Economic impact assessment of the biological control of yellow flag iris, *Iris pseudacorus* L., in New Zealand

February 2026

Simon Fowler, Chris McGrannachan, Ronny Groenteman

Manaaki Whenua – Landcare Research, a group of the Bioeconomy Science Institute

Contract Report Registration No: 2526-0034

Prepared for: The National Biocontrol Collective and Ministry for Primary Industries

Reviewed by:
Pike Stahlmann-Brown
Principal Scientist – Economics
Manaaki Whenua – Landcare Research

Approved for release by:
Duane Peltzer
Portfolio Leader – Managing Invasive Species
Manaaki Whenua – Landcare Research

Contents

Summary

Project and client

- Manaaki Whenua – Landcare Research, a group of the Bioeconomy Science Institute, was contracted to produce a report estimating the potential costs to the ornamental iris industry from non-target attack by the yellow flag iris flea beetle, *Aphthona nonstriata* (Goeze), if this insect is approved for release in New Zealand as a biocontrol agent for yellow flag iris, *Iris pseudacorus* L.
- We were also asked to compare these estimates with the cost of controlling *I. pseudacorus*, as well as estimating the cost to develop a biocontrol programme and the benefits from biocontrol. Finally, the report presents an overall benefit:cost analysis, culminating in the estimated economic impact of the biocontrol programme.
- This report was prepared for the National Biocontrol Collective and the Ministry for Primary Industries as part of the 'Multi-weed biocontrol' grant S3F20095.

Objectives

- To estimate the cost of managing any non-target attack by the yellow flag iris flea beetle, *A. nonstriata*, to commercial iris growing operations.
- To estimate the cost of the biocontrol programme against *I. pseudacorus*.
- To estimate the future benefits from successful biocontrol of *I. pseudacorus*.
- To compare the benefits of biocontrol with potential costs to the iris growing industry.

Methods

- The economic analysis ran from the year 2025 to the year 2045.
- The annual costs of controlling *I. pseudacorus* were estimated from the literature, and from surveying regional councils. Increasing costs from 2010 to 2045 were estimated using a logistic growth model with set points for control costs in 2010 and 2025 (from the literature/surveys), and with an assumed maximum annual control cost in New Zealand of $1 million (at 2025 rates). *I. pseudacorus* biocontrol programme costs were taken from past budgetary data, and future costs estimated from expert knowledge. Only the predicted control costs from 2025 onwards were used in the economic analysis. Earlier actual costs were treated as 'sunk'.
- The predicted effectiveness of a biocontrol programme against *I. pseudacorus* was also modelled logistically, following the predicted first agent releases in 2027 and reaching an asymptote at 90% effectiveness by 2045.
- The costs of managing non-target attack in ornamental iris nurseries were estimated based on the logistic increases in biocontrol effectiveness, plus assumptions about the size of the industry and estimated costs of materials and labour to deliver localised insecticidal control of the biocontrol agent if required.
- For the benefit:cost ratio calculations, all future annual costs and benefits were discounted back at an annual discount rate of 2% to give a present value (PV) for 2025. The overall benefit of biocontrol was the PV (2025) reduction in *I. pseudacorus* control costs delivered by biocontrol from 2025 to 2045. PV costs (2025) comprised the costs of the biocontrol programme, plus the costs to control any unwanted non-target Impacts from the biocontrol agent over the 2025–45 time period of the analysis.

- A sensitivity analysis tested how the economic analysis responded to changes in the discount rate, the costs of developing the biocontrol programme, the level of success of the biocontrol programme, the costs of controlling *I. pseudacorus*, and the area of commercial irises requiring protection from possible non-target attack.

