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Demonstrating the value of evidence-based prioritisation of farm management actions for biodiversity and broader environmental outcomes

Catriona J. MacLeod

1. *Landcare Research, Dunedin, NZ*

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Reviewed by:

Angela Brandt
Ecologist
Manaaki Whenua – Landcare Research

Approved for release by:

Jon Manhire
NZ Sustainability Dashboard project leader
The Agribusiness Group

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About this report series

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The New Zealand Sustainability Dashboard project Research Partners

Executive Summary

This report illustrates the value of evidence-based prioritisation of management actions for improving biodiversity and wider environmental outcomes on NZ farms. Using farm and industry level demonstrations, it shows how an evidence-based tool can help everyone achieve the best outcomes feasible with the natural capital available on their farm, working through this series of questions:

1. What are the effects of doing nothing?
2. What actions are currently feasible on the farm(s)?
3. What proportion of those actions should be implemented?
4. In what order should those actions be implemented?
5. What can be done next to add value to the farm(s)?

Biodiversity outcomes of management actions are assessed using an evidence-based tool designed for biodiversity assessments on NZ farms. This tool weights each of the 43 possible management actions on a farm according to benefits they are expected to deliver for overall biodiversity and 10 species groups (thus 11 biodiversity groups in total) identified as priorities by NZ stakeholders. The biodiversity benefits of each action were evaluated independently by a specialist judgement panel.

Maintaining and enhancing biodiversity on farms can help support multiple environmental outcomes. However, the outcomes achieved will depend on which biodiversity groups are affected by farm management actions. In this report, we show how the biodiversity scores derived from the NZ Sustainability Dashboard's (NZSD) biodiversity assessment tool can be used to evaluate broader environmental outcomes. We use the NZSD's agro-environmental assessment framework as a basis for this analysis.

Farm-level evaluations of biodiversity outcomes

We demonstrate how an evidence-based tool can be used by a land manager to evaluate their farms' biodiversity performance under different management scenarios based on (i) existing vs. added natural capital (e.g. shelterbelts, bush patches), (ii) implementing greater numbers of possible management actions given the farm's natural capital, and (iii) prioritising actions for implementation based on their biodiversity benefits, rather than implementing actions at random. Simply adding natural capital can double a farm's biodiversity performance relative to the baseline. Implementing 25%, 50%, or 100% of the baseline farm's possible actions at random can improve biodiversity benefits four, eight or 13-fold, respectively. Prioritising actions for implementation over a 10-year period leads to achievement of biodiversity gains much faster, with >50% increase in evidence-based tool score over random implementation.

Industry-level evaluations of biodiversity outcomes

Using data simulations to randomly allocate natural capital composition to 1000 farms, we show how the biodiversity tool can be used to assess the impact of different management strategies at the industry level. Biodiversity performance across farms was positively correlated with the types of natural capital present. Randomly implementing 25% to 100% of actions resulted in a 2.5-fold to seven-fold increase in biodiversity gains. Biodiversity gains will be achieved much faster when actions are prioritised (rather than randomised). Increasing natural capital within small and large non-production areas on a third of farms provided gains of 44% and 50%, respectively. Greatest gains were achieved when there was a 30% increase in natural capital within large non-production areas and each farm applied their full suite of possible actions.

How to define and refine biodiversity management goals and strategies

We show how the biodiversity tool can help the industry refine their biodiversity performance goals, by defining the target score for individual farms as well as the timeframe and the percent of farms required to meet the target, and management strategies for achieving those goals. For our data simulations, we show that:

- Very few farms, if any, will meet a target of ≥10% score increase within 10 years if all land managers opt to do nothing with their existing natural capital. However, the target would be met by all farms within 7 years if ≥25% of prioritised possible actions were implemented on every farm.
- For all farms to meet a target of ≥30% score increase within 10 years would require adding natural capital to 30% of farms and every farm to implement ≥75% or 100% of their possible actions (prioritised or randomised respectively).
- It would not be viable for all farms to achieve a target of ≥50% score increase within 10 years under any of the management scenarios considered in our analysis. If only 50% of farms were required to reach this target increase within 10 years, this would be feasible if the available natural capital within large non-production areas was increased by 30% across the industry and the full suite of possible actions for every farm was implemented over 10 years. This goal would be achieved three years earlier if the possible actions were prioritised (vs. randomised).

Evaluating broader environmental goals

At the indicator level, average scores for our baseline farms were lowest for ‘animal health and wealth’, highest for ‘water quality and withdrawal’ and most variable for ‘new agricultural pests’, ‘agricultural pest dominance’ and ‘genetic diversity’. When the full suite of actions implemented on the baseline farms were tailored according to the natural capital available: (a) all farms at least triple their indicator performance scores; (b) average indicator scores increased at least seven-fold; and (c) some farms achieve much higher gains (up to 20-fold) for a subset of indicators. Adding natural capital to either small or large non-production areas on a third of farms improved average indicator performance by 20% to 60%, with some farms more than

doubling their scores. When natural capital was added to small (vs. large) non-production areas, higher performance gains were achieved for ‘pollination’, ‘new agricultural pests’, ‘agricultural pest dominance’, ‘animal health and welfare’, ‘genetic diversity’, and ‘beneficial species status’, Conversely, adding natural capital to large (vs. small) non-production areas resulted in, higher gains for ‘water quality and withdrawal’, ‘landcover’, ‘contamination risk’, ‘contamination levels’, ‘ecosystem protection’ and ‘species composition’.

At the objective level, average performance scores on the baseline farms were lowest (c. 4%) for ‘maintaining livestock welfare’, for which the highest gains (8-fold) were achieved when all possible actions were implemented. Adding natural capital to small (vs. large) non-production areas on average resulted in greater improvements for ‘agricultural pests’ and ‘livestock well-being’, but lower improvements for ‘ecosystem composition’, ‘resilience to shocks’ and ‘limit contaminants’.

At the outcome level, when all possible actions were applied to every baseline farm, average scores increased about 7-fold; a small subset of farms increased their performance for the ‘resilience secured’ outcome up to 16-fold. By adding natural capital to large (vs. small) non-production areas, greater gains were achieved for the ‘natural heritage’ outcome (60% vs. 30%) but lower gains were attained for the ‘resilience secured’ outcome (50% vs. 60%).

Conclusions

Evidence-based tools can help land managers evaluate the impact of different management strategies on biodiversity and broader environmental outcomes on farms to:

- achieve the best outcomes with the natural capital available,
- prioritise mangement actions to improve performance and deliver benefits faster,
- explore what can be done next to add value,
- define and refine realistic environmental goals and management strategies for achieving them.

Our data simulation approach could be tailored to meet the specific needs of any catchment, region or sector as well as provide an in-depth impact assessment for a species group(s) or a broader evaluation of mulitple sustainability outcomes.

The hierarchical assessment framework evaluates broader environmental outcomes, while providing a more detailed and transparent appraisal of management practices in relation to specific but aligned objectives, indicators and measures.

Recommendations

- Adapt the data simulations in this report to meet specific stakeholder needs, including identifying management strategies likely to deliver specified environmental goals.
- Quantify the direct costs of implementing each of the 43 actions within the NZSD biodiversity assessment tool as well, as the opportunity costs of taking each action.

- Identify which other environmental and sustainability outcomes are stakeholder priorities, and undertake an evidence-based evaluation of the effectiveness of each action within the NZSD biodiversity tool for delivering those outcomes.
- Undertake a panel-based assessment of the relevance of each of the species groups for each of the indicators in the NZSD environmental assessment framework.

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1 Introduction

This report supports the development of a sustainability assessment, reporting and learning tool, the *New Zealand Sustainability Dashboard* (NZSD), for the country's production landscapes. Specifically, it demonstrates the value of evidence-based prioritisation of management actions for improving biodiversity and wider environmental outcomes on NZ farms. Using farm and industry level demonstrations, it shows how an evidence-based tool can help everyone achieve the best outcomes feasible with the natural capital available on their farm, working through this series of questions:

1. What are the effects of doing nothing?
2. What actions are currently feasible on the farm(s)?
3. What proportion of those actions should be implemented?
4. In what order should those actions be implemented?
5. What can be done next to add value to the farm(s)?

1.1 Evaluating biodiversity outcomes

Most farm management assessment schemes give equal weights to all actions implemented irrespective of the benefits those actions are expected to deliver. This increases the risk that land managers waste time and resources implementing management actions that do not deliver the desired outcomes or are less effective at delivering benefits.

In this report, biodiversity outcomes of management actions are assessed using an evidence-based tool designed for biodiversity assessments on NZ farms (MacLeod et al. 2019a,b). This tool weights each of the 43 possible management actions on a farm according to biodiversity benefits they are expected to deliver (Figure 1). It allows the user to evaluate the benefits for overall biodiversity and 10 species groups (which include taxa that are beneficial for production as well as native fauna and flora), for a total of 11 biodiversity groups. The biodiversity groups and actions included in the tool were identified as a priority by >200 stakeholders involved in managing NZ's production landscapes. The biodiversity benefits of each action were independently assessed by a panel of biodiversity specialists based on a structured judgement evaluation (Brandt et al. 2018a,b).

Using the underlying tool infrastructure, we set up a series of data simulations to quantify the biodiversity outcomes of different management scenarios over time and across multiple farms. For the purposes of this report, we evaluate biodiversity performance as the total biodiversity score achieved for each farm and the speed of biodiversity gains.

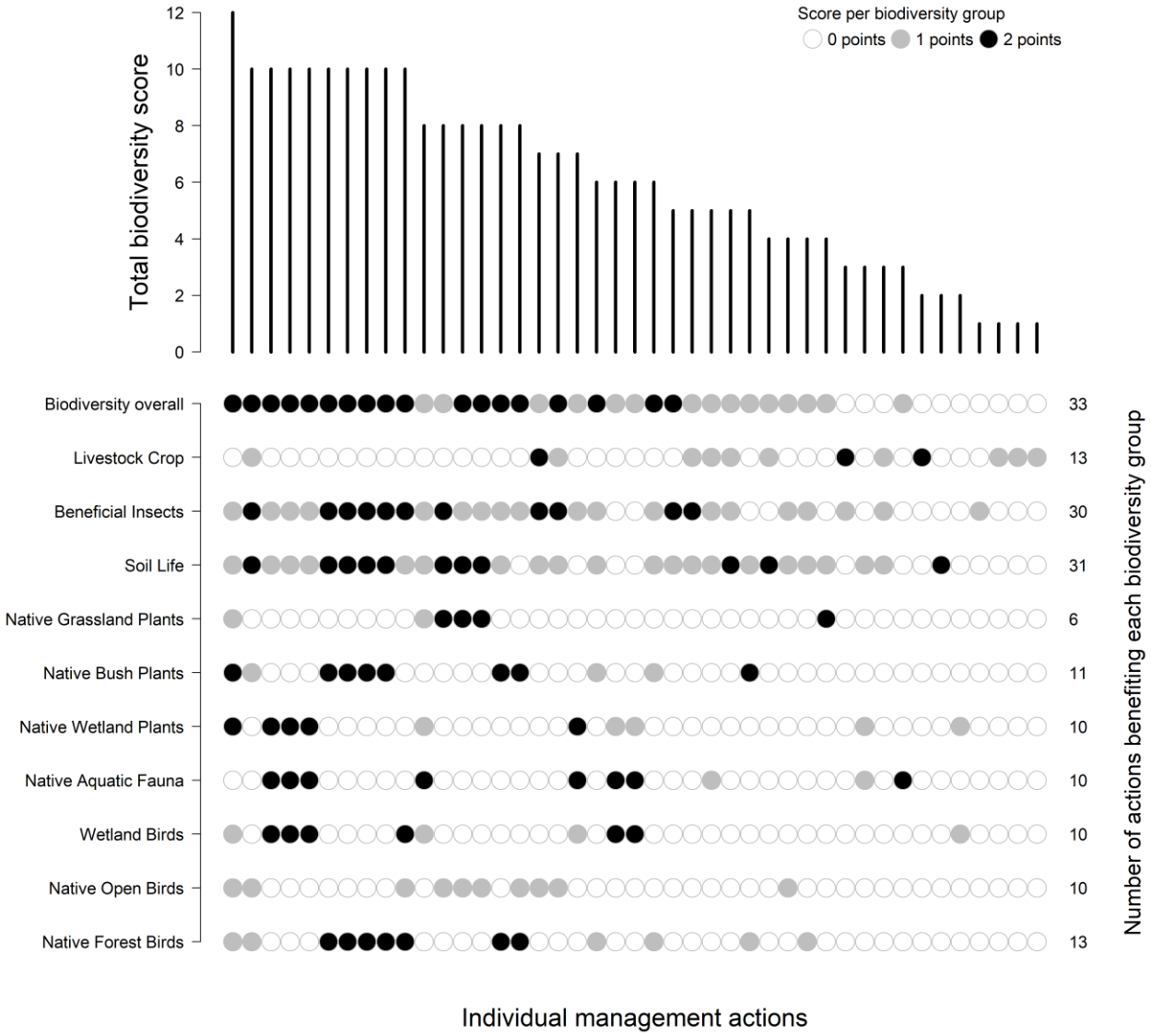

Figure 1 Total biodiversity score per management action. For each biodiversity group, the number of points assigned per action and number of actions expected to deliver benefits for that group. If all actions were implemented, the total possible biodiversity score would be 258 points.

