach two also set the mean at high levels for uncertainty risk (+20 %) given the lack of information surrounding vibrational impacts on herpetofauna.

[2] These are two of several parameters that a user of the model chooses as part of 'programming' the model. Tables 1 and 2 list all of the parameters, and show which ones were varied as part of this sensitivity analysis, and why.

Table 1. Fixed parameters, their values, and their summarised justification in the BOAM model. Further details are provided in the OGNZL Assessment of effects on native frogs (RMA Ecology 2025).

Fixed parameters	Value	Justification
Impact discount rate	0	Impacts are assumed to occur immediately.
Offset discount rate	0.03	As recommended in the BOAM user manual (Maseyk et al. 2015) and in the offset study by Gibbons et al. (2015).
Areas	314, 318	Vibration footprint is 314 ha, and the offset area is 318 ha.
Times	0, 15	Impacts are assumed to occur immediately, and the pest control programme will be undertaken for a minimum of 14.5 – 15 years.
Benchmark value	900	Chosen as a reasonable expectation for a long-term benchmark, and informed by density estimates from the study by Lloyd.
Estimated value	286	Calculated by dividing a mid-range population estimate by the study area, and informed by the study by Lloyd.

Table 2. Non-fixed parameters and their values in the two approaches for the BOAM model. Further details are provided in the text and also in the OGNZL Assessment of effects on native frogs (RMA Ecology 2025).

Non-fixed parameter	Minimum value	Maximum value	Approach one	Approach two
Ecological value impact proportion	0.1	1	Uniform	Normal: mean = 0.25, sd = 0.25
Offset effect confidence	0.5	0.99	Uniform	Normal: mean = 0.75, sd = 0.1
Offset benefit multiplier	1.5	4.5	Uniform	Normal: mean = 3, sd = 0.35

Table 3. Fixed parameters and their values in the BCM model. Further details are provided in the OGNZL Assessment of effects on native frogs (RMA Ecology 2025).

Fixed parameters	Value	Justification
Discount rate	0.03	As recommended in the BCM user guide (Baber et al. 2021).
Benchmark value	5	The benchmark is always 5 (Baber et al. 2021).
Estimated value	1.5	Based on the current degraded site baseline relative to a population after long-term intensive pest control programme.
Net gain target	0.1	As recommended in the BCM user guide (Baber et al. 2021).
Areas	314, 318	Vibration footprint is 314 ha, and the offset area is 318 ha.
Times	15	The pest control programme will be undertaken for a minimum of 14.5 – 15 years.

Table 4. Properties for the non-fixed parameters in the two approaches for the BCM model. Further details are provided in the text and also in the OGNZL Assessment of effects on native frogs (RMA Ecology 2025).

Non-fixed parameter	Minimum value	Maximum value	Approach one	Approach two
Ecological value impact proportion	0.1	1	Uniform	Normal: mean = 0.25, sd = 0.25
Impact risk (ecological)	1	1.2	Uniform	Normal: mean = 1.1, sd = 0.025
Impact risk (uncertainty)	1.05	1.2	Uniform	Normal: mean = 1.2, sd = 0.05
Compensation effect confidence	0.5	0.99	Uniform	Normal: mean = 0.75, sd = 0.1
Compensation benefit multiplier	1.5	4.5	Uniform	Normal: mean = 3, sd = 0.35

2.2 Net Value Outcome

A histogram of the net value outcomes distribution across all simulations was produced, and 99 % confidence intervals were calculated for the mean of all values, for the mean of values below the mean (pessimistic scenario), and a mean for the values above the mean (optimistic scenario). Additionally, the proportion of negative cases out of all simulated cases was calculated, along with a binomial proportion 99 % confidence interval, using a one-sample proportion test. This test determines whether the proportion of negative outcomes was different than chance (50 %). The test of proportions was run using the *prop.test* function from the *stats* package in R.

2.3 Logistic Regression

A logistic regression model (with the logit link function) was fitted to the simulated data to assess the relationship between the non-fixed parameters and the binary outcome of positive net value outcome. This model fits parameters and identifies their positive or negative association with the net value outcome. The regression model was fitted using the *glm* function from the *stats* package in R.

2.4 Threshold Analyses

Target non-fixed parameters were individually isolated from the others. All non-target non-fixed parameters were held constant at their mean value. Each model was run across one thousand even increments of the full range of the target parameter. The purpose was to identify the individual association of each target parameter with the net value outcome. By holding all other variables constant, it was possible to analyse the effect each target parameter had by itself. In particular, a 50 % threshold value was calculated which identifies the point along the range at which the parameter is associated with a switch from a positive to negative outcome or *vice versa*. For the non-fixed parameters, a set of one-variable-at-a-time sensitivity analyses was performed:

1. For each parameter, a sequence of 1,000 values was generated across its range.
2. The remaining variables were held constant at their mean values.
3. Predictions were generated using the previously fit logistic regression model (from Section 2.3.1).
4. The point at which the predicted probability of a positive net value outcome equalled 0.5 was identified as the threshold (inflection point).

Non-fixed parameters whose 50 % thresholds fell within its available range were considered influential. These represent thresholds at which the model outcome flips from negative to positive or *vice versa*. Non-fixed parameters whose 50 % threshold points lay beyond their available range (either above or below the limits) were interpreted as having little to no individual effect on the outcome. Instead, their role may be more conditional on particular values of other non-fixed parameters.

3 Results

3.1 Input Parameters

All non-fixed parameters for the BOAM (Appendix A) and BCM (Appendix B) models and the corresponding two approaches were sampled as intended.

3.2 Net Value Outcomes

3.2.1 *BOAM*

Both BOAM approaches had similar means. Approach one had a mean of 84.0 % net gain (99 % CI: 82.5, 85.6), and Approach two had a mean of 121.9 % net gain (99 % CI: 121.0, 122.8). The distribution of net value outcomes for Approach one was positively skewed and had a range from –81.6 % to 387.9 %. The distribution of Approach two was normally distributed around the mean and had a range from –57.8 to 305.1%.

The pessimistic scenario (taking the mean of values below the mean) for Approach one was 21.6 % net gain (99 % CI: 20.7, 22.6) and was lower than Approach two at 82.9 % net gain (99 % CI: 82.1, 83.6). The optimistic scenario for Approach one was 159.7 % net gain (99 % CI: 158.1, 161.3) and was lower than Approach two at 161.4% net gain (99 % CI: 160.6, 162.2).

Regarding simulations with negative outcomes, in Approach one, 16.4 % of simulations were net losses (99 % CI: 15.7, 17.1), whereas in Approach two, 0.4 % of simulations were net losses (99 % CI: 0.3, 0.5).

Although the non-fixed parameters had different associated trends with the net value outcome, the trends were consistent between Approach one and two (Appendix C). The proportional impact on ecological values was negatively associated with net value outcomes, whereas the compensation effect confidence and offset benefit multiplier were both positively associated with net value outcomes.

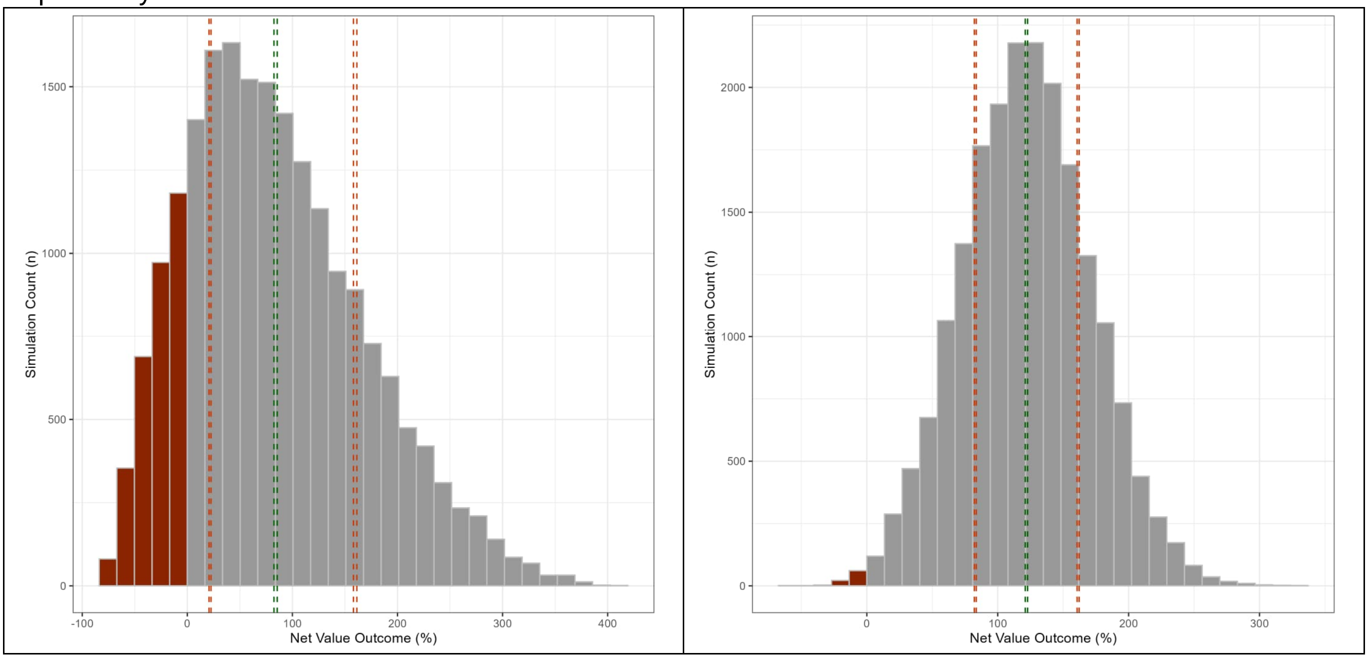

Figure 1. Distribution of net value outcomes for Approach one (left) and Approach two (right) of the BOAM model. Vertical lines delineate the 99 % confidence intervals for the mean (green), pessimistic (values below the mean), and optimistic (values above the mean). Net losses are highlighted as red bars.