Results

- All the dollar figures reported are at 2025 rates.
- Control costs for *I. pseudacorus* in New Zealand in 2024 were calculated from stakeholder data at $321,000. In comparison, annual control costs for 2010 were estimated as $76,000, which reflects the rapidly increasing importance of *I. pseudacorus* in New Zealand. In the logistic model, annual control costs (in the absence of biocontrol) reached $870,000 by 2045, heading towards the assumed asymptote of $1 million.
- The total costs associated with the introduction of one agent, *A. nonstriata*, were estimated to be $421,000 incurred from 2015 to 2028, but only the costs from 2025 onwards were included in the benefit:cost analysis as earlier costs are considered 'sunk'.
- Biocontrol success (represented as a reduction in control costs) was also assumed to follow a logistic pattern, reaching a maximum of 90%, mirrored by a reduction in control costs of 90% in 2045, representing an ongoing annual saving to stakeholders of $780,000.
- The annual cost to alleviate non-target attack was estimated at $8,200 in 2045, comprising 1.1% of the predicted annual benefits from biocontrol in that year.
- The benefit:cost ratio for the overall biocontrol programme in 2025 (with a 20-year time frame) was 33:1, varying from 14:1 to 67:1 in extensive sensitivity testing of individual parameters. In an extremely unlikely worst-case scenario, where all parameters were applied negatively simultaneously, the benefit:cost ratio still remained positive at 2:1.
- The benefit:cost ratio was most sensitive to changes to the cost of developing the biocontrol programme, followed by changes to the discount rate, then by changes to the costs of controlling *I. pseudacorus*, and equally by changes to the level of biocontrol success. Importantly, increasing the cost of alleviating potential non-target impacts on commercial irises had minimal impacts on the overall benefit:cost ratio.
- The assumptions made in the analysis are discussed in depth.
- While we cannot rule out the possibility of *A. nonstriata* damage to ornamental irises, the evidence we have, albeit with limitations, suggests that any such damage will be minimal (possibly zero) and easily managed.

Conclusions

- While non-target impacts to ornamental irises from *A. nonstriata* are highly unlikely, it is not possible to guarantee that they will not occur.
- Should such non-target impacts occur, we estimate the costs of controlling these beetles in iris nurseries remain negligible in comparison to the costs of managing the weed.

Recommendations

- Based on the economic impact assessment presented here, we recommend that the application to the Environmental Protection Authority to release *A. nonstriata* as a biocontrol agent for *I. pseudacorus* should proceed.

1 Introduction

This report estimates the potential costs to the ornamental iris industry from non-target attack by the yellow flag iris flea beetle, *Aphthona nonstriata* (Goeze), if this insect is approved for release in New Zealand as a biocontrol agent for yellow flag iris, *Iris pseudacorus* L. The report also compares these estimates to the cost of controlling yellow flag iris, as well as estimating the cost to develop a biocontrol programme and the benefits from biocontrol. Finally, the report presents an overall benefit:cost analysis, culminating in the estimated economic impact of the biocontrol programme. This report was prepared for the National Biocontrol Collective and the Ministry for Primary Industries as part of the 'Multi-weed biocontrol' grant S3F20095.

2 Background

2.1 Pest status and distribution in New Zealand

Yellow flag iris, *Iris pseudacorus*, is an unwanted organism in New Zealand under the Biosecurity Act 1993. It is also a National Plant Pest Accord species, which prevents its sale and distribution in New Zealand. It is considered a regional pest plant in Northland ('eradication pest plant'; Northland Regional Council 2017), Auckland ('surveillance pest plant'; Auckland Regional Council 2007), Waikato and the Bay of Plenty ('containment pest plant'; Waikato Regional Council 2014, Bay of Plenty Regional Council 2011). In the South Island, yellow flag is considered a 'regional surveillance pest' in the Tasman-Nelson and Canterbury regions (Canterbury Regional Council 2011; Tasman District Council and Nelson City Council 2012), and a 'progressive control plant' on the West Coast (West Coast Regional Council 2010). For a deeper analysis of the pest status of *I. pseudacorus* in New Zealand, please refer to McGrannachan & Barton 2019.