1.2 Evaluating broader environmental outcomes

Maintaining and enhancing biodiversity on farms can help support multiple environmental outcomes. However, the outcomes achieved will depend on which biodiversity groups are affected by farm management actions. In this report, we show how the biodiversity scores derived from the NZSD biodiversity assessment tool can be used to evaluate broader environmental outcomes.

We use the NZSD's agro-environmental assessment framework (MacLeod and Moller 2013 a,b; MacLeod, Brandt and Moller 2019) as a basis for this analysis. This harmonised framework was designed to help stakeholders more clearly define their environmental goals, outcomes and objectives for New Zealand's production landscapes (Figure 2; Table 1). Indicators (and measures) aligned to each objective are used to assess progress toward or away from shared goals or to assess the state of a resource at any particular time (Yoccoz et al., 2001; Jones et al., 2013a). It was designed to be applicable to the national context, using established theoretical concepts and monitoring schemes as a basis for the inclusion of particular outcomes, objectives and indicators.

Multiple objectives in this framework are considered relevant to the biodiversity domain (MacLeod, Brandt and Moller 2019). Table 1 presents the relevance of the 10 species groups in the NZSD biodiversity tool to each of the 23 NZSD environmental indicators. This preliminary analysis identified at least one species group of moderate or high relevance to 15 indicators, seven objectives and three outcomes In this report, our analysis focuses on evaluating the broader environmental outcomes based on the subset of species groups considered of moderate or high relevance to the NZSD indicators.

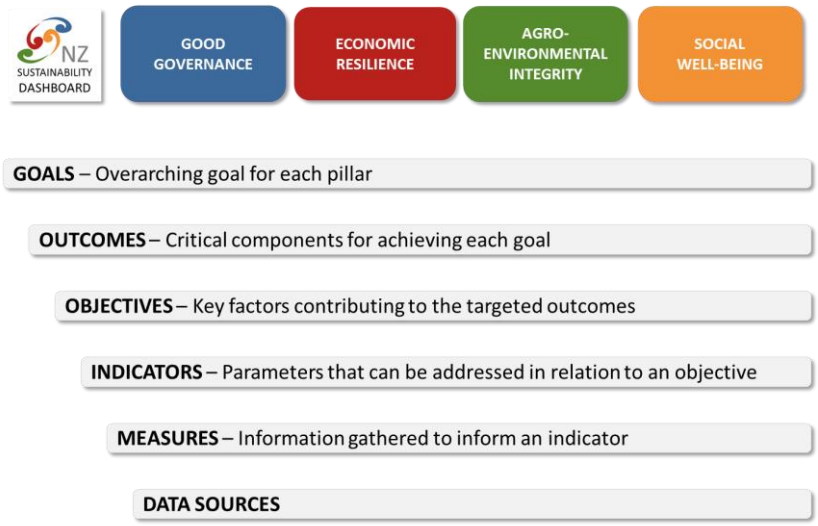

Figure 2 Structural components of the sustainability assessment framework

Table 1. The NZSD environmental assessment framework includes 15 indicators, seven objectives and three outcomes where at least one species group was considered of moderate (open circles) or high (closed circles) relevance.

NZSD environmental framework components			Biodiversity groups relevance to each indicator									
Outcome	**Objective**	**Indicator**	**Livestock Crop**	**Beneficial Insects**	**Soil Life**	**Native Grassland Plants**	**Native Bush Plants**	**Native Wetland Plants**	**Native Aquatic Fauna**	**Wetland Birds**	**Native Open Birds**	**Native Forest Birds**
Natural capital maintained	Maintaining ecosystem processes	Soil quality	○	○	●	○	○				○	○
		Water quality & withdrawal	○		○	○	○	●	●	●		
		Landcover	○	○	○	○	○	○	○	○	○	○
		Pollination	○	●		○	○					
	Reducing agricultural pests	New agricultural pests	○	○	○							
		Agricultural pest dominance	○	○	○							
	Limiting environmental contaminants	Contamination risk		○	○	○	○	○	○	○	○	○
		Contamination levels		○	○	○	○	○	○	○	○	○
Resilience secured for future use	Minimising material and energy subsidies	Renewable materials										
		Energy use										
		Waste reduction & disposal										
	Maintaining livestock well-being	Animal health & welfare	○			○	○					
	Maintaining agro-biodiversity	Genetic diversity	●	○	○							
		Beneficial species status	○	●	○	○	○				○	
		Diverse landscapes	○	○	○	○	○	○	○	○	○	○
	Building resilience to shocks	Land disturbance	○	○	○	○	○	○	○	○	○	○
Contributed to national 'natural heritage' goals	Improving ecosystem representation and composition	All ecosystems protected		○	○	○	○	○	○	○	○	○
		Species composition		○	○	●	●	●	●	●	●	●
	Preventing extinctions and declines	Status of threatened species										
	Reducing conservation pest threats	New conservation pests										
		Conservation pest dominance										
Global environmental change obligations met	Reducing emissions	Greenhouse gas emissions										
	Increasing carbon sequestration	Carbon storage & fluxes										

2 Farm-level evaluation of biodiversity outcomes

Here we illustrate how the biodiversity assessment tool could be used to evaluate different management strategies for enhancing biodiversity outcomes on an individual farm. At the outset, we assume that our demonstration farm had two existing types of natural capital (shelterbelts and a waterway) and the land manager posed the following questions:

1. What is the value of the existing natural capital on my farm (assuming no management actions are undertaken to benefit biodiversity on my farm)?
2. What actions are possible taking into consideration my farm's existing natural capital?
3. If I randomly implement all or a subset of the possible management actions, what are the expected biodiversity gains from those different scenarios?
4. What will be the biodiversity gains for my farm if I prioritise the suite of possible actions and then implement all or a subset of them?
5. If I add natural capital to my farm at the outset and prioritise my actions accordingly, how will that affect my farm's biodiversity performance?

2.1 Value of my existing natural capital?

The farm would be awarded only nine points or 5% of the total possible biodiversity score based on its existing natural capital alone, assuming the land manager opts not to implement any biodiversity management actions. In addition to overall biodiversity, six species groups (encompassing native fauna and flora as well as taxa considered beneficial for production) are expected to benefit, with greatest gains being delivered for native aquatic fauna and wetland birds. Four species groups (i.e. subsets of native birds and plants) will not benefit from the available natural capital.

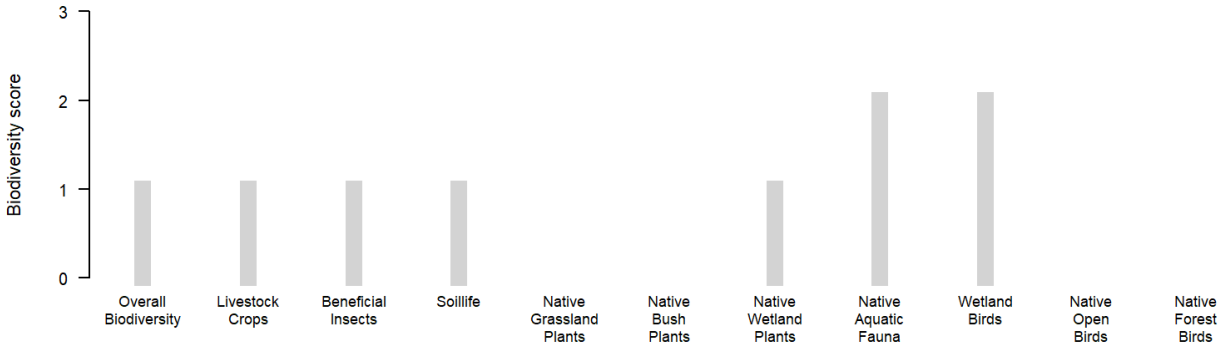

Figure 3 Expected scores for each of 11 biodiversity groups on a farm with shelterbelts and a waterway but no biodiversity management actions implemented

2.2 What actions are possible within my existing natural capital?

Taking into consideration the available natural capital (in this case shelterbelts and waterways), 21 actions were identified as feasible for our demonstration farm (Table 2). If this suite of possible actions were implemented, this farm could attain an additional 109 points, equivalent to 42% of the total possible biodiversity score (which is 258 points; Figure 1).

Overall, the two top actions for delivering greatest gains and benefiting the widest range of biodiversity groups on the farm, including overall biodiversity, would be ‘controlling stoats, rats, hedgehogs, or other predators’ (10 points, with benefits delivered for five biodiversity groups) and ‘controlling deer, goats, pigs, or other animals that alter habitat (12 points, with benefits delivered for nine biodiversity groups). By implementing just the two actions in shelterbelts (providing 10 points and benefiting four biodiversity groups) and four to waterways (24 points and benefiting seven biodiversity groups), the farm’s biodiversity performance score would increase from 3% to 17% (of the total possible).

2.3 Effects of varying the proportion of actions I implement?

Here we explore the effects of varying the proportion of the 21 possible actions implemented over a 10-year period (where 10% of the relevant subset of actions are applied each year; Figure 4). Biodiversity gains were evaluated relative to the baseline (i.e. opting to implement no biodiversity management actions). If only 25% or 50% of the possible actions were implemented, the farm's overall biodiversity gains would quadruple or increase eight-fold, respectively. If the full suite of possible actions were implemented over 10 years, biodiversity gains would triple within just three years and increase 13-fold overall (as the total number of points awarded increases from nine to 118).

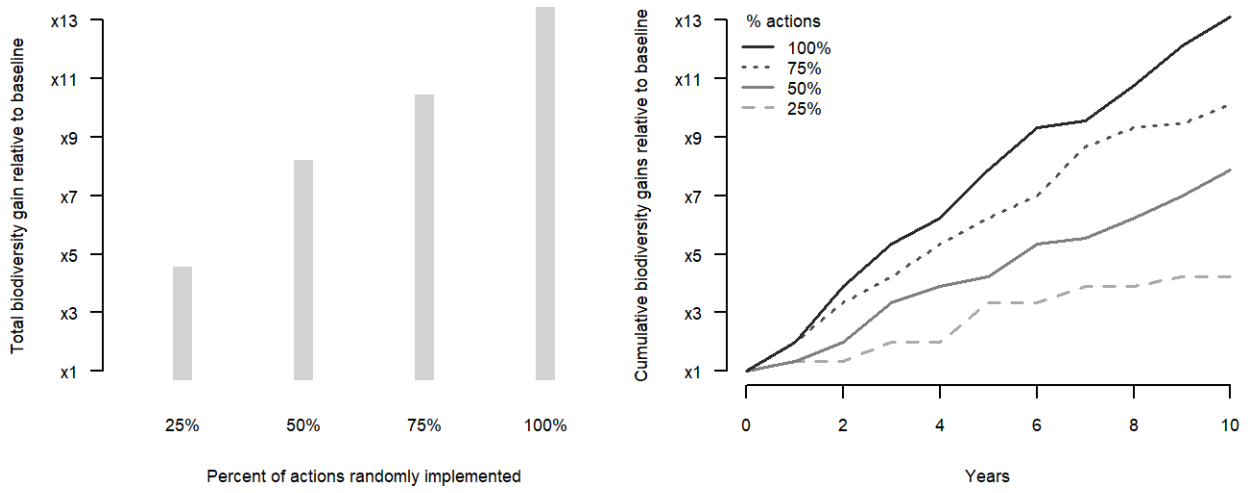

Figure 4: Total (left) and cumulative (right) biodiversity gains over 10 years from varying the proportion implemented randomly on the farm relative to the baseline (where no biodiversity management actions were implemented).