3.2.2 *BCM*

Both BCM approaches had similar means. Approach one had a mean of 194.2 % net gain (99 % CI: 188.5, 200.0), and Approach two had a mean of 362.0 % net gain (99 % CI: 356.1, 367.8). The distributions of net value outcomes were also positively skewed for both approaches. Approach one had a range from –85.7 % to 3037.1 %, and Approach two had a range from –67.9 % to 2222.9 %.

The pessimistic scenario for Approach one was estimated at 35.5 % net gain (99 % CI: 34.0, 37.0) and was lower than Approach two at 167.16 % net gain (99 % CI: 164.9, 169.4). The optimistic scenario for Approach one was 543.5 % net gain (99 % CI: 531.8, 555.2) and was higher than Approach two at 691.7 % net gain (99 % CI: 682.9, 700.5).

In Approach one, 24.7 % of simulations were net losses (99 % CI: 23.9, 25.5), whereas in Approach two, 1.7 % of simulations were net losses (99 % CI: 1.5, 2.0).

Similar to the BOAM model, the non-fixed parameters in the BCM model had different associated trends with the net value outcome, but the trends were consistent between Approach one and two (Appendix D). The proportional impact on ecological values was strongly negatively associated with net value outcomes. The compensation confidence was weakly positive, and the two impact contingency risks, ecological and uncertainty, were weakly negative. The offset benefit multiplier was strongly positively associated with net value outcome.

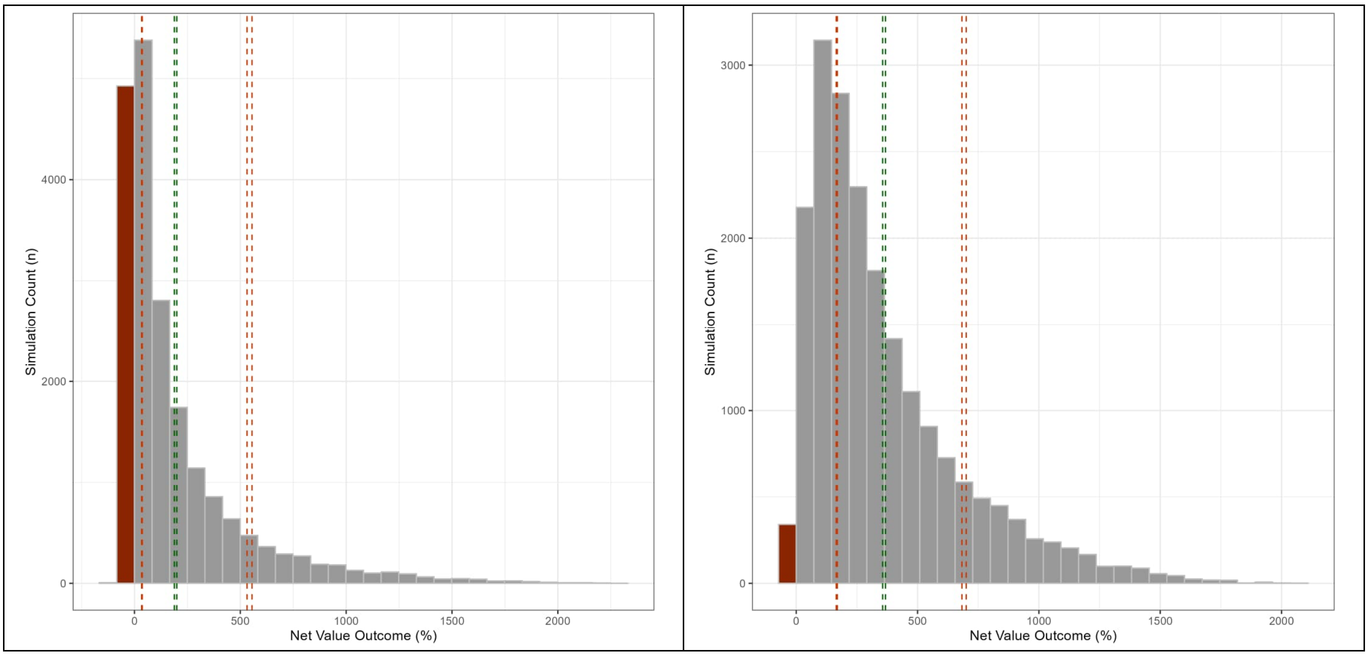

Figure 2. Distribution of net value outcomes for Approach one (left) and Approach two (right) of the BCM model. Vertical lines delineate the 99 % confidence intervals for the mean (green), pessimistic scenario (values below the mean), and optimistic scenario (values above the mean). Net losses are highlighted as red bars.

3.3 Logistic Regression

The coefficient estimates for the parameters in the logistic regression analyses were similar to the associated trends that the parameters had in relation to the net value outcomes. However, the logistic regression analyses evaluate the relationship between the non-fixed parameters and a net gain outcome or a net loss outcome instead of the net value.

3.3.1 *BOAM*

In the BOAM models (including Approaches one and two), the proportional ecological value impact had a strong negative coefficient, whereas both the offset effect confidence and the offset benefit multiplier had strong positive coefficients. All coefficient estimates were statistically significant.

3.3.2 *BCM*

In the BCM models (including Approaches one and two), the proportional ecological value impact had a strong negative coefficient estimate, and the offset benefit multiplier had a strong positive coefficient. The compensation benefit confidence was positive in both Approach one and two, but it was weaker in Approach one. The two impact contingency risks, ecological and uncertainty, were weakly negative in both Approaches. All coefficient estimates were statistically significant.

3.4 Threshold Identification

3.4.1 *BOAM*

The range for the proportional ecological value impact (loss of frogs) is 0.1 to 1. The threshold was 0.98 in Approach one and 0.99 in Approach two (Fig. 3). There were 1.65 % of simulation cases in Approach one and 0.02 % of cases in Approach two in which the impact value was above its threshold; 0.86 % of Approach one and 0.01 % of Approach two in which it was above and the outcome was a net loss; and 0.80 % of Approach one and 0.01 % of Approach two in which it was above and the outcome was a net gain.

The range for the offset benefit multiplier is 1.5 to 4.5. The threshold was 1.77 in Approach one and 1.5 in Approach two (Fig. 4). In Approach one, there were 9.20 % of simulation cases in which the offset benefit multiplier was below its threshold; 5.52 % of simulation cases in which it was below its threshold and the outcome was negative; and 0.80 % of simulation cases in which it was below its threshold and the outcome was positive. Because the threshold was identified at the lower limit in Approach two, there were no cases in which the offset benefit multiplier was below its threshold.

The threshold for the confidence in offset effect was on the edge of its range limits in both Approach one and two. There were no simulation cases in either approach in which the threshold was tipped.

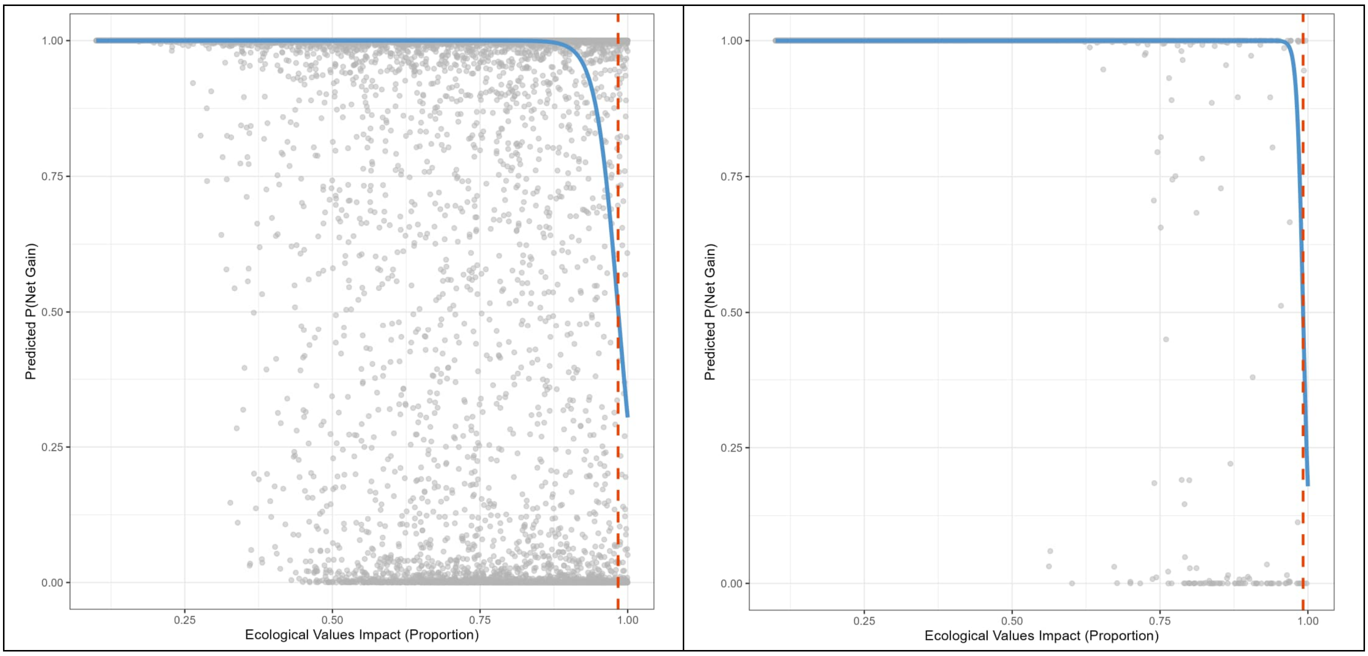

Figure 3. Threshold analyses for Approach one (left) and Approach two (right) for the BOAM model. Blue line indicates the relationship between the proportional impact on ecological values and the predicted probability of a net gain outcome. The red dashed line indicates the threshold point at which the parameter tips the probability from a net gain to a net loss and vice versa.