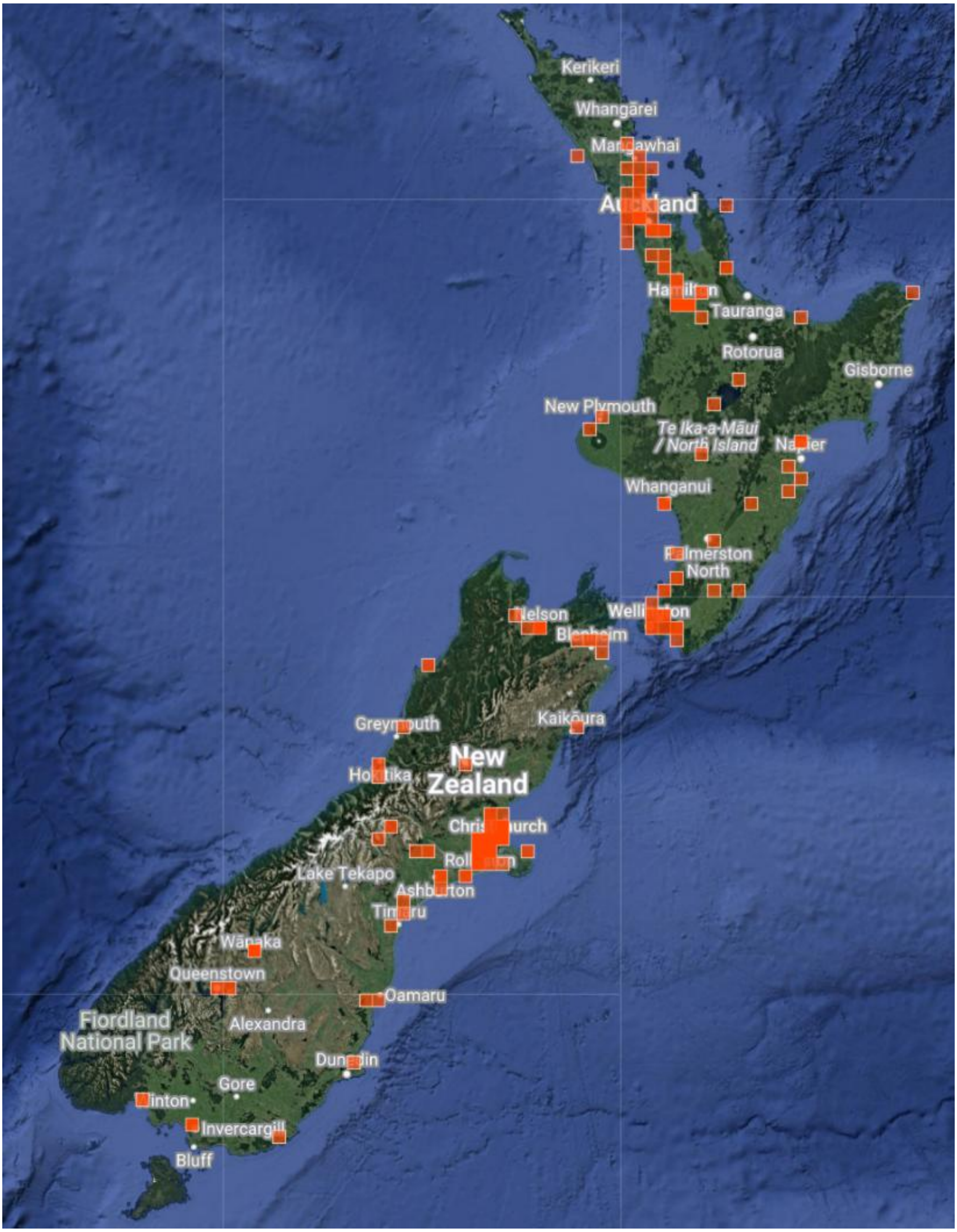

Figure 1. Records of *I. pseudocarus* in New Zealand on iNaturalist.

2.2 Detrimental impacts of *Iris pseudacorus*

2.2.1 Environmental and ecological impacts

Iris pseudacorus is responsible for several negative environmental and ecological impacts in its introduced range. Its ability to reproduce vegetatively allows the formation of dense stands and thick, submerged rhizome mats (Morgan et al. 2025). These rhizome mats prevent the germination and growth of many native species, such as sedges and rushes, eventually resulting in their complete displacement from local environments (Lui et al. 2010; Morgan et al. 2025).

The dense mats can also alter water flows and hydrological systems, as well as raising ground level locally, through the trapping of sediments (Sarver et al. 2008; King County Noxious Weed Program 2009). This can create a feedback loop in which the dense rhizome mats trap sediment, allowing for the growth of new seedlings, which in turn enables the accumulation of more sediment (Jacobs et al. 2011; Morgan et al. 2025). The accumulation of sediment can also create new habitat for other plant species, such as trees and shrubs, which in turn causes ecosystems to become drier (Sarver et al. 2008; Lui et al. 2010).