Table 2 Prioritised list of possible actions for the farm's existing natural capital (asterisk signals actions dependent on presence of shelterbelts and waterway)

Action	Biodiversity overall	Livestock Crop	Beneficial Insects	Soil Life	Native Grassland Plants	Native Bush Plants	Native Wetland Plants	Native Aquatic Fauna	Wetland Birds	Native Open Birds	Native Forest Birds	Total biodiversity score
Control deer, goats, pigs, or other animals that alter habitat	2	0	1	1	1	2	2	0	1	1	1	12
Control stoats, rats, hedgehogs, or other predators	2	0	2	1	0	0	0	0	2	1	2	10
Provide woody or grassy buffers between production areas and waterways, including fencing that excludes livestock from the buffer strip*	1	0	1	1	1	0	1	2	1	0	0	8
Control possums	2	0	1	0	0	2	0	0	0	1	2	8
Use barriers to prevent pollutants from entering waterways, such as sediment traps or constructed wetlands*	1	0	1	0	0	0	2	2	1	0	0	7
Grow a mixed pasture sward in your paddock (e.g. mixed grasses, or grasses and clover)	1	2	2	1	0	0	0	0	0	1	0	7
Promote a natural hydrological regime, such as allowing flooding or maintaining sufficient water levels for wildlife*	1	0	0	0	0	0	1	2	2	0	0	6
Maintain a mixture of species in shelterbelts or small forest, including native woody plants*	2	0	1	1	0	1	0	0	0	0	1	6
Control mice or other animals that compete with wildlife for food and nest sites	2	0	1	1	0	1	0	0	0	0	1	6
Minimise bare ground, such as by planting cover crops in arable fields, maintaining ground cover in orchards and vineyards, or maintaining vegetation cover in paddocks	1	1	1	1	0	0	0	1	0	0	0	5
Provide semi-natural habitats near crops so beneficial insects can help with pest control, such as beetle banks	2	0	2	1	0	0	0	0	0	0	0	5
Use biological control methods	1	1	2	1	0	0	0	0	0	0	0	5
Maintain or increase soil organic matter, such as by leaving straw or crop residues, growing green manure crops, or adding compost or organic mulches	1	1	1	2	0	0	0	0	0	0	0	5
Minimise soil compaction and pugging by carefully managing machinery and livestock	1	1	0	2	0	0	0	0	0	0	0	4
Manage shelterbelts to promote biodiversity, such as by avoiding spraying or not pruning too often*	1	0	1	1	0	0	0	0	0	0	1	4
Add the right amounts and types of fertilisers (including organic inputs), and only in response to a demand for nutrients (such as that indicated by plant or soil testing, or assessment of paddock requirements) and at appropriate timings and frequency to minimise leaching and runoff	0	0	0	1	0	0	1	1	0	0	0	3
Have culverts or bridges over streams that allow fish passage*	1	0	0	0	0	0	0	2	0	0	0	3
Predominantly use shallow tillage or no tillage as the main method of cultivation	0	0	0	2	0	0	0	0	0	0	0	2
Practice cultural controls, such as mechanical/physical control of weeds and crop disease prevention (such as selecting resistant crop varieties, planning rotations, avoid leaving crop residues in which diseases or pests could develop)	0	0	1	0	0	0	0	0	0	0	0	1
Pesticides (including herbicides) are used only when and where they are needed as determined through monitoring of pests or crop damage and if recommended by an agronomist or crop advisor	0	1	0	0	0	0	0	0	0	0	0	1
Only selective pesticides targeted to the specific pest or weed are used, and which are compatible with biological control	0	1	0	0	0	0	0	0	0	0	0	1

2.4 Benefits gained from prioritising my actions?

Total biodiversity gains for the farm were consistently greater when management actions were prioritised (rather than randomly implemented) over 10 years, unless the full suite of possible actions was undertaken (Figure 5). Biodiversity gains were also achieved faster when actions were prioritised, irrespective of the proportion of actions implemented (Figure 5 cf. Figure 4).

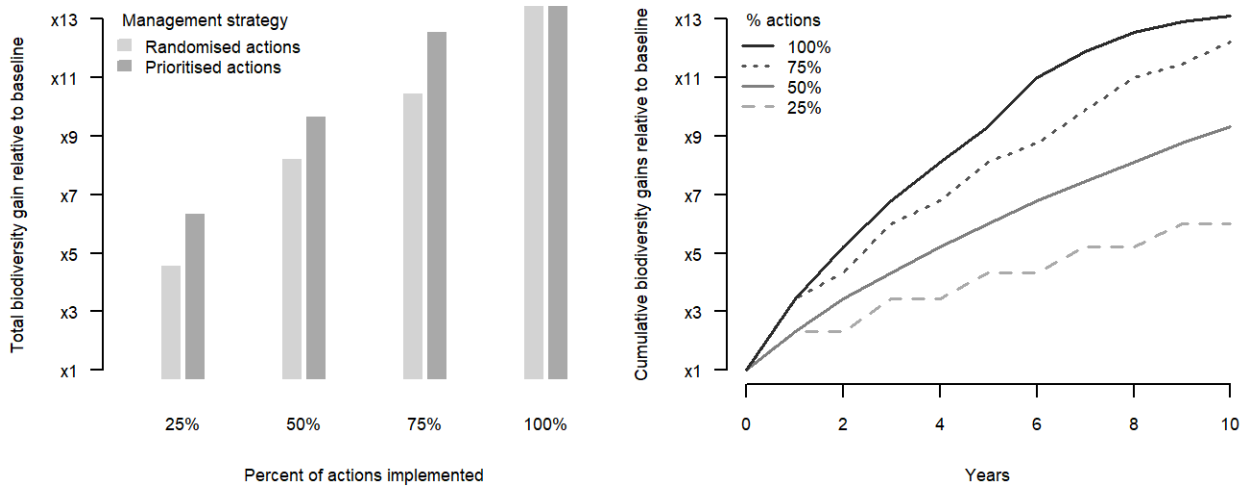

Figure 5 Total biodiversity gains from randomised and prioritised actions over 10 years relative to the baseline (left). Cumulative biodiversity gains over 10-years for prioritised actions relative to the baseline (where no biodiversity management actions were implemented on the farm; right).

2.5 Value of adding natural capital and prioritising actions accordingly?

Regardless of the type of natural capital added to the farm, the farm's biodiversity performance score doubled relative to the baseline (where performance was based solely on the presence of natural capital and assumed no biodiversity actions were implemented; Figure 6).

The suite of possible actions was tailored to include those relevant for the available natural capital. When the small bush patch was added to the farm, this suite of actions remained unchanged (relative to the baseline scenario). Three new actions were added for wetlands (Table 3), increasing the total possible biodiversity score for the farm by 22 points, with five species groups benefitting, as well as overall biodiversity.

Hence, the farm's biodiversity gains from adding and managing a large wetland were more than double those achieved from adding a small bush patch (Figure 6). When a large wetland was added and the full suite of possible actions was implemented, the farm's overall biodiversity gains were 27% compared to just 8% for adding the small bush patch (these gains are measured relative to the baseline scenario, where no natural capital was added but all possible actions were implemented).

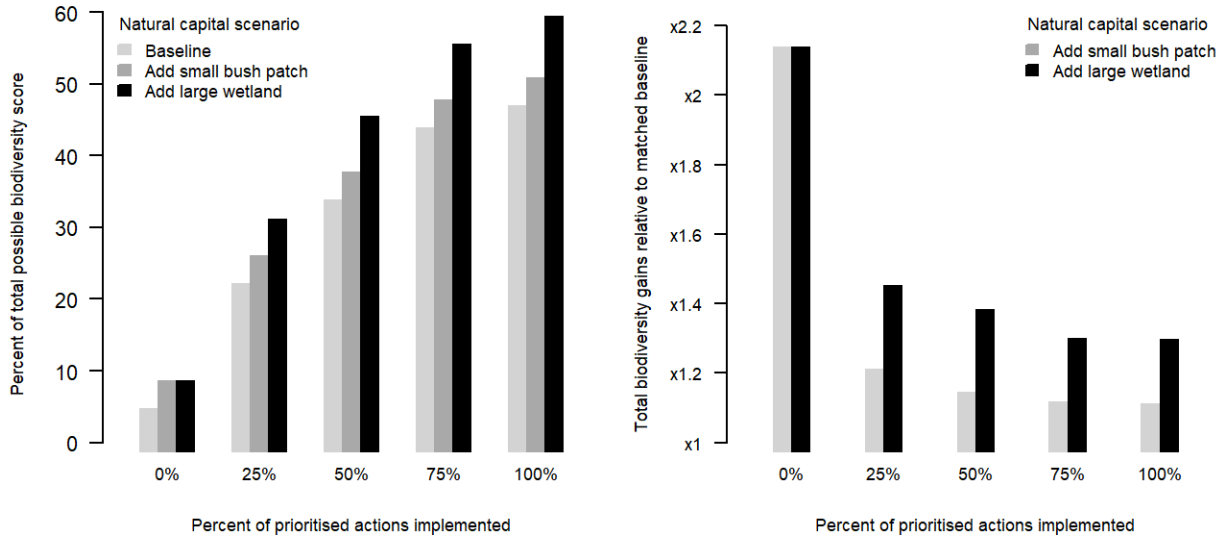

Figure 6 Biodiversity scores for three natural capital scenarios (left) and total biodiversity gains relative to the matched baseline (right), where the list of possible actions was tailored and prioritised according to the available natural capital whilst varying the proportion of implemented over 10 years.

Table 3 Three possible actions for adding a large wetland to the farm's existing natural capital

Action	Biodiversity overall	Livestock Crop	Beneficial Insects	Soil Life	Native Grassland Plants	Native Bush Plants	Native Wetland Plants	Native Aquatic Fauna	Wetland Birds	Native Open Birds	Native Forest Birds	Total biodiversity score
Formally protected, such as in a QEII covenant	2	0	1	1	0	0	2	2	2	0	0	10
Exclude livestock by fencing	2	0	1	1	0	0	2	2	2	0	0	10
Control weedy non-native plants, such as by spraying, grazing, or mechanical methods	0	0	0	0	0	0	1	0	1	0	0	2

3 Industry-level evaluation of biodiversity outcomes

Here we show how the biodiversity tool can be used to assess the impact of different management strategies at the industry level, assuming the following questions were posed:

1. What is the value of the existing natural capital across our farms (assuming no management actions are undertaken to benefit biodiversity)?
2. If land managers randomly implement all or a subset of the possible management actions, what are the expected biodiversity gains for the industry from those different scenarios?
3. What will be the biodiversity gains for the industry if land managers prioritise the suite of possible actions and then implement all or a subset of them?
4. If the proportion of farms with natural capital in small vs. large non-production areas were increased by 10%, 20% or 30%, what level of biodiversity gains would be achieved?
5. If land managers tailored and prioritised their actions while adding new natural capital to their farms, how will that effect our industry's biodiversity performance?

For the purposes of this analysis, we assumed that natural capital on farms was provided by nine land-cover types typically associated with small and large non-production areas (Table 4)**Error! Reference source not found.**. The baseline natural capital composition of 1000 farms was simulated by randomly and independently assigning each land-cover type to a specified proportion of farms (Table 4**Error! Reference source not found.**). This resulted in individual farms having up to 7 different land-cover types present, with some having no natural capital present, others only having natural capital either in small or large non-production areas respectively, and a small subset having natural capital in both small and large non-production areas.

Table 4 Baseline specifications for farm composition, where each land-cover type was randomly and independently assigned to relevant the proportion of farms.