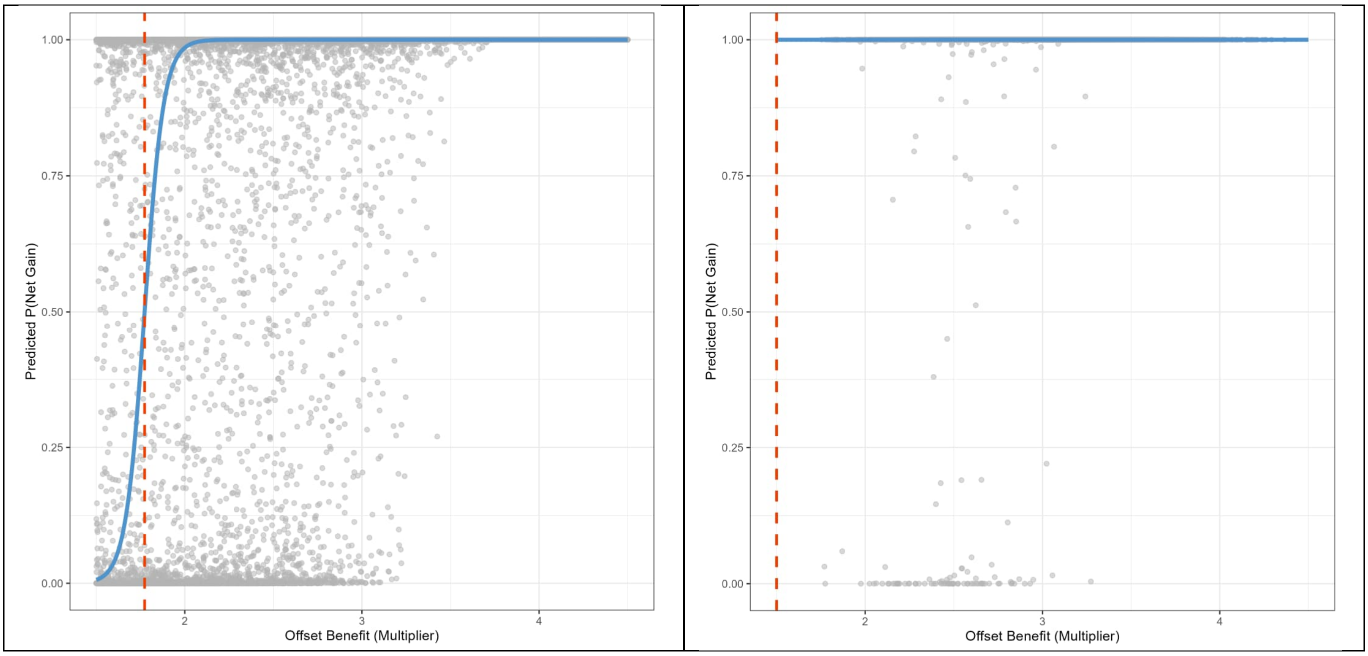

Figure 4. Threshold analyses for Approach one (left) and Approach two (right) for the BOAM model. Blue line indicates the relationship between the offset benefit multiplier and the predicted probability of a net gain outcome. The red dashed line indicates the threshold point at which the parameter tips the probability from a net gain to a net loss and vice versa.

3.4.2 *BCM*

The range for the proportional ecological value impact is 0.1 to 1. The threshold was 0.81 in Approach one and 0.86 in Approach two (Fig. 5). There were 21.16 % of simulation cases in Approach one and 0.58 % of simulation cases in Approach two in which the impact value was above its threshold; 13.61 % of Approach one and 0.58 % of Approach two in which it was above and the outcome was a net loss; and 7.54 % of Approach one and 0.21 % of Approach two in which it was above and the outcome was a net gain.

The range for the offset benefit multiplier is 1.5 to 4.5. The threshold was 1.91 in Approach one and 1.50 in Approach two (Fig. 6). In Approach one, there were 13.98 % of simulation cases in which the offset benefit multiplier was below its threshold; 8.89 % of simulation cases in which it was below its threshold and the outcome was negative; and 5.09 % of simulation cases in which it was below its threshold and the outcome was positive. Because the threshold was identified at the lower limit in Approach two, there were no cases in which the offset benefit multiplier was below its threshold.

The thresholds were all on the range limits for the impact contingency risks (ecological and uncertainty) and the compensation confidence. For these three non-fixed parameters, there were no simulation cases in either Approach in which the thresholds were tipped.

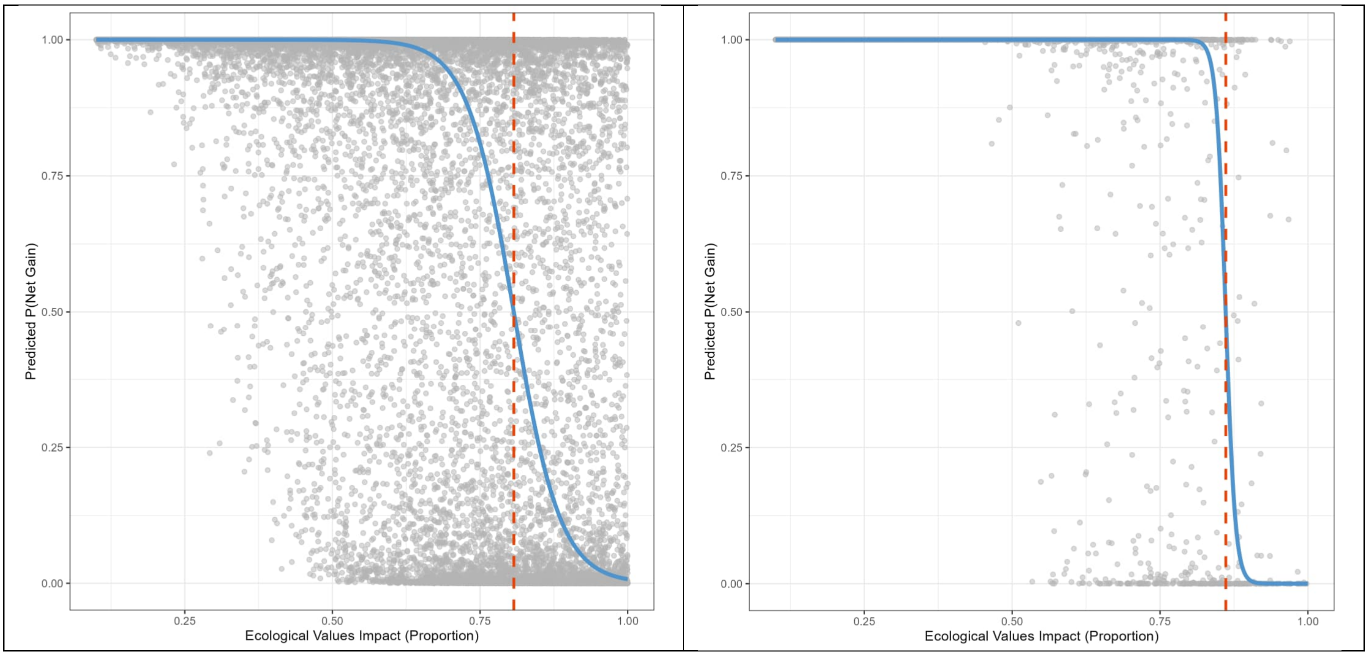

Figure 5. Threshold analyses for Approach one (left) and Approach two (right) for the BCM model. Blue line indicates the relationship between the proportional impact on ecological values and the predicted probability of a net gain outcome. The red dashed line indicates the threshold point at which the parameter tips the probability from a net gain to a net loss and vice versa.