In systems with flowing water, *I. pseudacorus* may decrease water movement by clogging irrigation and flood control ditches, and drainage pipes, and by reducing stream width (Jaca & Mkhize 2015; Morgan et al. 2025), resulting in increased flooding risk. Natural water-filtration processes and services provided by native aquatic and riparian flora can also be detrimentally altered (DiTomaso & Kyser 2016).

Finally, *I. pseudacorus* can directly outcompete native plant species, which can have flow on impacts to other native species.

2.2.2 Socio-economic impacts

In waterbody margins where *I. pseudacorus* forms dense stands, fishing and recreational activities may be restricted (Wildland Consultants 2011). This may have an impact on the tourism industry in areas adversely affected by *I. pseudacorus*.

Iris pseudacorus is usually unpalatable to wildlife and livestock, but sheep and cattle will graze it if feed is limited (Sutherland 1990). If ingested, it can be toxic to both humans and animals due to glycosides found within all parts of the plant (but particularly the rhizomes) (Cooper & Johnson 1984; Burrows & Tyrl 2001). Yellow flag poisoning can result in a range of symptoms, including spasms, staggering, paralysis, gastroenteritis, abdominal pain, nausea and vomiting, and diarrhoea (Tu 2003). It may even result in death for some animals, such as dogs (Burrows & Tyrl 2001). The plant's sap can also act as a skin irritant to humans, causing dermatitis (Fuller & McClintock 1986; Williams & Champion 2008).

2.3 Beneficial uses

Several studies have shown *I. pseudacorus* to be a suitable candidate for phytoremediation of wetlands and waterbodies, and particularly for the removal of heavy metals from sewage treatment areas (Gedebo & Froud-Williams 1998; Yousefi & Mohseni-Bandpei 2010; DiTomaso & Kyser 2016). We have found no evidence of the use of *I. pseudacorus* for phytoremediation in New Zealand.

In its native range *I. pseudacorus* may be beneficial for native species by providing shelter and habitat. However, there are no known records of indigenous New Zealand species benefiting from *I. pseudacorus* (Probst et al. 2022).

Although seldom used medicinally nowadays, there have been many herbal and natural uses for *I. pseudacorus*. The root of *I. pseudacorus* was widely used as a powerful cathartic despite it being highly acrid (Grieve 1971). The root, when held against an aching tooth, is thought to bring relief (Phillips & Foy 1992). The seeds have been used as a substitute for coffee when they are well roasted (Phillips & Foy 1992). Other herbal-based uses include using the flower to create a yellow dye and using the root to make ink (Grieve 1971). We have found no evidence of any of these uses of *I. pseudacorus* in New Zealand.

2.4 Control options

Mechanical and manual methods have been used to control *I. pseudacorus* in its introduced range, but these are very labour- and time-intensive. Except for small or new infestations, these methods are seldom effective, as even a small piece of the extensive rhizome mats can resprout (Tu 2003). However, in invaded regions with high-density populations, mechanical and manual methods, and possibly fire, may be the only viable and available options for management (Sandenbergh et al. 2024).

Digging, backhoeing or grubbing rhizomes may only be effective if all the rhizomes are removed and the method is repeated every 3–4 years, as populations will re-establish otherwise (Jacobs et al. 2011; Morgan et al. 2025). These manual removal methods in moving water systems may cause dislodged rhizome pieces to be carried downstream, where they are likely to establish new populations (USDA-APHIS 2013). They can also cause fragmented rhizomes to germinate, or promote the germination of other weed species present in the soil seed bank (GISD 2025). Furthermore, the disturbance created by mechanical and manual methods in sensitive aquatic areas may detrimentally affect native species and could facilitate the establishment of other weed species (DiTomaso & Kyser 2016).

Mowing and/or clipping the flower heads before seed production can help to reduce the number of viable seeds but will not kill the plant (Tu 2003; DiTomaso & Kyser 2016). General pulling or cutting of the plant annually over the course of several years may weaken and eventually kill the targeted plant (Tu 2003). The placement of rubber matting (also known as benthic barriers) has been shown to work well against *I. pseudacorus* (Tarasoff et al. 2016).

Chemical control methods have been widely used against *I. pseudacorus*. Glyphosate is an effective herbicide commonly applied, often directly onto foliage or immediately after cutting leaf and stem surfaces (GISD 2025). Large-scale herbicide application may, however, be impractical in aquatic settings, such as in shallow water or the muddy verges of ponds, lakes, streams or canals (DiTomaso & Kyser 2016).