Non-production area	Biodiversity tool		Land cover type	
	Question	Answer		Proportion of farms with land cover present
Small	6	14	Field margins adjacent to production areas	0.3
	6	15	Flowering plants adjacent to production areas	0.3
	7	16	Shelterbelts present	0.3
	7	17	Solitary trees	0.3
	7	18	Small bush patch	0.3
	9	21	Waterway present*	0.7
Large	11	26	Large patch tussock, grassland or shrubland	0.1
	13	30	Large patch naturally occurring wetland	0.01
	15	34	Large patch of native forest/bush	0.1

For each farm, the suite of possible management actions implemented was tailored according to the natural capital present on the farm. For example, if you do not have a waterway, you cannot implement waterway-focussed actions. All performance scores were calculated as a percentage of the 'total possible biodiversity score' (258 points; Figure 1) for the biodiversity assessment tool as a whole, irrespective of which actions were feasible on individual farms.

Three scenarios were simulated, assuming for each farm the land manager chooses: (a) not to implement any actions, (b) to adopt actions randomly or (c) to implement targeted investments, adopting actions which will deliver greatest benefits first. For these simulations, the proportion of actions implemented was increased, in steps of 25%, from 0% to 100%.

Increases in natural capital within small and large non-production areas were then simulated independently. The proportion of the 1000 farms with the relevant subset of land-cover types (Table 4) was increased by 10%, 20% or 30%. The distribution of these land-cover types was randomly and independently assigned to the 1000 farms. Note that the simulations assumed that it was not possible to increase the proportion of farms with waterways.

Three management scenarios were then applied to the 1000 farms within each of these new natural capital scenarios, adjusting the list of possible actions for each farm according to the available natural capital: (a) not to implement any actions, (b) to adopt actions randomly or (c) to implement targeted investments, adopting actions which will deliver greatest benefits first. For these simulations, the proportion of actions implemented was also increased, in steps of 25%, from 0% to 100%.

3.1 Value of existing natural capital across the industry?

Across the industry, the baseline score for biodiversity performance was, on average, 5% (range 0 to 17%). Biodiversity performance was highest on farms that had natural capital within both small and large non-production areas (Figure 7). Average biodiversity scores for farms with natural capital only in small or large non-production areas were comparable, but half that of farms with natural capital in both areas. Biodiversity performance was also positively correlated with the number of different land-cover types of existing natural capital (Figure 7).

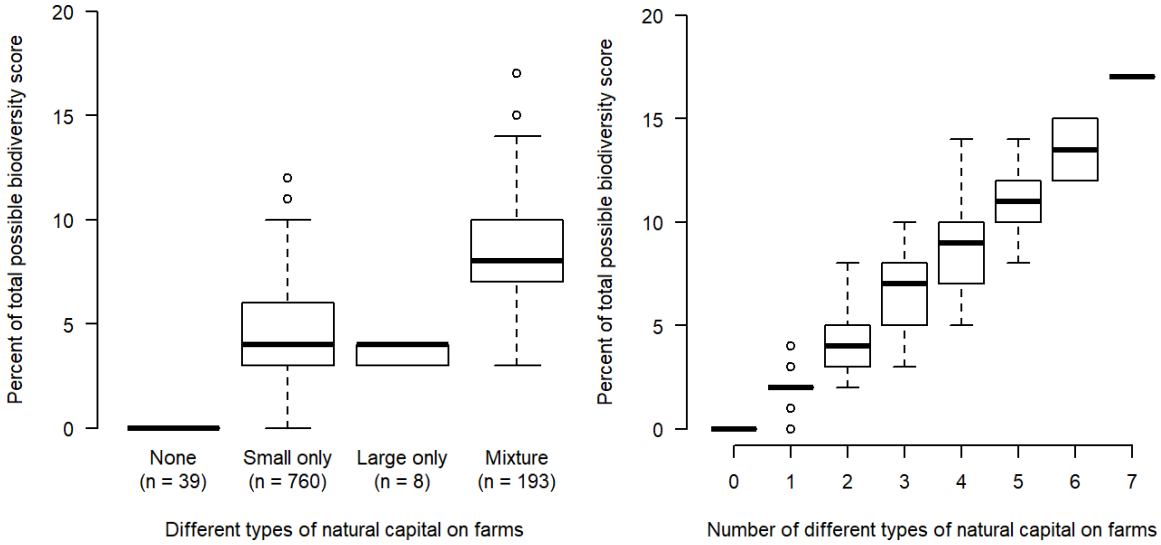

Figure 7 Biodiversity scores in relation to the type (small or large non-production areas) and number of types of natural capital (see Table 4) on 1000 farms.

3.2 Effects of varying the proportion of implemented actions?

Relative to the baseline (of opting to do nothing), randomly implementing 25 to 100% of actions will deliver, on average, a 2.5-fold to seven-fold increase in biodiversity gains across all farms (Figure 8). A small proportion of farms, however, will attain much greater increases (>10-fold) under all management scenarios.

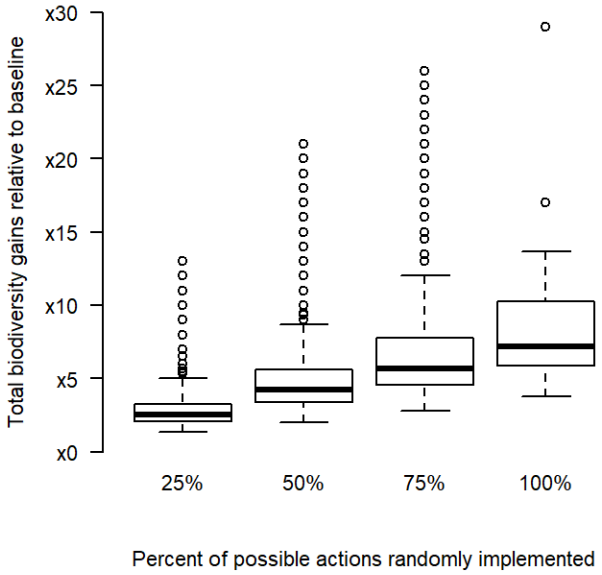

Figure 8 Biodiversity gains relative to the baseline for implementing varying proportions of possible actions at random across 1000 farms over 10 years.

3.3 Benefits gained from prioritised actions?

Biodiversity gains are expected to increase, on average, by 81%, 45% or 25% when farms implement 25%, 50% or 75% of their possible actions over 10 years, respectively, and those actions are prioritised (rather than randomised; Figure 9). Biodiversity gains are also achieved faster when actions are prioritised (vs. randomised), irrespective of the proportion of actions implemented (Figure 9). When the full suite of possible actions is implemented, the greatest gains (c. 55%) are made in the first two years. When only 25% of actions are implemented, the biodiversity gain is slow to be realised initially but is then sustained at a relatively high level.

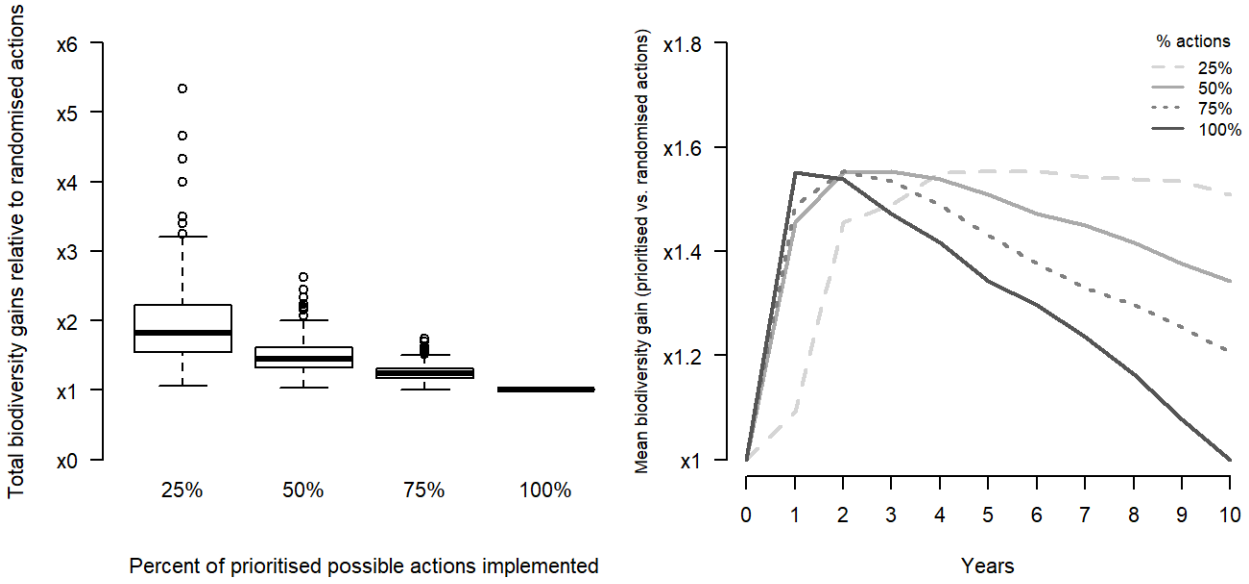

Figure 9 Total biodiversity gains (left) and mean biodiversity gains per annum (right) for implementing varying proportions of prioritised (vs. randomised) actions across 1000 farms over 10 years.

3.4 Effects of adding natural capital to farms and then tailoring actions accordingly?

Here we explore the effects of adding natural capital to either small or large non-production areas across the 1000 farms.

Average biodiversity gains of 23% and 44% were achieved when natural capital within small non-production areas increased by 20% or 30%, respectively (Figure 10). Within large non-production areas, a 30% increase in natural capital was required before there was any change in the average biodiversity gain estimates; when this threshold was met, average scores increased by c. 50%. Under each scenario, however, a small proportion of farms more than doubled their biodiversity gains by adding natural capital, regardless of where it was added.

When natural capital was added and the full suite of possible actions was implemented over 10 years, average biodiversity gains were 8-fold or greater (compared to 7-fold when all possible actions were implemented on the baseline farms; Figure 10). Greatest gains were achieved when there was a 30% increase in natural capital within large non-production areas and the full suite of actions was applied.

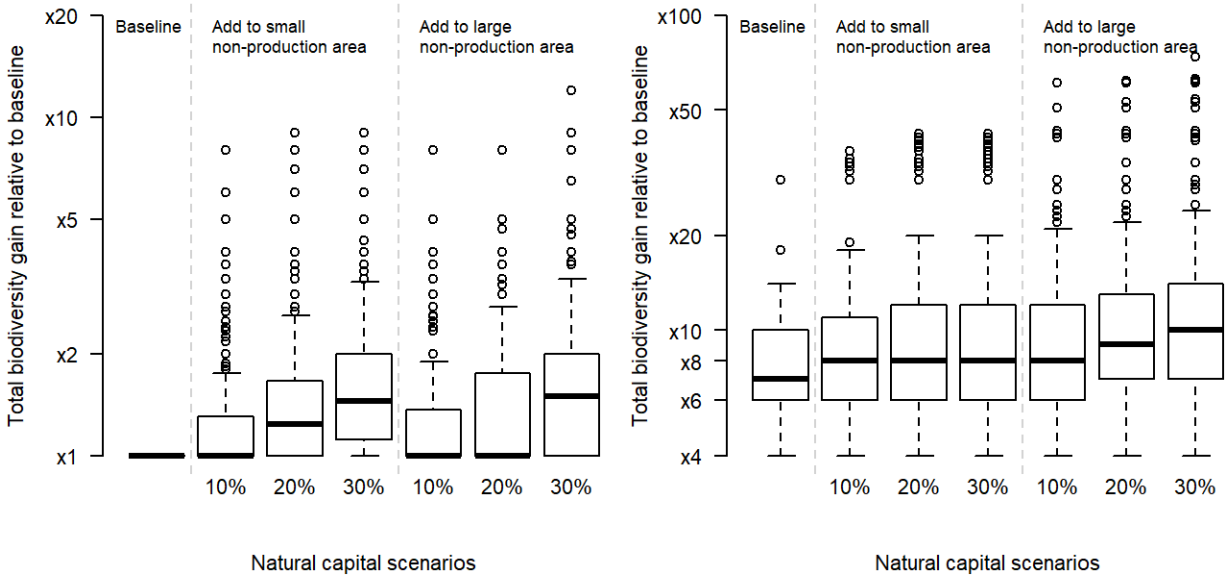

Figure 10 Total biodiversity gains (relative to the baseline farms without implementing any management actions) for adding natural capital to either small or large non-production areas in varying proportions of 1000 farms (left) and then implementing the full suite of possible actions to each farm (right).