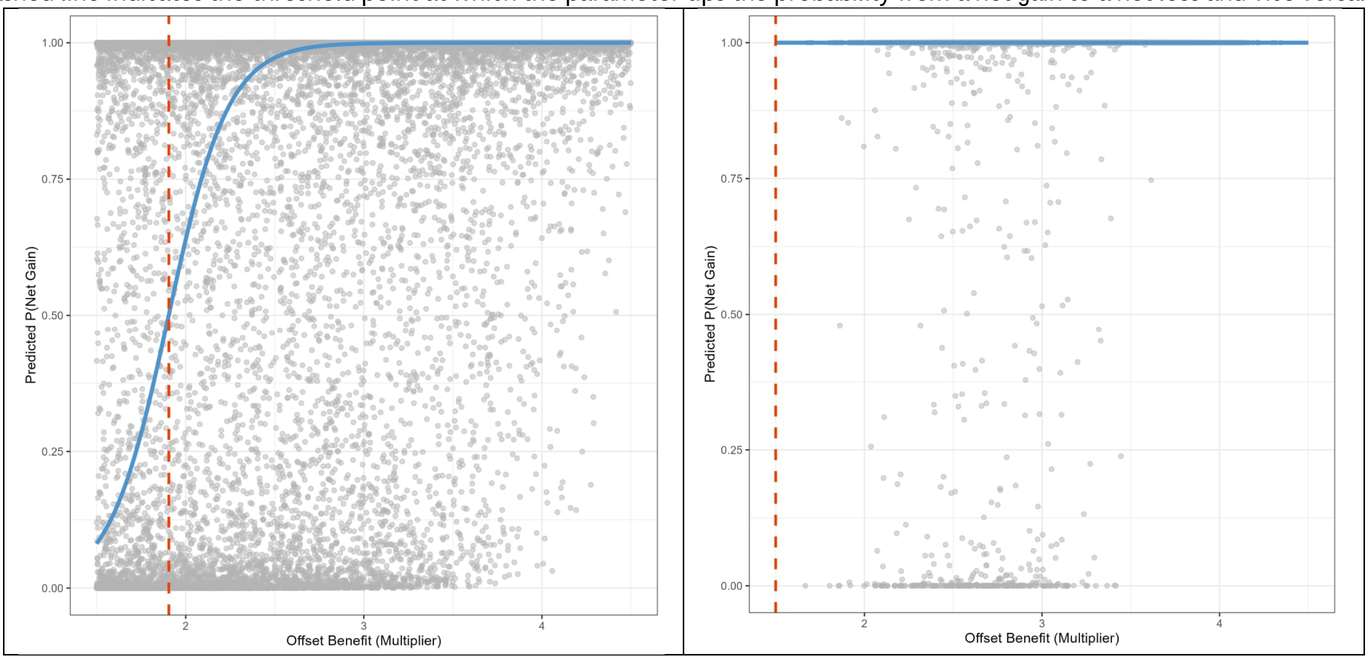

Figure 6. Threshold analyses for Approach one (left) and Approach two (right) for the BCM model. Blue line indicates the relationship between the offset benefit multiplier and the predicted probability of a net gain outcome. The red dashed line indicates the threshold point at which the parameter tips the probability from a net gain to a net loss and vice versa.

4 Conclusions

This study provides a comprehensive understanding of net value outcomes for vibration impacts on native frog populations. The study evaluated the BOAM and BCM behaviour using 20,000 randomised simulations. Moreover, two further approaches were incorporated within each model, in which the non-fixed parameters were sampled from both uninformed uniform distributions (Approach one) and informed truncated normal distributions (Approach two).

The distributions of net value outcomes were generally positive in all scenarios. Both BOAM and BCM models for both Approach one and two had positive net value outcomes even in the pessimistic scenarios (measuring the mean of all values below the mean). The lower percentage of simulated net losses for Approach two suggests that the negative outcomes in Approach one were overestimated because of unrealistic parameter setting (i.e. the scenarios modelled were not plausible in a real world setting).

The threshold analyses identified two non-fixed parameters as influential: the proportion of ecological impact (percentage of the frog population that may die due to vibration effects) and the offset benefit multiplier (the degree to which the frog population may increase with pest animal control). These factors are also shared between the BOAM and BCM models. In the BOAM model, the threshold for value impact was identified as 0.99, meaning that the probability switch from net gain to net loss occurs when more than 99 % of the frog population at the impact site are lost. The BCM estimated a lower threshold at 0.81 (Approach one) and 0.86 (Approach two), meaning the probability switch from net gain to net loss occurs when more than 81 % or 86 % of the frog population at the impact site are lost. However, the probability of these events is very low. In Approach one of the BCM model, for example, only 13.6 % of cases were both above the 81 % threshold and resulted in net losses.

For the offset benefit multiplier, Approach one of the BOAM model estimated that 5.52 % of cases were both below the offset benefit multiplier threshold and resulted in net losses; Approach two of the BOAM model estimated none. Similarly, the BCM Approach one estimated that 13.61 % of cases were both below the offset benefit multiplier threshold and resulted in net losses.

The compensation and offset model analyses here indicate that although the chances are not zero, there is a very low chance that there will be a net loss outcome that results from the proposed mine programme, and from the proposed frog population enhancement pest animal control programme.

The values indicated in the threshold analyses for parameters tipping the probability into net loss outcomes were always very different from the expectations provided by the OGNZL expert advisory group. The worst threshold impact proportion was 98 % for the BOAM model and 81 % for the BCM model. Both of these are far above the expectation from the advisory group which conservatively estimates 25 %, but they acknowledge this also may be overestimated.

Similarly, the worst case threshold for offset or compensation benefit require at least a 1.77 (BOAM Approach one) or a 1.91 (BCM Approach one) multiplier value at the minimum to reach a positive outcome. Yet prior research and expert judgement expect that the offset or compensation package will generate at least 3 times value for frog abundance under the proposed pest animal control programme, meaning that again, the chances of a net-loss outcome are very small, and that pest control programme favours by a large margin a net-benefit and net-gain outcomes for frogs at the site.

This sensitivity analysis reinforces the robustness of the BOAM and BCM calculations presented in RMA Ecology 2025.

There is very high confidence in the outcomes of the models, and the sensitivity analyses demonstrate that to produce net loss outcomes requires that implausible assumptions about both impacts on frogs from mine development and failure of predator control to increase frog numbers need to be made.

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Lloyd B 2023. Estimating the proportion of the Coromandel's Archey's frog population in the area affected by vibrations from the proposed Wharekirauponga Mine. Report prepared for OGNZL.

Maseyk F, Maron M, Seaton R & Dutson G 2015. A biodiversity offsets accounting model for New Zealand: User Manual. Report prepared for Department of Conservation, Hamilton, New Zealand.

RMA Ecology Ltd. 2025. OGNLZ Wharekirauponga mine: potential adverse effects on native frogs. Report prepared for OceanaGold (NZ) Ltd. 30 pages plus Appendices.

Appendix A: Input Parameter Histograms – BOAM

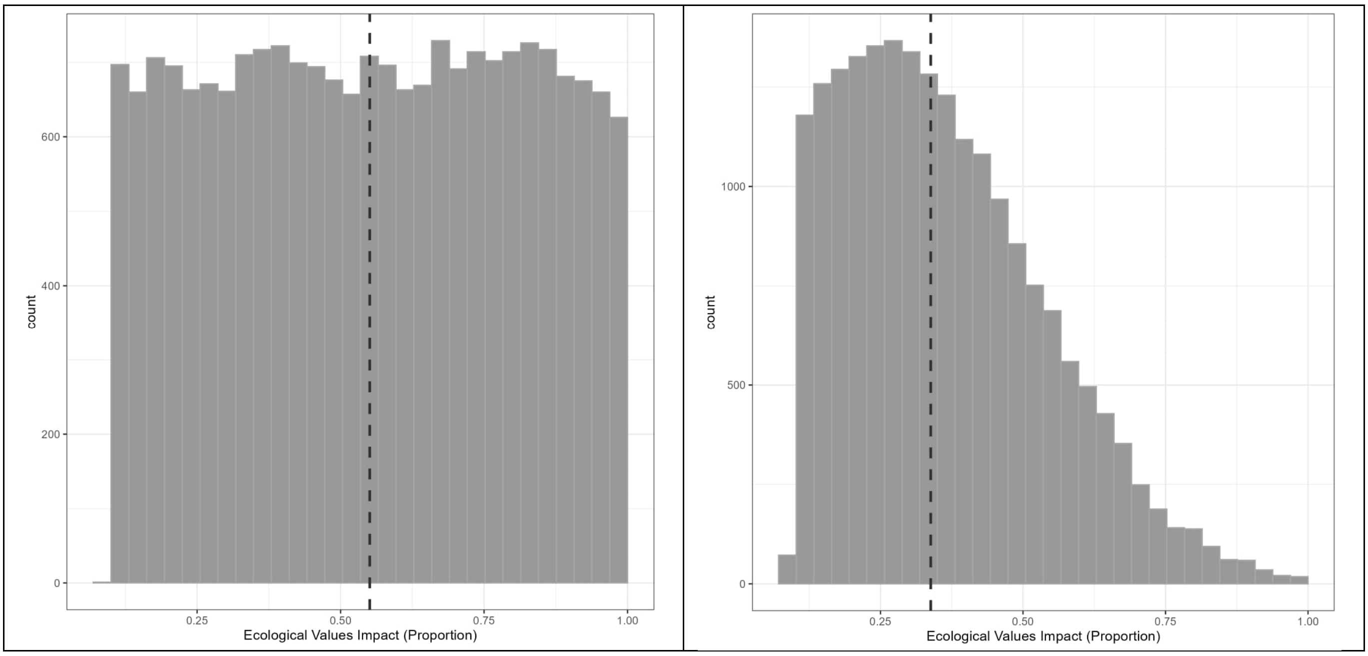

Figure A1. Distributions for the proportional impact for the BOAM model for Approach one (left) and Approach two (right). Simulation cases were sampled from a uniform distribution (left) or a manually set truncated normal distribution (right). Dashed vertical line indicates the median.