In New Zealand, manual control is not considered an effective management technique against *I. pseudacorus* (Williams & Champion 2008). Instead, the current recommended management method is chemical control using either metsulfuron or glyphosate (Wildland Consultants 2011). Metsulfuron application over water requires resource consent (Weedbusters 2025). This usually requires repeat applications, both to prevent re-infestation from nearby populations and to control seedlings at sites with a developed seed bank (Wildland Consultants 2011). It has been estimated that the cost (both labour and herbicide) of chemical control of *I. pseudacorus* is $100 to $340 per hectare when dealing with isolated patches, and as much as $1,350 or more when cover exceeds

40% (Wildland Consultants 2011). In November 2010 labour costs (288 hours) of *I. pseudacorus* control along c. 23 km of shoreline at Lake Waikare were $18,720 (Wildland Consultants 2011). This reflects the high costs of continued chemical control efforts of *I. pseudacorus*.

2.5 Suitability of *Iris pseudacorus* as a target for biological control

Manual control of *I. pseudacorus* is often ineffective because small rhizome pieces will readily resprout (Tu 2003). Chemical control is currently the preferred method in New Zealand, but requires repeat applications, is time, labour and cost intensive, and risks polluting waterways. As a result, in 2019 Manaaki Whenua – Landcare Research was contracted by Waikato Regional Council to conduct a feasibility study to ascertain whether biocontrol of *I. pseudacorus* was achievable in New Zealand (McGrannachan & Barton 2019). The feasibility study concluded that biocontrol is a feasible option.

Host range testing for the first candidate agent in the biocontrol programme against *I. pseudacorus* in New Zealand, the flea beetle *Aphthona nonstriata* (Goeze) (Coleoptera: Chrysomelidae), was completed in May 2025. The testing confirmed that the beetle's host range is restricted to the genus *Iris*, and that some ornamental species of *Iris* are included in the fundamental/physiological host range of the beetle. While attack of these other irises under natural conditions is of low likelihood, it is not possible to guarantee that such attack will not occur. We therefore assessed the economic impact that such attack could have on the iris growing industry and compared it to the economic impact of the biocontrol programme against *I. pseudacorus*.

3 Objectives

- To estimate the cost of managing any non-target attack by the yellow flag iris flea beetle, *A. nonstriata*, to commercial iris growing operations.
- To estimate the cost of the biocontrol programme against *I. pseudacorus*.
- To estimate the future benefits from successful biocontrol of *I. pseudacorus*.
- To compare the benefits of biocontrol with the costs to the iris growing industry.

4 Methods

4.1 Control costs for *I. pseudacorus* in New Zealand

Information for this analysis was sourced from:

- a detailed study in the lower Waikato River (Wildland Consultants 2011)
- management cost figures provided by regional councils and other local government bodies (which have regional responsibilities for invasive weed management under the New Zealand Biosecurity Act 1993), and from the Department of Conservation (which manages the conservation estate in New Zealand).

The first year for which we had control cost data was 2010, so we took 2010 as the starting year for this economic analysis.

Most stakeholder data were provided for 2024, but in two instances (Department of Conservation Waikato and Environment Canterbury) earlier data were adjusted to 2024 using the New Zealand Consumer Price Index[1] (Table 1). To model increases in *I. pseudacorus* control costs over time, all data in Table 1 were further adjusted to 2025 rates (using an assumed 2024/25 inflation rate of 2.5%), rounded to the nearest $1,000, then summed to generate the total figure for the base analysis.

Table 1. ***Iris pseudacorus*** **control costs, 2010 to 2024 (adjusted to 2025)**

Organisation/cost category	Control cost*
Department of Conservation, Waikato (2010)	$27,000
Environment Canterbury (2022)	$4,000
Auckland Council (2024)	$6,000
Bay of Plenty Regional Council (2024)	$46,000
Christchurch City Council (2024)	$23,000
Waikato Regional Council (2024)	$215,000
Total = base analysis	**$321,000**
High control costs (2 × base)	$642,000
Low control costs (0.5 × base)	$160,500

* Data provided by stakeholders. The control costs for the base analysis (row 8) are the sum of the stakeholder costs (rows 2–7; all figures are adjusted to 2025). Rows 9 and 10 show the high/low control cost figures used in the sensitivity tests.