4 How to define and refine biodiversity management goals

Here we illustrate how data simulations from the previous section (based on the biodiversity tool components) can be used to define and refine biodiversity management goals across farms. These goals clearly define the target biodiversity performance score that individual farms need to meet as well as the timeframe and the percent of farms meeting the target. We also demonstrate how management strategies for achieving those goals can be identified.

Our example focusses on the 1000 farms described in the previous section, akin to a sector wide monitoring programme. However, a similar approach could be used to help define goals for farms within a catchment or region. Alternatively, the approach could be used to set goals across regions within a sector or across sectors at the national level.

4.1 Goal encompasses a biodiversity performance target of ≥10%

We start by setting a low bar for biodiversity performance, where each farm is required to meet a target of ≥10% of the total possible biodiversity score (based on the biodiversity tool; Figure 11). If all land managers opt to do nothing with their existing natural capital or added natural capital (either in small or large non-production areas), only a very small proportion of farms, if any, will meet this target within 10 years.

If the strategy required at least 25% of prioritised possible actions to be implemented on each farm, then the target would be met by all farms within 7 years. However, if the strategy allowed land managers to implement their possible actions at random, then at least 50% of actions would need to be applied; under this strategy the target would be met within 9 years.

If the industry wanted to achieve a target score of ≥10% across all farms within five years, the following management strategies could be put in place to meet this goal:

- Assuming no new natural capital is added to the farms, the suite of possible management actions for each farm is prioritised and at least 50% of those actions are applied.
- Assuming natural capital in small non-production areas was increased by 30% across the farms, then the suite of possible management actions for each farm could either be: (1) prioritised and at least 50% applied; or (2) randomised but 75% implemented.

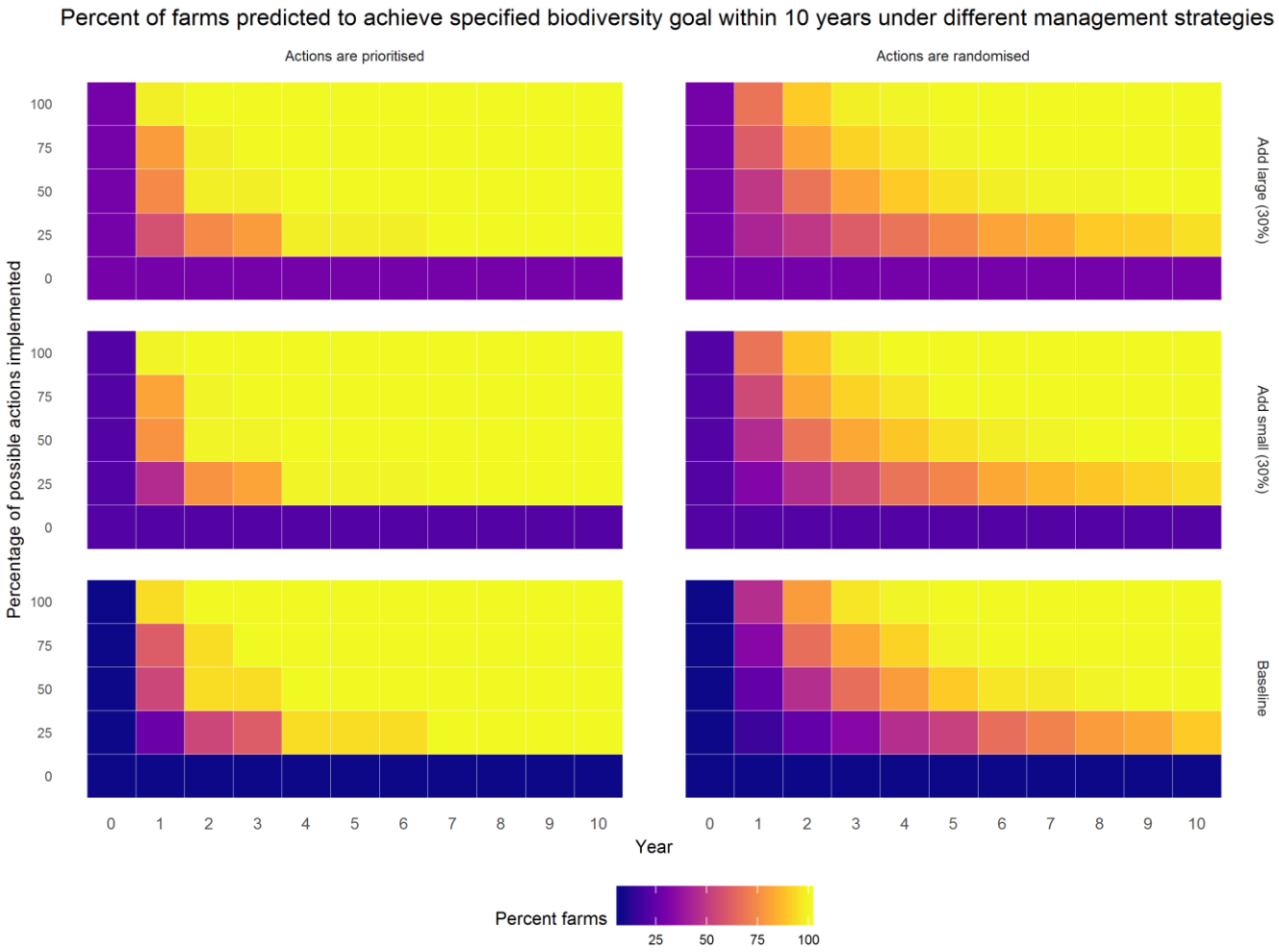

Figure 11 Percent of 1000 farms that met 10% biodiversity score target based on the existing natural capital (baseline) or increasing natural capital by 30% across the 1000 farms in either small or large non-production areas ('Add small (30%)' or 'Add large (30%)', respectively), whilst also varying the proportion of possible actions implemented over 10 years. Actions were assumed to be prioritised before implementation (left) or implemented at random (right).

4.2 Goal encompasses a biodiversity performance target of ≥30%

Here we raise the biodiversity performance target to 30% and explore the feasibility of all farms meeting this target within 10 years (Figure 12). This goal would not be met under a management strategy where no natural capital is added to the farms, even if all the possible actions for each farm are implemented. However, the goal could be achieved within 10 years in natural capital were increased in small non-production areas and 75% of prioritised possible actions were implemented, or in 7 years with increase in large non-production area capital and 100% prioritised action implementation. If natural capital were increased and actions were randomised accordingly, then 100% of actions would need to be implemented to meet this goal within 10 years.

Adjusting the goal to require at least 50% of farms to meet the 30% target within 5 years, then the management strategy options would include:

- Land managers do not add natural capital to their farms but are on track to apply the full suite of prioritised possible management actions for their farm within 10 years.
- Natural capital in small or large non-production areas is increased by 30% across the farms and land managers are on track to implement at least 75% of prioritised possible management actions for their farm over 10 years.

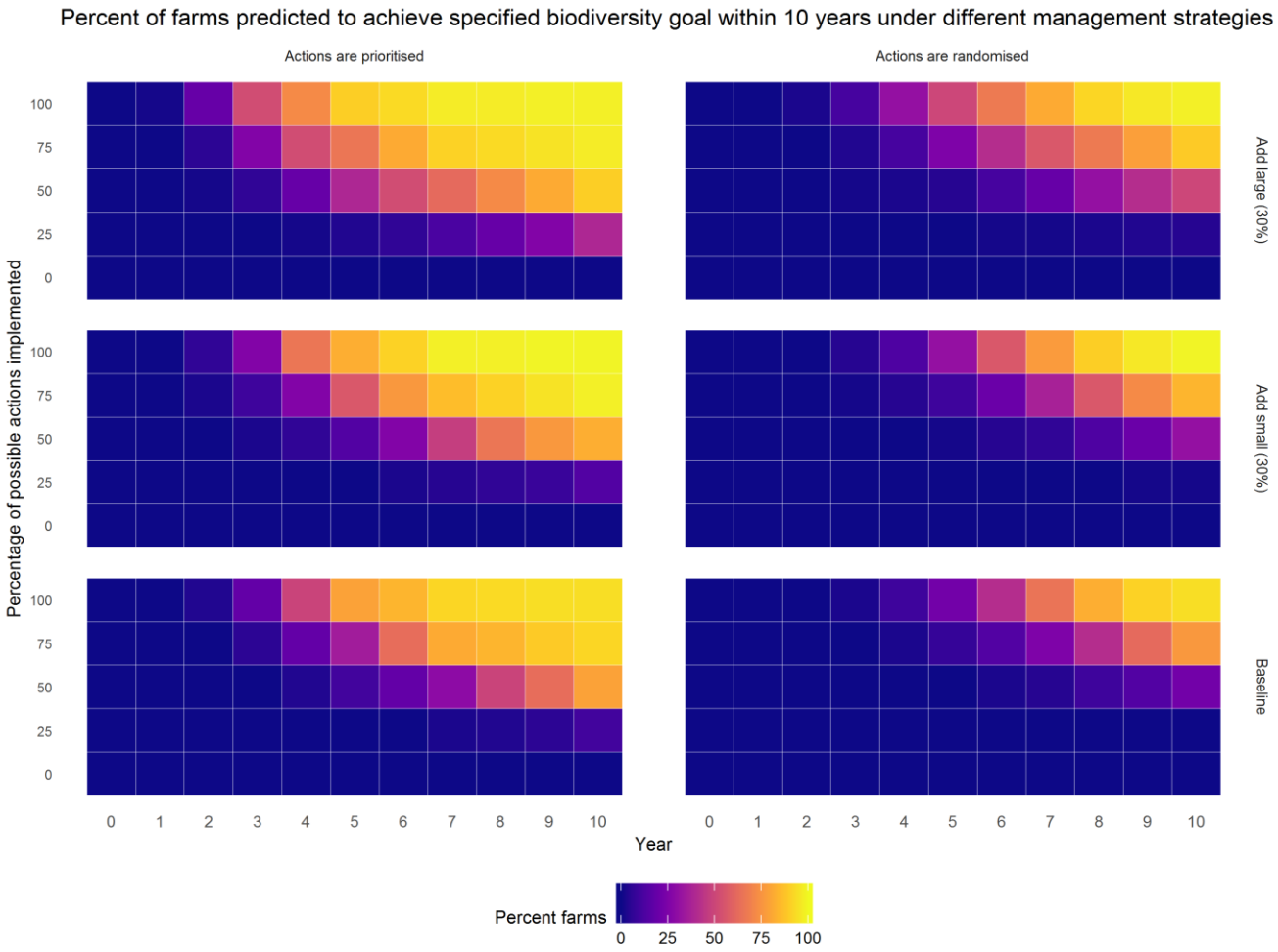

Figure 12 Percent of 1000 farms that met 30% biodiversity score target based on the existing natural capital (baseline) or increasing natural capital by 30% across the 1000 farms in either small or large non-production areas ('Add small (30%)' or 'Add large (30%)', respectively), whilst also varying the proportion of possible actions implemented over 10 years. Actions were assumed to be prioritised before implementation (left) or implemented at random (right).

4.3 Goal encompasses a biodiversity performance target of ≥50%

If the biodiversity performance target were increased to ≥50%, it would not be feasible for all farms to achieve this target within 10 years under any of the management scenarios considered in our analysis (Figure 13). However, if the aim were for >50% of farms to reach this target within 10 years, then it would be feasible if the industry implemented a management strategy which increased, across its 1000 farms, the available natural capital within large non-production areas by 30% and the full suite of possible actions for every farm was implemented over 10 years. This goal would be achieved three years earlier if the possible actions were prioritised (vs. randomised).