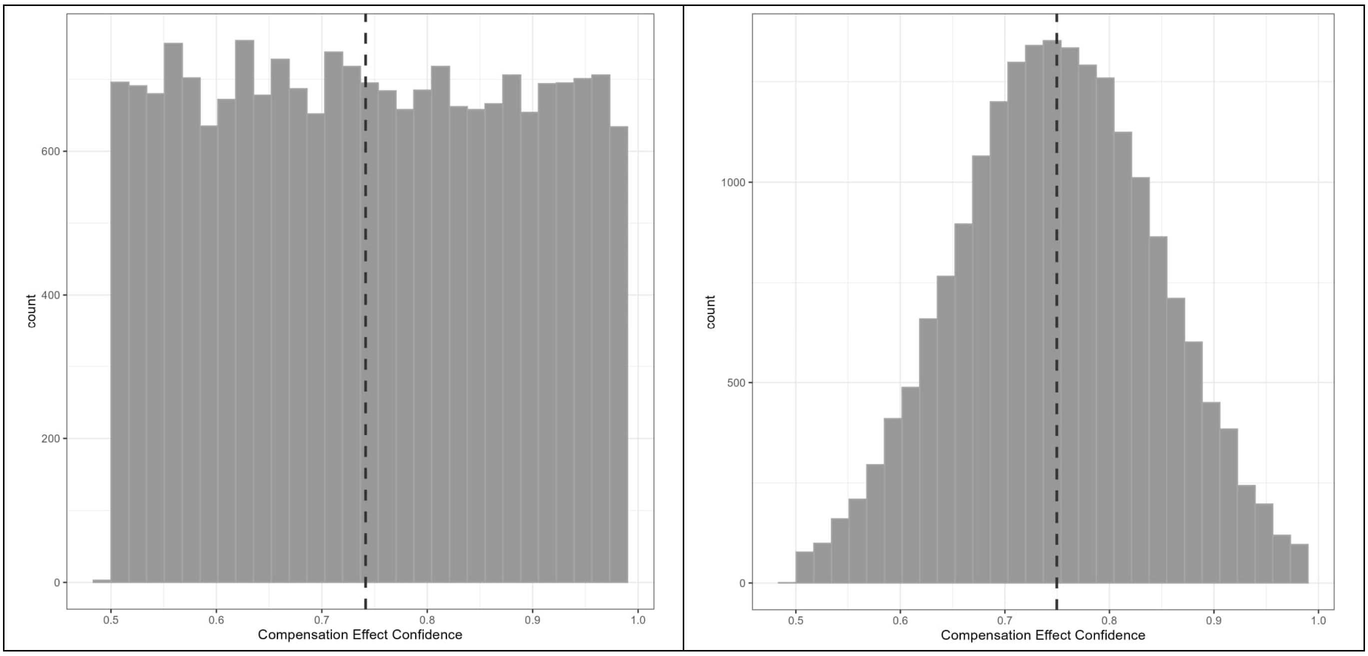

Figure A2. Distributions for the offset effect confidence for the BOAM model for Approach one (left) and Approach two (right). Simulation cases were sampled from a uniform distribution (left) or a manually set truncated normal distribution (right). Dashed vertical line indicates the median.

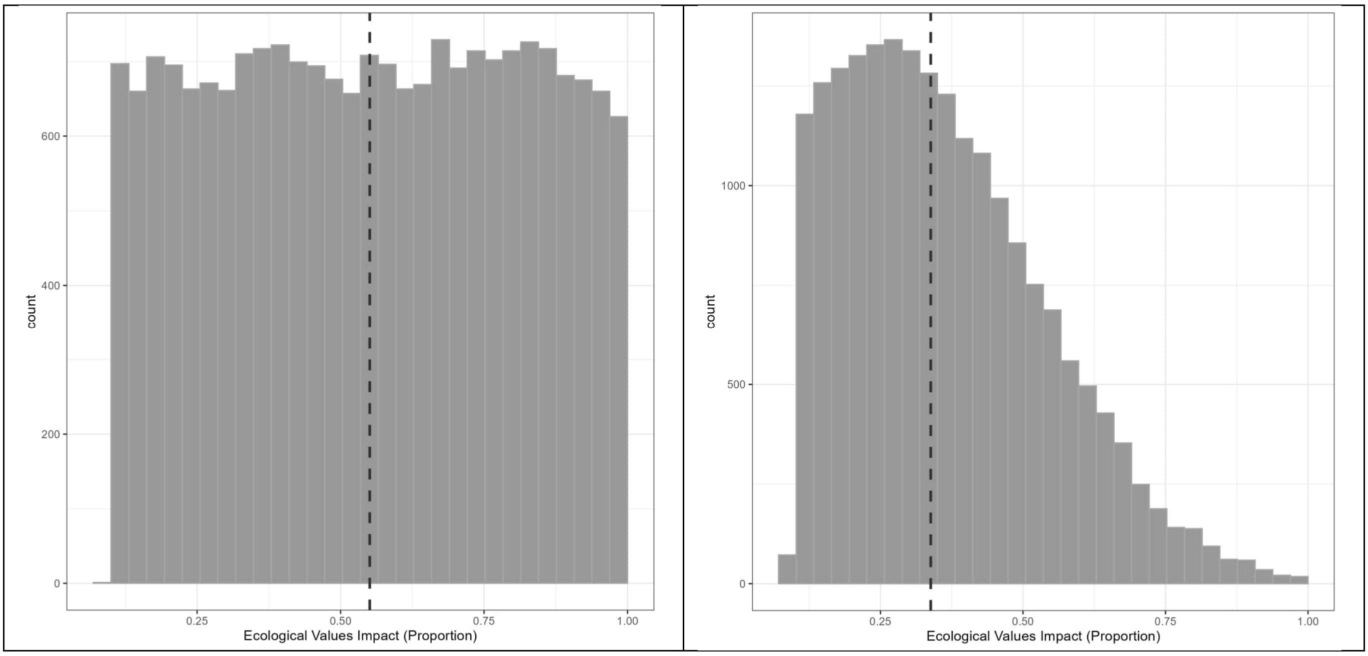

Figure A3. Distributions for the offset benefit multiplier for the BOAM model for Approach one (left) and Approach two (right). Simulation cases were sampled from a uniform distribution (left) or a manually set truncated normal distribution (right). Dashed vertical line indicates the median.

Appendix B: Input Parameter Histograms – BCM

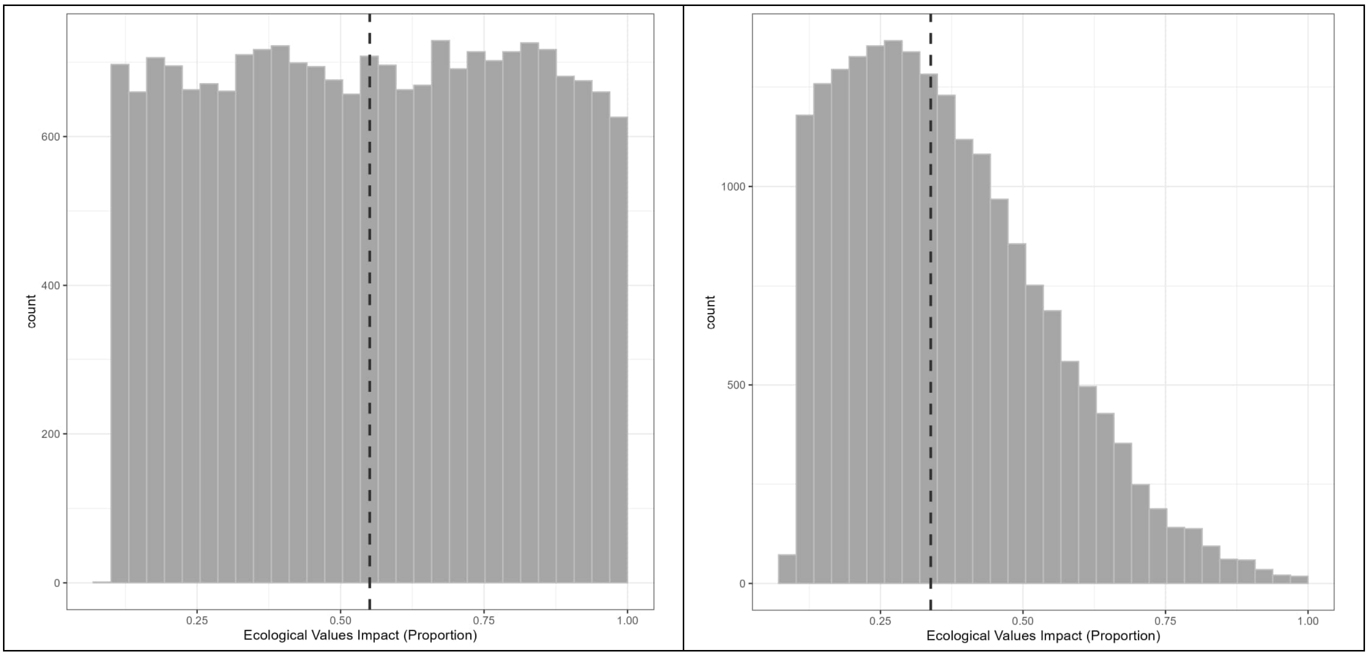

Figure B1. Distributions for the proportional impact for the BCM model for Approach one (left) and Approach two (right). Simulation cases were sampled from a uniform distribution (left) or a manually set truncated normal distribution (right). Dashed vertical line indicates the median.