4.2 Base analysis and sensitivity analysis

The total control cost of $321,000 was the key stakeholder annual control cost figures input into the logistic model of the annual *I. pseudacorus* control costs in New Zealand, applying the same generalised logistic equation used in Fowler, Groenteman et al. 2023:

$$f_{(x)} = \frac{L}{1 + e^{-k(x - x_0)}}$$

where:

- f(x) = the cost of *I. pseudacorus* control in year x
- *L* = the maximum control cost of *I. pseudacorus* (asymptote)
- x_o = the year in which the curve is at its steepest point (mid-point of the curve)
- *k* = the steepness of the curve.

The models were fitted with the asymptote, *L*, constant at $1 million, representing an estimate of the maximum that stakeholders in New Zealand would be willing to invest annually in control of *I. pseudacorus* given budget constraints and the ever-present need to manage other pest species.

[1] https://www.rateinflation.com/consumer-price-index/new-zealand-historical-cpi/, accessed 26 May 2025).

The costs in year 2024 (at 2025 rates) were fixed at the level provided by stakeholders for the base analysis ($321,000, Table 1).

Model fit was obtained by solving the base analysis equation for a mid-point selected as 2030 to give a value for steepness, *k*, of 0.125. Steepness (*k*) and mid-points (x_0) were then adjusted (with *L* held at $1 million) to create the high- and low-cost scenarios, with the requirement that 2024 costs were, respectively, 2× (i.e. $642,000) and 0.5× (i.e. $160,500) of the stakeholder costs from the base analysis ($321,000; Table 1).

The logistic models were also required to fit to appropriate starting costs for *I. pseudacorus* in 2010. These 2010 starting points for the models were based on *I. pseudacorus* control data for 2010 (adjusted to 2025 rates) in Wildland Consultants 2011; i.e. a total of $38,000, comprising $27,000 for the Department of Conservation and $11,000 for Waikato Regional Council. However, because this cost figure of $38,000 only covered the lower Waikato River region and was derived from just two stakeholders, it was certain to be a substantial underestimate of national *I. pseudacorus* control costs in 2010. Hence, in the absence of any more detailed information, we doubled this figure to $76,000 to approach what we considered would be a better approximation of national *I. pseudacorus* control costs in 2010 (at 2025 rates).

For the sensitivity analysis we varied this figure by 0.5× ($38,000 for the lower-cost scenario) and 2.0× ($152,000 for the higher-cost scenario). These estimated 2010 *I. pseudacorus* control costs are the y intercepts (at year 2010) of the three cost scenario lines in Figure 2.