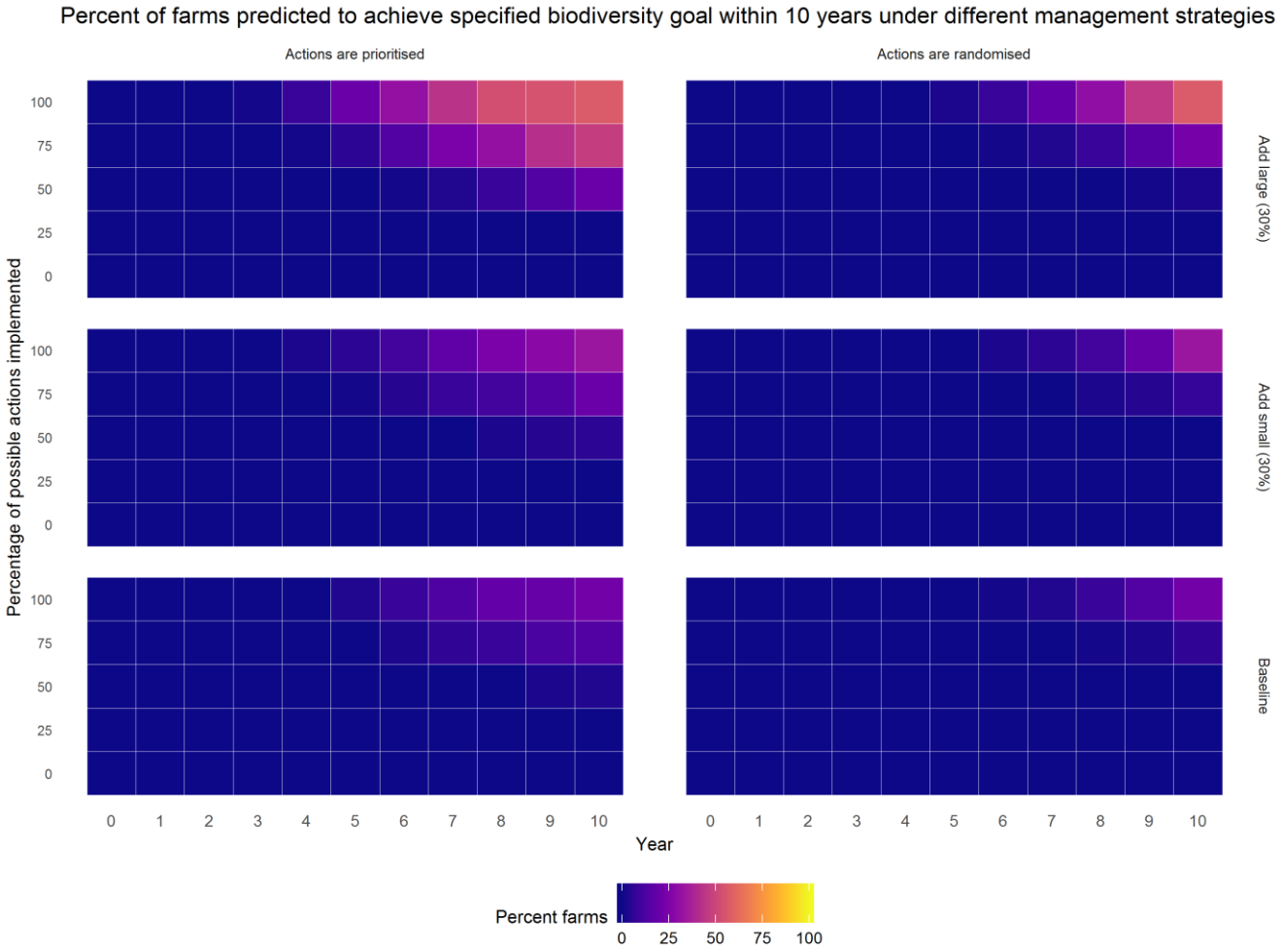

Figure 13 Percent of 1000 farms that met 50% biodiversity score target based on the existing natural capital (baseline) or increasing natural capital by 30% across the 1000 farms in either small or large non-production areas ('Add small (30%)' or 'Add large (30%)', respectively), whilst also varying the proportion of possible actions implemented over 10 years. Actions were assumed to be prioritised before implementation (left) or implemented at random (right).

5 Evaluating broader environmental outcomes

Here we consider how biodiversity scores can be used in the context of the NZSD framework to evaluate the broader environmental performance of an industry. Performance scores are calculated a percentage of the total possible score for each of the 15 indicators, seven objectives and three outcomes (Table 1). We consider the following scenarios:

1. What is the value of the existing natural capital across our farms (assuming no management actions are undertaken to benefit biodiversity)?
2. If land managers implement all the possible management actions for their existing natural capital, what are the expected environmental gains for the industry?
3. If the proportion of farms with natural capital in small vs. large non-production areas were increased by 30%, what level of environmental gains would be achieved?

5.1 Value of existing natural capital across the industry?

Baseline performance scores were, on average, about 5% across the 15 indicators (Figure 14), with lowest scores detected for ‘animal health and wealth’ and highest scores for ‘water quality and withdrawal’ indicators. Performance scores were most variable for ‘new agricultural pests’, ‘agricultural pest dominance’ and ‘genetic diversity’ indicators where some farms achieved scores of over 15%.

At the objective level (Figure 15), average performance scores were lower (c. 4%) for ‘maintaining livestock welfare’ than other objectives (c. 5%). Scores were most variable for ‘reducing agricultural pest threats’ where a few farms achieved scores of >15%.

The distribution of performance scores was similar across the three environmental outcomes (Figure 16), with an average score of 5%.

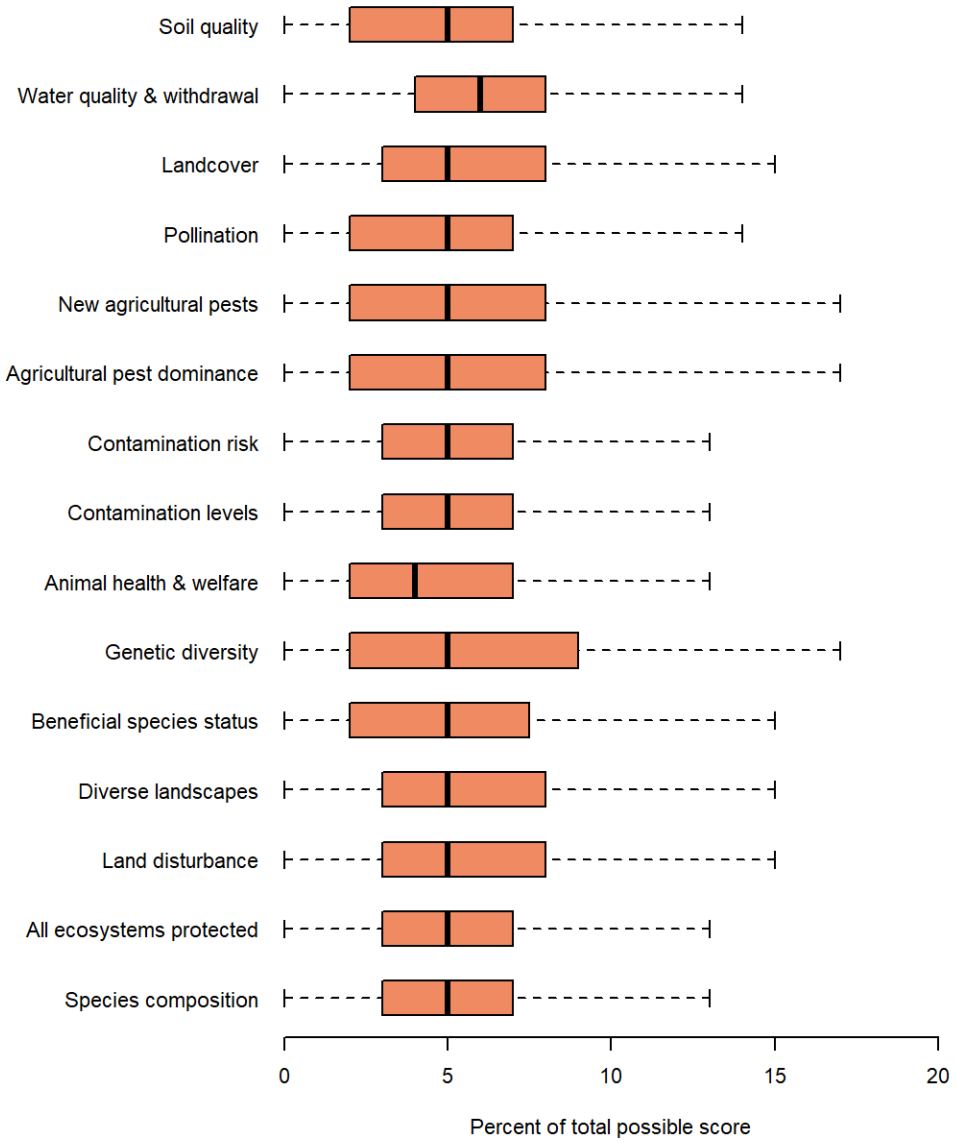

Figure 14 Percent of total possible score for baseline farms (where no actions are implemented; n = 1000).

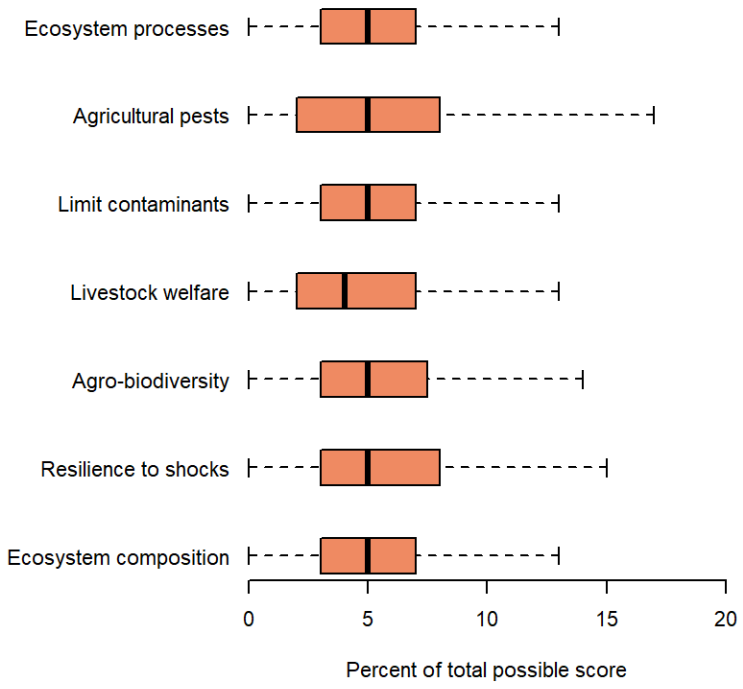

Figure 15 Evaluating performance in relation to seven environmental objectives. Boxplots show the percent of the total possible score for 1000 baseline farms (where no actions are implemented).

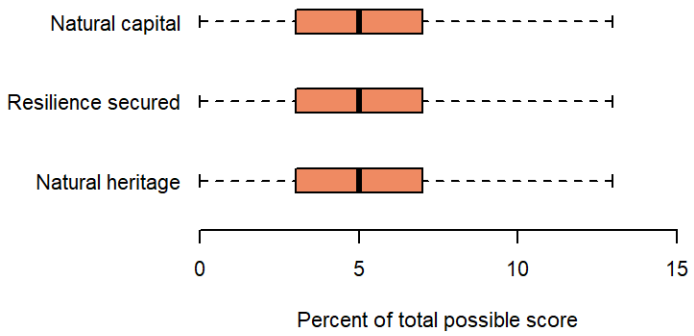

Figure 16 Evaluating performance in relation to three NZSD environmental outcomes. Boxplots show the percent of the total possible score for 1000 baseline farms (where no actions are implemented).

5.2 Effects of implementing all possible actions?

When the full suite of actions implemented on the baseline farms were tailored according to the natural capital available, improvements in environmental performance across the 15 indicators are achieved (Figure 17). All farms at least triple their performance scores with, on average, at least a seven-fold increase achieved across the indicators. Some farms achieve much greater gains for a subset of indicators, up to 20-fold relative to the baseline (where no biodiversity management actions are implemented). The distribution of performance scores was most variable for ‘pollination’, ‘new agricultural pests’, ‘agricultural pest dominance’, and ‘beneficial species’ indicators.