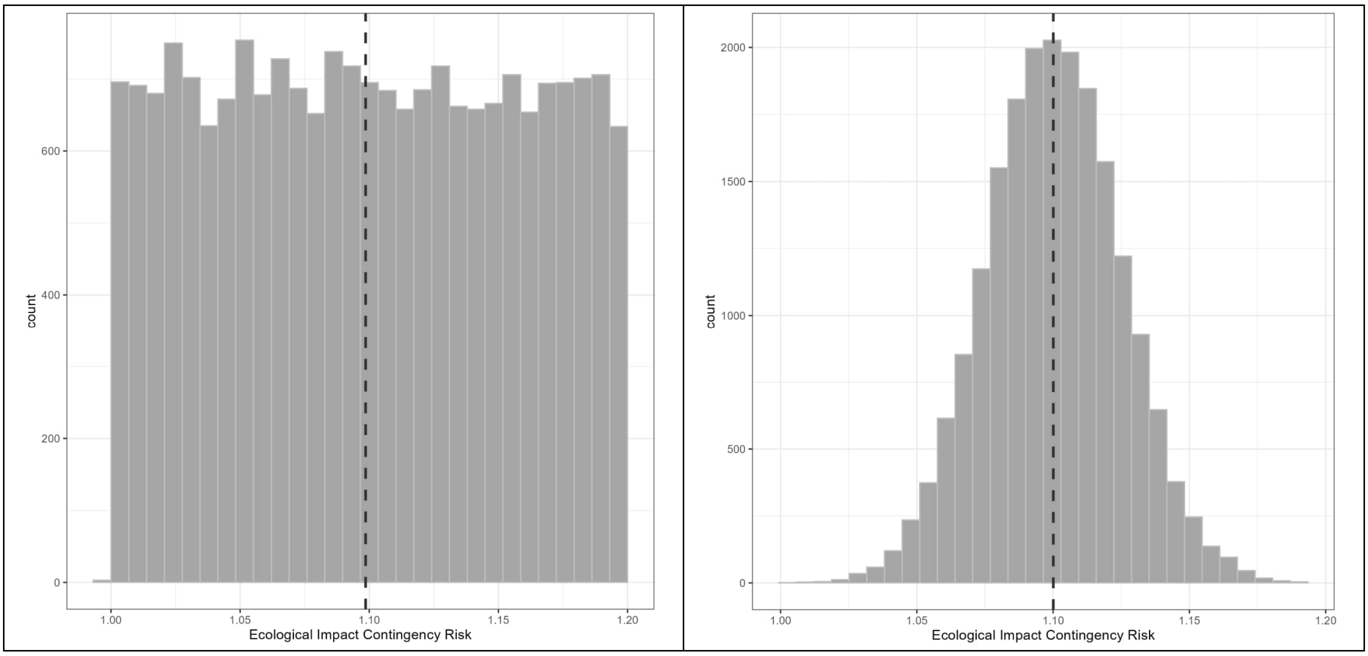

Figure B2. Distributions for the ecological impact contingency risk for the BCM model for Approach one (left) and Approach two (right). Simulation cases were sampled from a uniform distribution (left) or a manually set truncated normal distribution (right). Dashed vertical line indicates the median.

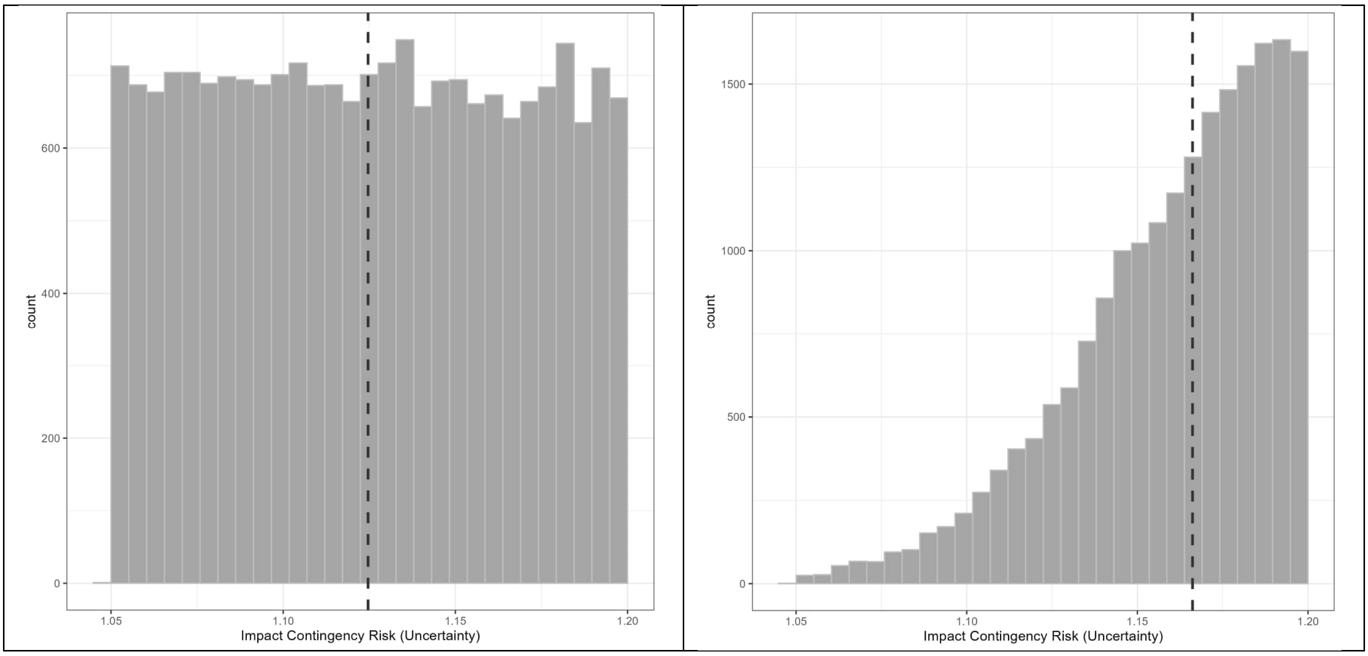

Figure B3. Distributions for the impact contingency uncertainty risk for the BCM model for Approach one (left) and Approach two (right). Simulation cases were sampled from a uniform distribution (left) or a manually set truncated normal distribution (right). Dashed vertical line indicates the median.

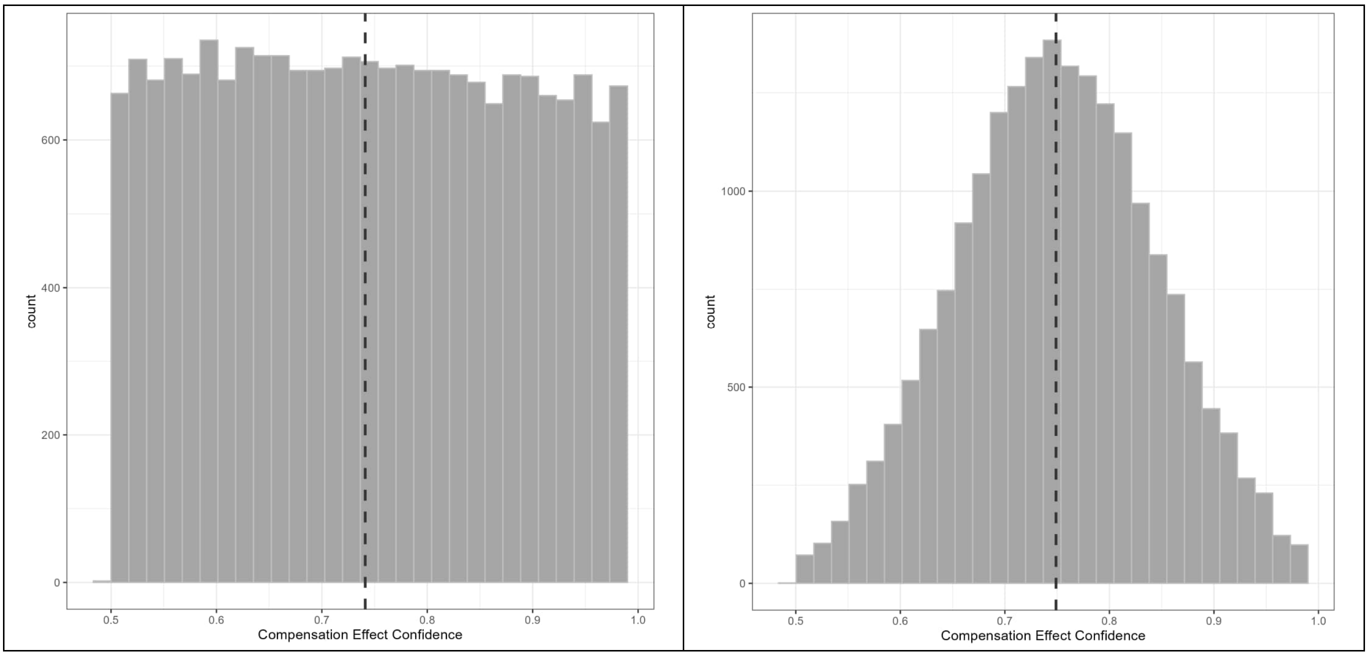

Figure B4. Distributions for the compensation effect confidence for the BCM model for Approach one (left) and Approach two (right). Simulation cases were sampled from a uniform distribution (left) or a manually set truncated normal distribution (right). Dashed vertical line indicates the median.