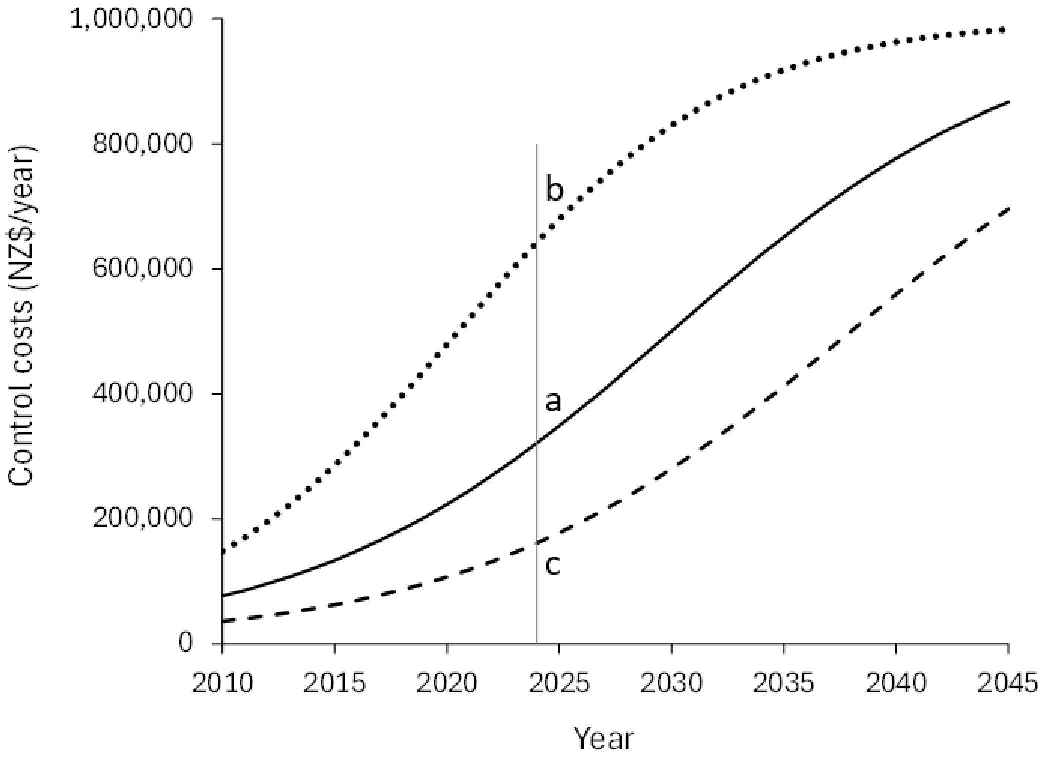

Figure 2. The predicted annual costs for *I. pseudacorus* control in NZ used in the economic analysis.

Notes: All figures are at 2025 rates. The base scenario (solid line) is modelled using a logistic equation and estimates of *I. pseudacorus* control costs by stakeholders from 2010 to 2024, with an upper limit for the logistic curve set as $1 million. The higher-cost scenario (dotted line) and the lower-cost scenario (dashed line) were created by varying parameters in the logistic model and used in the sensitivity analyses. The grey vertical line at year 2024 intersects the base analysis cost trajectory (a) at $321,000, and the higher (×2; b) and lower (×0.5; c) cost trajectories of this value. Further details in the text.

The overall economic analysis was carried forward from 2025 for 20 years to 2045, giving the prospective biological control programme sufficient time to reach maximum effectiveness even in our most pessimistic scenario (Figure 3). The annual cost data input into the economic analysis were therefore estimated total *I. pseudacorus* control costs for stakeholders for each year, 2025 to 2045 (at 2025 rates).

4.3 Cost and effectiveness of the biocontrol programme

Future biocontrol programme costs for *I. pseudacorus* in New Zealand were estimated (2025 rates) following the methods used in recent New Zealand analyses (Paynter et al. 2015; Fowler et al. 2016; Fowler, Barringer et al. 2023; Fowler, Groenteman et al. 2023). In the sensitivity analysis the biocontrol costs were decreased by 50% and increased by 100%. The first releases of the biocontrol agent were assumed to occur in 2027.

Increases in the percentage effectiveness of biocontrol (resulting in matched decreases in *I. pseudacorus* control costs) were modelled using the same logistic equation as used to model *I. pseudacorus* control costs above. The final level of biocontrol effectiveness, the asymptote of the logistic curve, was assumed to be 90% (i.e. a 90% reduction in *I. pseudacorus* control costs). For the base analysis (Figure 3), the mid-point of the logistic equation, x_0, was the year 2035, 8 years after the predicted first releases of the biocontrol agent in 2027. The steepness, k, was 0.7, which resulted in biocontrol effectiveness approaching 90% by 2040, 13 years after the first agent is released.