At the objective level, highest gains were achieved for the ‘livestock well-being’ with an 8-fold improvement in performance scores (Figure 18). Performance was most variable across the farms for the ‘agricultural pests’ objective.

At the outcome level, performance scores across the sector were least variable for ‘natural capital’ and most variable for ‘resilience secured’ (Figure 19). The average gains for each outcome were about 7-fold, but with small subset of farms increased their performance up to 16-fold under the ‘resilience secured’ outcome.

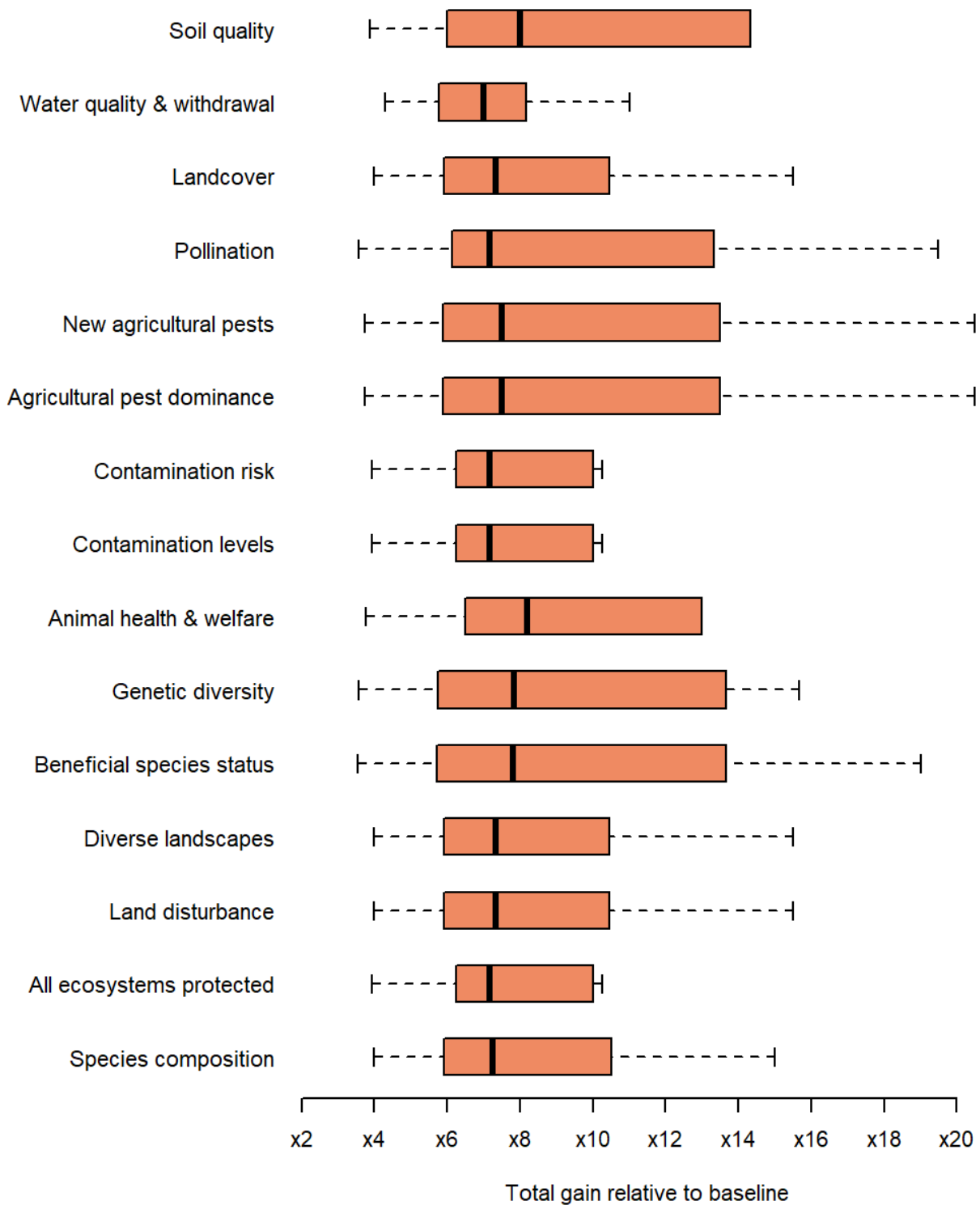

Figure 17: Total gains across 15 indicators for implementing all possible biodiversity management actions on each farm relative the baseline (of opting to 'do nothing').

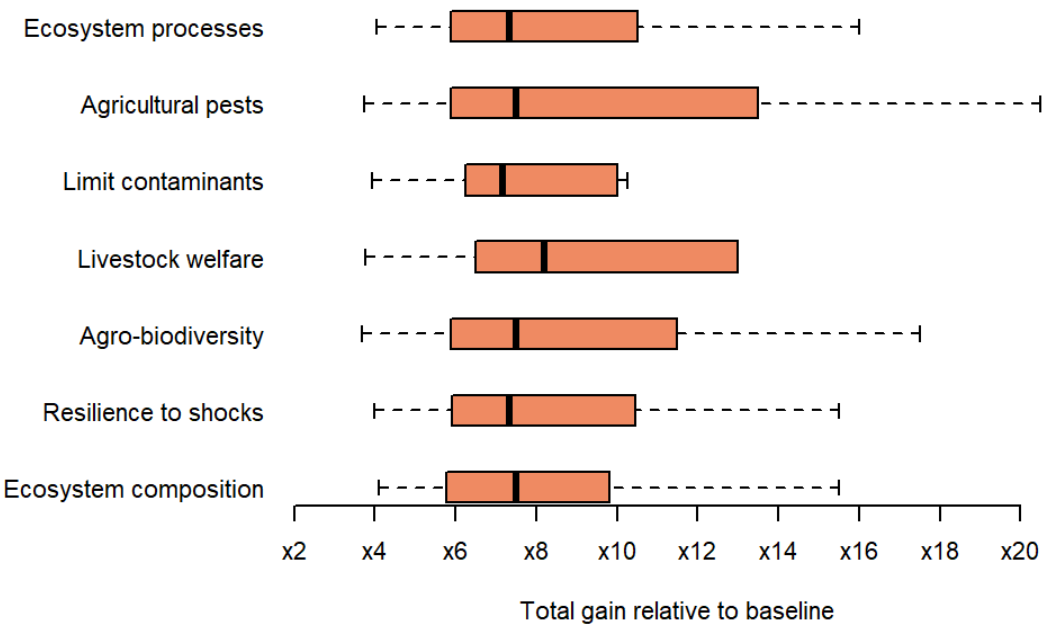

Figure 18 Total gains across 7 objectives for implementing all possible biodiversity management actions on each farm relative the baseline (of opting to 'do nothing').

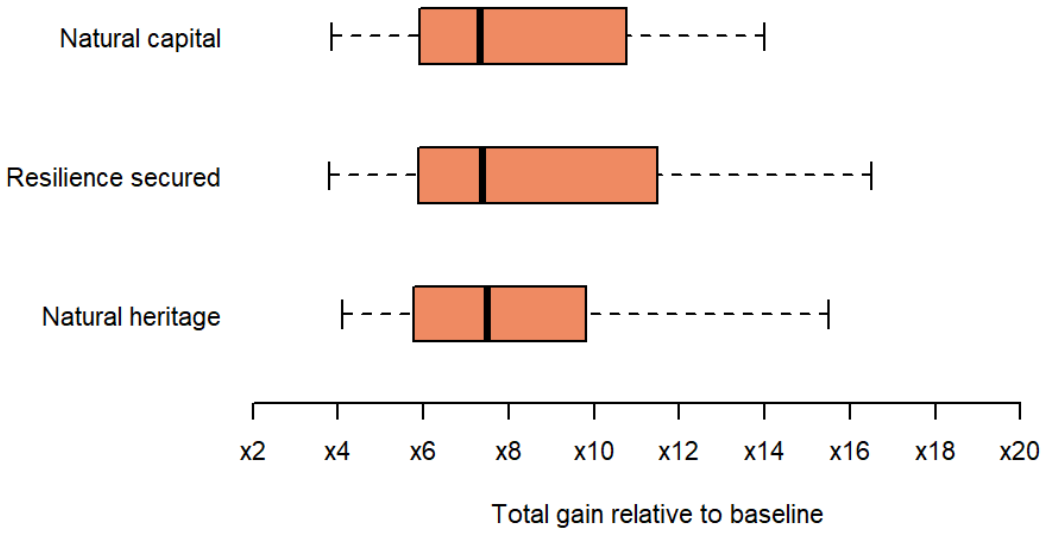

Figure 19 Total gains across three outcomes for implementing all possible biodiversity management actions on each farm relative the baseline (of opting to 'do nothing').

5.3 Effects of adding natural capital?

Adding natural capital to either small or large non-production areas on 30% of farms, improves performance across the 15 indicators by between 20 to 60% but with some farms more than doubling their performance (Figure 20). Greater gains are achieved for ‘pollination’, ‘new agricultural pests’, ‘agricultural pest dominance’, ‘animal health and welfare’, ‘genetic diversity’, and ‘beneficial species status’ when natural capital is added to small (vs. large) non-production areas (as indicated by the median and/or upper quantile estimates in Figure 20). In contrast, greater gains are achieved for ‘water quality and withdrawal’, ‘landcover’, ‘contamination risk’, ‘contamination levels’, ‘ecosystem protection’ and ‘species composition’ when natural capital is added to large (vs. small) non-production areas (as indicated by the median and/or upper quantile estimates in Figure 20).

At the objective level, adding natural capital to small (vs. large) non-production areas results greater improvements (on average) for ‘agricultural pests’ and ‘livestock well-being’ (Figure 21). Conversely, adding natural captial to large (vs. small) non-production areas, results in greater improvements (on average) the ‘ecosystem composition’, ‘resilience to shocks’ and limit contaminants.

At the outcome level, greater gains were achieved for ‘natural heritage’ (c. 60% vs. 30% gain) by adding natural capital to large (vs. small) non-production areas and for ‘resilience secured’ (60% vs. 50% gain) by adding natural capital to small (v.s large) non-production areas (Figure 22).