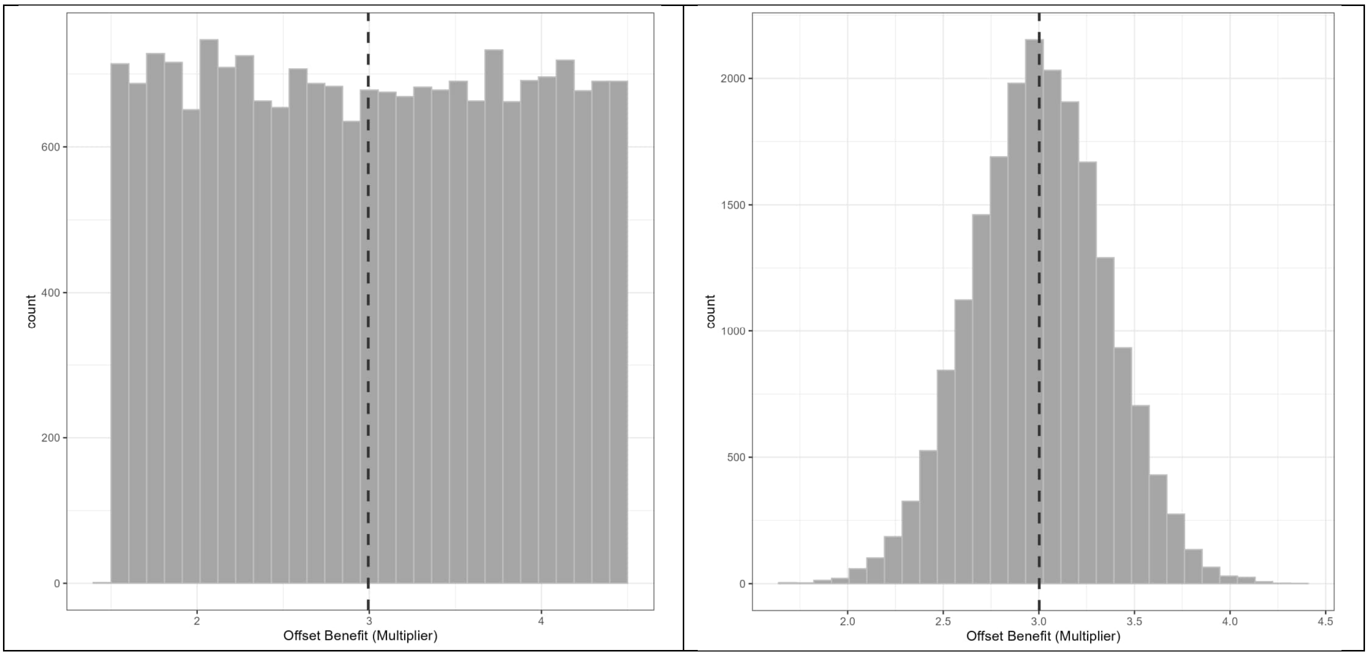

Figure B5. Distributions for the compensation benefit multiplier for the BCM model for Approach one (left) and Approach two (right). Simulation cases were sampled from a uniform distribution (left) or a manually set truncated normal distribution (right). Dashed vertical line indicates the median.

Appendix C: BOAM Net Value Outcome vs Parameter Associations

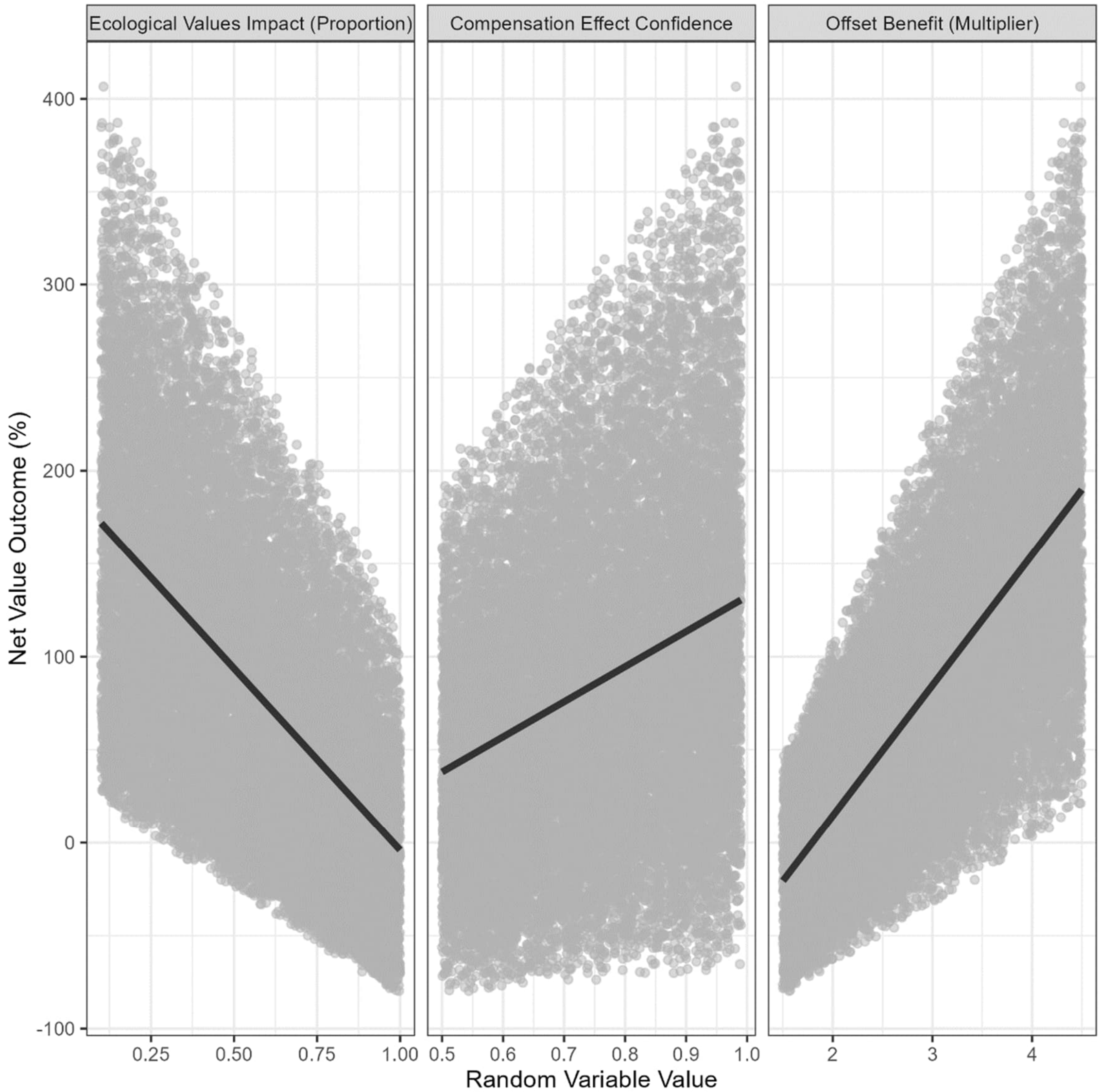

Figure C1. Association between the non-fixed parameters and the net value outcome for the BOAM model using Approach one (uniform distribution sampling). Black lines show trends. Each point is a simulation result.

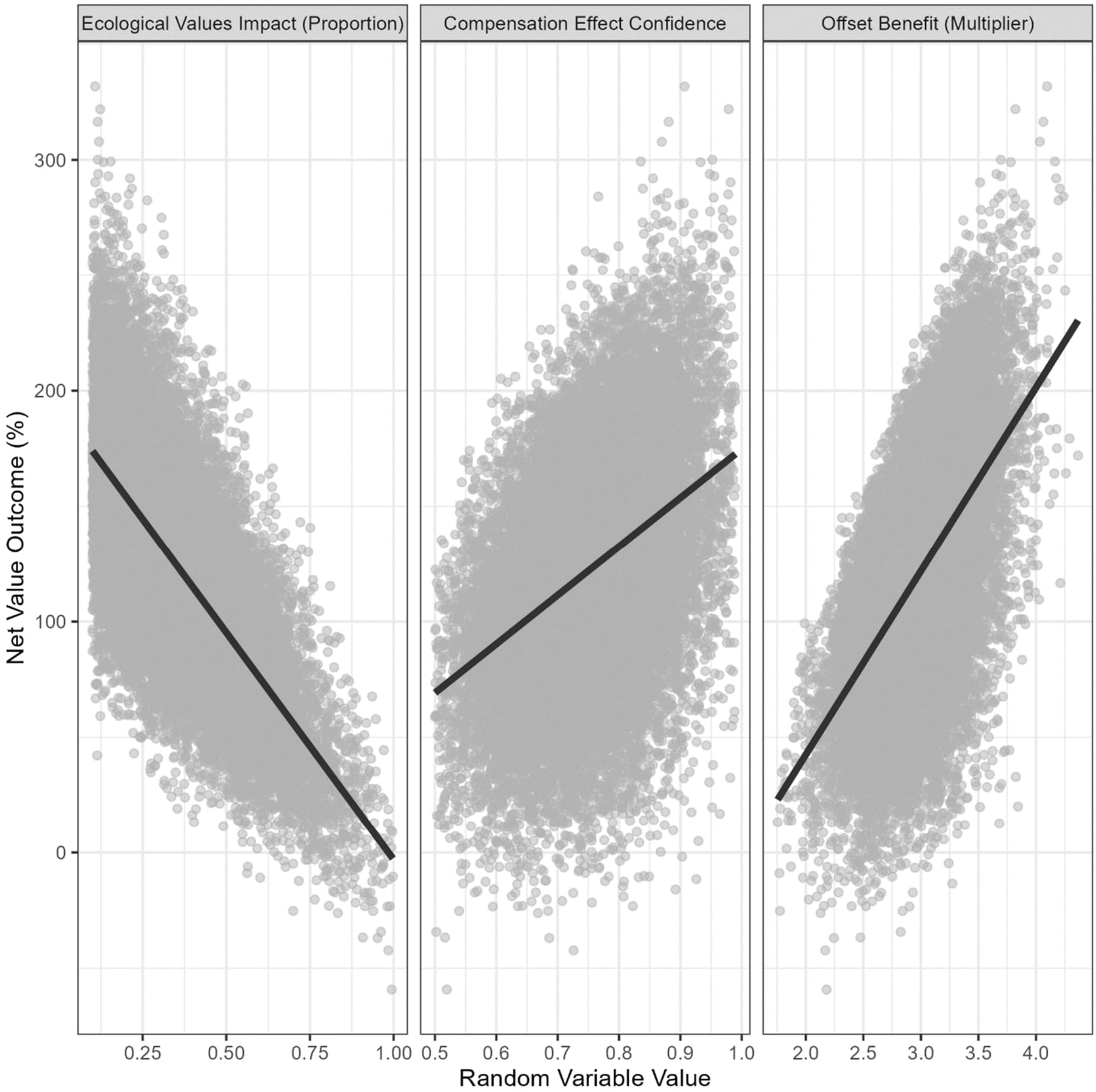

Figure C2. Association between the non-fixed parameters and the net value outcome for the BOAM model using Approach two (truncated mean distribution sampling). Black lines show trends. Each point is a simulation result.