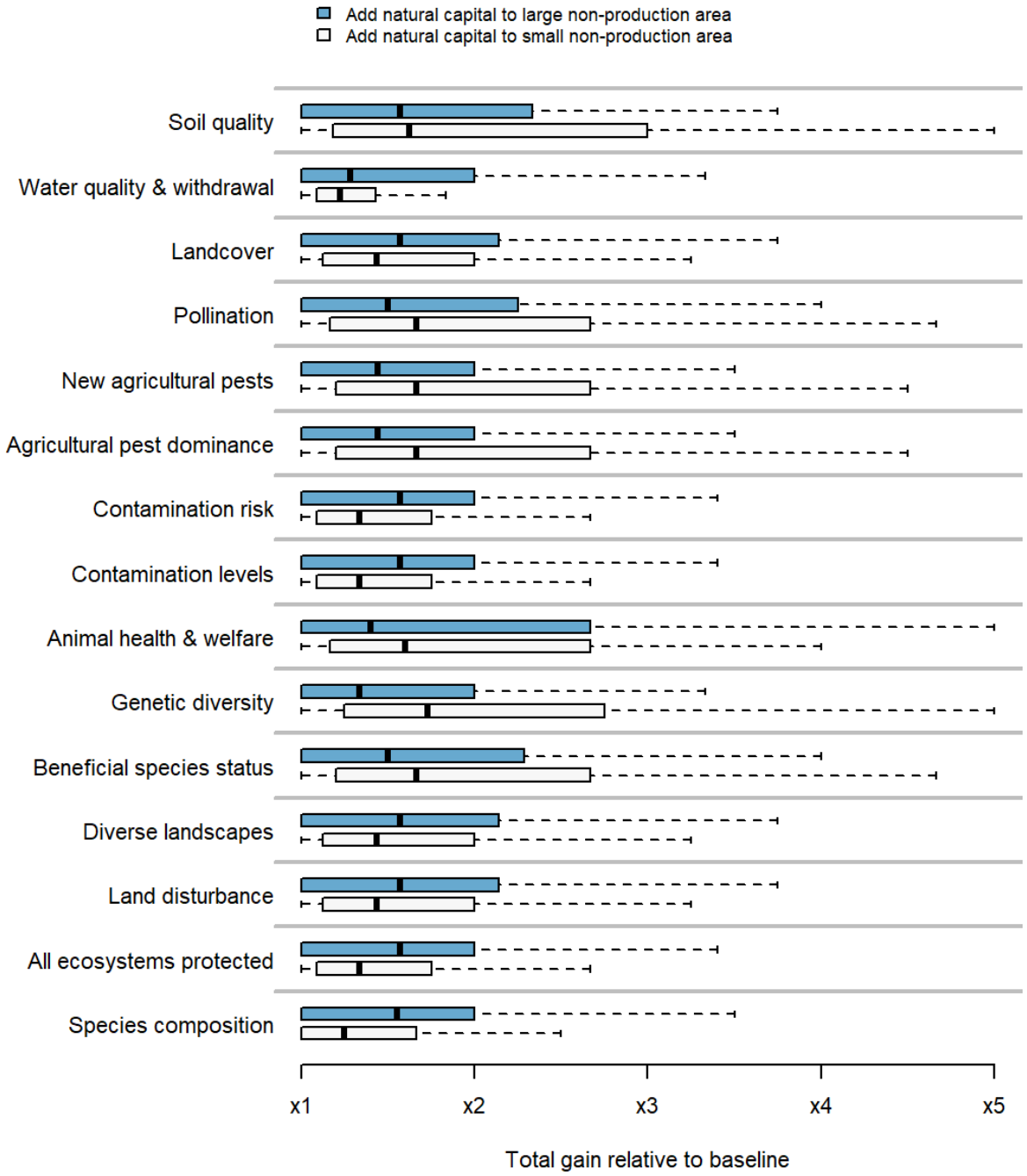

Figure 20 Performance gains for 15 indicators of adding natural capital alone to baseline farms

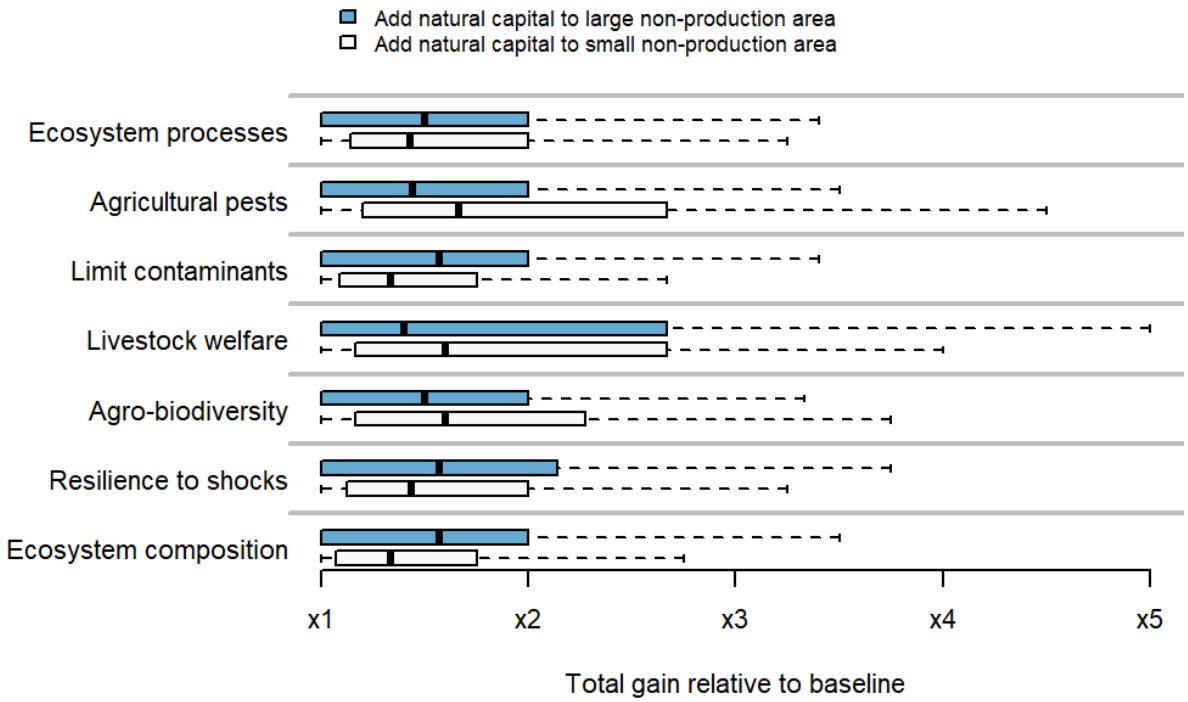

Figure 21 Performance gains for 7 objectives of adding natural capital alone to baseline farms

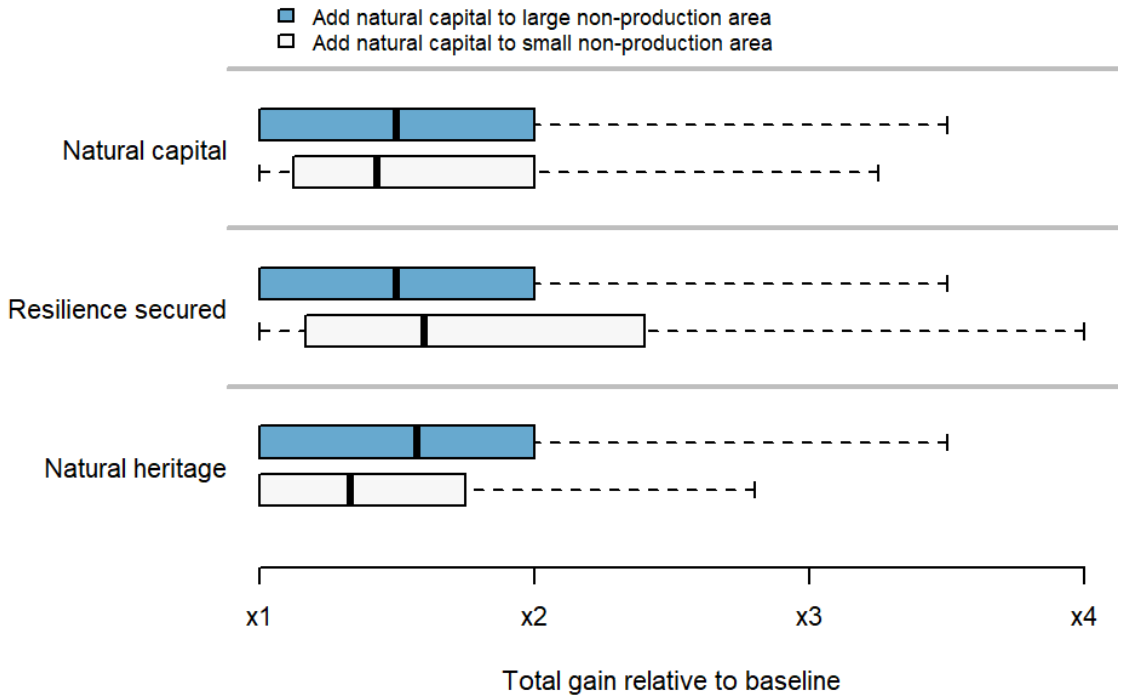

Figure 22 Performance gains for three outcomes of adding natural capital alone to baseline farms

6 Conclusions

This report shows how evidence-based tools can help land managers evaluate the impact of different management strategies on biodiversity and broader environmental outcomes, for individual farms or a group of farms, to:

- achieve the best outcomes with the natural capital available,
- prioritise mangement actions to improve performance and deliver faster benefits,
- explore what can be done next to add value,
- define and refine realistic management goals by exploring which strategies can be applied for a specified number of farms to reach a target biodiversity or environmental score within a stated timeframe.

This demonstration was based on a hypothetical set of farms and management strategies derived from data simulations – an approach that could be readily tailored in the future to:

- meet the specific needs of farms within any catchment, region or sector, while stipulating which management actions are relevant to different farm types present,
- provide a more in-depth assessment of the impact of different management strategies on each species group or a subset of groups of particular interest,
- encompass other sustainability outcomes.

These adaptations would help faciliate the development of more nuianced management strategies, where a suite of complementary management approaches could be applied across a group of farms to deliver desired outcomes.

Scores derived from the biodiversity assessment tool were linked to a hierarchical assessment framework to evaluate broader environmental outcomes (Table 1; MacLeod and Moller 2013; MacLeod, Brandt and Moller 2019). Performance was evaluated in relation to three high-level environmental outcomes, providing metrics that can be readily and succinctly reported. For example, in our case, showing that adding natural capital to large (vs. small) non-production areas could double the natural heritage gains on farms. This high-level evaluation was informed by a more detailed and transparent appraisal of management practices in relation to specific objectives, indicators and measures (e.g. species group scores), all of which are aligned to a specific environmental outcome.

Our approach would ideally be expanded to include a broader cost-benefit analysis of different management strategies on New Zealand farms, by incorporating the direct costs of implementing each of the 43 actions within the NZSD biodiversity assessment tool as well as the opportunity costs of taking each action. An evidence-based evaluation of the effectiveness of each action within the NZSD biodiversity tool for benefiting other environmental (e.g. soil quality, water quality, biosecurity) or sustainability (production, economic, governance, social) outcomes would add value to the assessment process.

7 Recommendations

- Adapt the data simulations in this report to meet specific stakeholder needs, including identifying management strategies likely to deliver specified environmental goals.
- Quantify the direct costs of implementing each of the 43 actions within the NZSD biodiversity assessment tool, as well as the opportunity costs of taking each action.
- Identify which other environmental and sustainability outcomes are stakeholder priorities, and undertake an evidence-based evaluation of the effectiveness of each action within the NZSD biodiversity tool for delivering those outcomes.
- Undertake a panel-based assessment of the relevance of each of the species groups for each of the indicators in the NZSD environmental assessment framework.

8 References

Brandt AJ, MacLeod CJ, Dicks LV, Shackelford G. 2018. Effectiveness of farm management actions for enhancing NZ biodiversity: Specialist judgement assessment. NZ Sustainability Dashboard Research Report 18/06. Published by ARGOS.

Brandt AJ, MacLeod CJ, Dicks LV, Shackelford G 2018. Effectiveness of farm management actions for enhancing NZ biodiversity: Evidence evaluation assessment. NZ Sustainability Dashboard Research Report 18/07. Published by ARGOS.

MacLeod CJ, Brandt AJ, Moller H. 2019. Agro-environmental assessment framework for the NZ Sustainability Dashboard (version 2). NZ Sustainability Dashboard Research Report 19/01. Published by ARGOS.

MacLeod CJ, Brandt AJ, Collins K, Miller S, Shackelford G, Dicks LV (2019a). Co-design evidence-based, locally-relevant and useful tools to improve sustainability performance. New Zealand Sustainability Dashboard Policy Brief Series.

MacLeod CJ, Brandt AJ, Collins K, Dicks LV, Shackelford G, Wordley C, Sutherland W (2019b). Cost-effective mechanisms for ensuring New Zealand makes best use of global scientific evidence. New Zealand Sustainability Dashboard Policy Brief Series.

MacLeod CJ, Moller H (2013a). Environmental monitoring for sustainable land management in New Zealand's production landscapes. NZ Sustainability Dashboard Research Report 13/10. Published by ARGOS. [Online at: www.nzdashboard.org.nz]

MacLeod CJ, Moller H (2013b). Monitoring to secure agro-environmental integrity in New Zealand. In: Hunt L, McCusker K, MacLeod CJ, Moller H, Reid J, Barr T, Lambert S, Rosin C, le Quellec I, Manhire J 2013. Framework and KPIs for 'The New Zealand Sustainability Dashboard': reflecting New Zealand's economic, social, environmental and management values. New Zealand Sustainability Dashboard Research Report 13/09 37 pp. Prepared by ARGOS.