Appendix D: BCM Net Value Outcome vs Parameter Associations

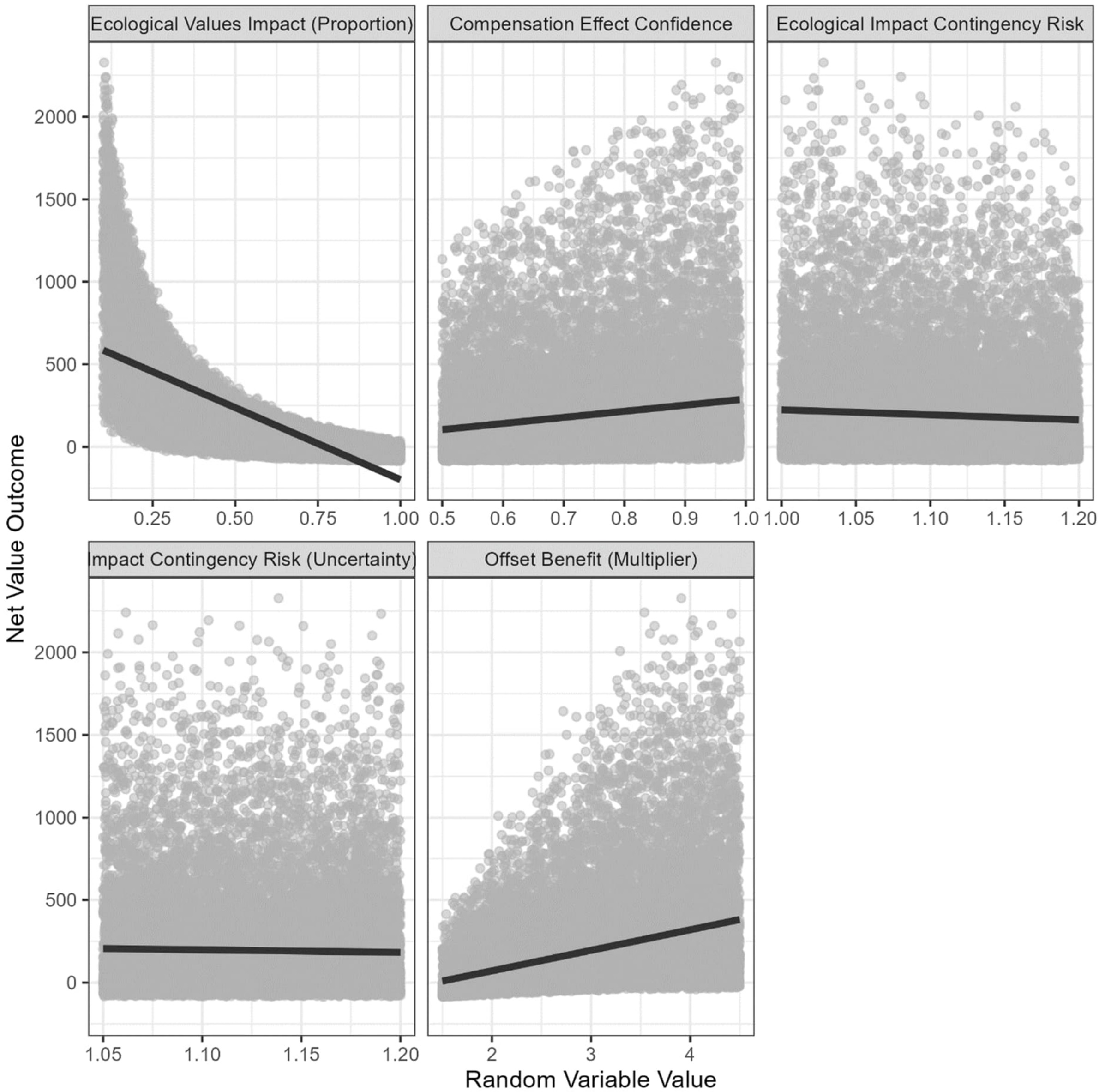

Figure D1. Association between the non-fixed parameters and the net value outcome for the BCM model using Approach one (uniform distribution sampling). Black lines show trends. Each point is a simulation result.

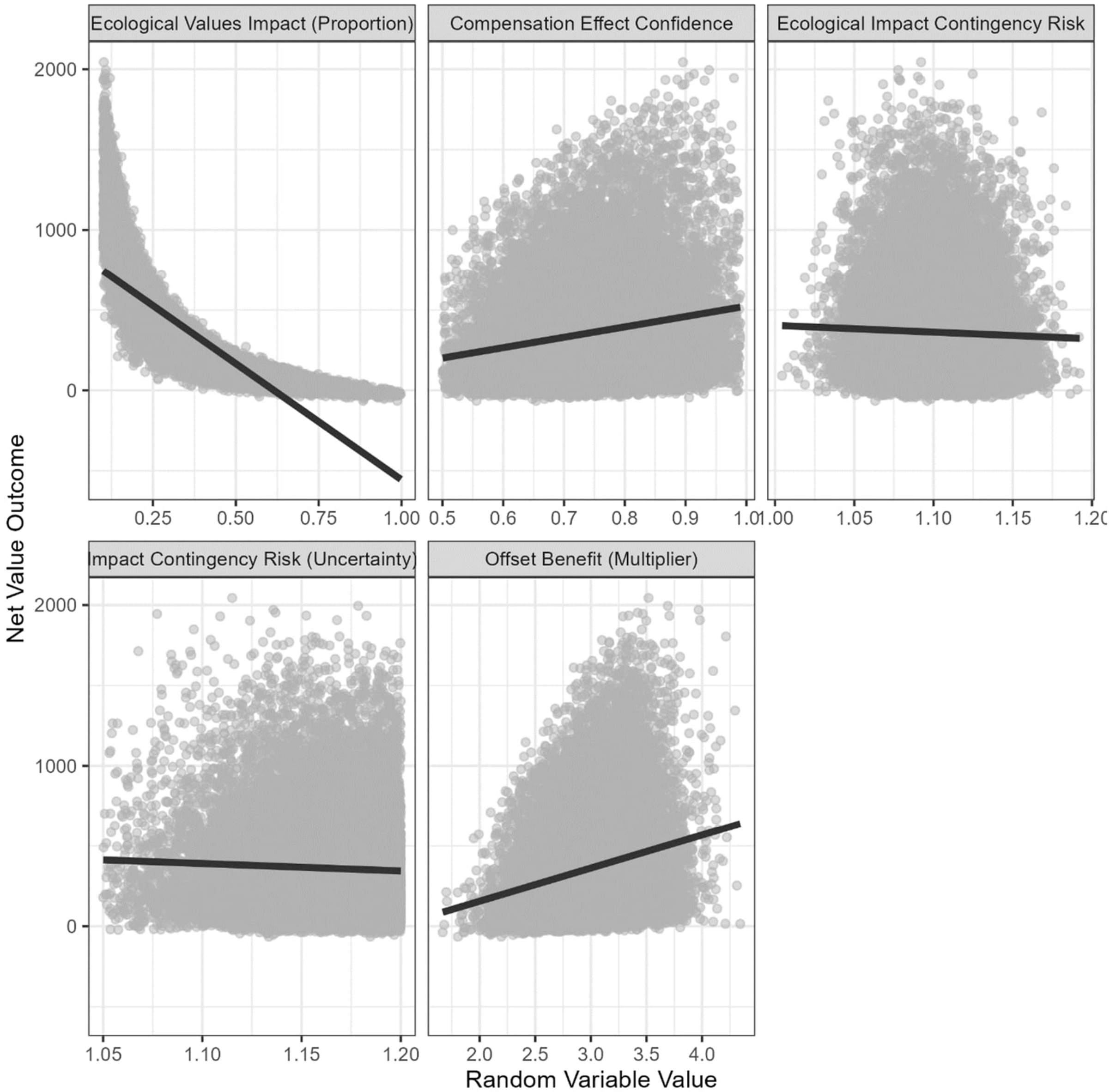

Figure D2. Association between the non-fixed parameters and the net value outcome for the BCM model using Approach two (truncated mean distribution sampling). Black lines show trends. Each point is a simulation result.