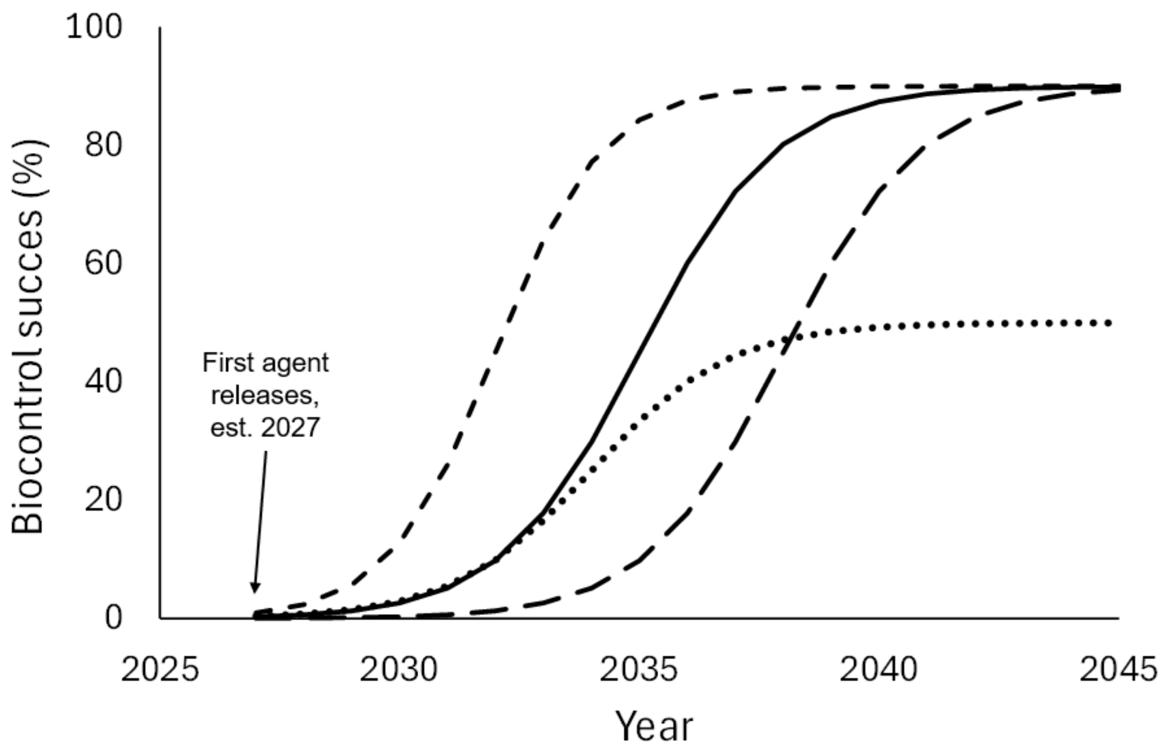

Figure 3. The scenarios for increasing biocontrol success used in the sensitivity testing: base analysis (solid line), biocontrol success more rapid (short-dashed line), biocontrol success slower (longer-dashed line), biocontrol success only reaches 50% (dotted line).

For the sensitivity tests, three other biocontrol scenarios were modelled (Figure 3): slower, faster, and a final level of control achieved of 50% rather than 90%. For the slower biocontrol scenario, the mid-point of the curve was set to 2038 with k = 0.7. For the faster biocontrol scenario, the mid-point was 2032 with k = 0.9 (the increased steepness being required to ensure effectiveness did not start increasing above zero before the first agent release in 2027). To model a lower final biocontrol effectiveness, the asymptote, L, was reduced to 50% with steepness, k, = 0.7, and the mid-point set as year 2034 to give an initial trajectory that closely matched the base analysis (Figure 3).

4.4 Costs of non-target impacts

Given how closely related *I. pseudacorus* is to some of the species and cultivars of ornamental irises grown in New Zealand, it was not possible to completely exclude the possibility of some non-target attack on ornamental irises by *A. nonstriata* after release and establishment in New Zealand. However, the risk of any non-target attack on plants other than ornamental irises was considered negligible and was excluded from the current economic analysis.

As in Jarvis et al. (2006), we used the estimated costs of overcoming any potential non-target impacts on ornamental irises using insecticide application to kill the biocontrol agent. Like Jarvis et al. (2006), we considered that one effective application of an appropriate insecticide in spring would achieve sufficient control of a univoltine[2] biocontrol agent with adult beetles emerging from overwintering in spring. With *A. nonstriata*, any need for an insecticide application would be conveniently signalled by the appearance of the diagnostic epidermal strip-feeding of the adult beetles that leaves conspicuous pale lines parallel to the margins of iris leaves (Iris flea beetle *Aphthona nonstriata* 2025).

Not surprisingly, no information was available on insecticidal control of *A. nonstriata*, but we sourced information on effective control methods for other species of flea beetles that can be significant pests (e.g. of *Brassica* crops, Johnson 2025). For costing purposes, we selected one insecticide that was recommended to control flea beetles, active ingredient lambda-cyhalothrin, a reasonably persistent synthetic pyrethroid, often sold as Karate Zeon™ (Syngenta 2025). Karate Zeon™ was also used successfully to control heather beetle, *Lochmaea suturalis* (Thomson), in experimental impact studies of this weed biocontrol agent in New Zealand (Peterson et al. 2020).

We assumed that the individually small areas of irises that would potentially need protection from *A. nonstriata* would usually best be tackled using standard 15 L knapsack sprayers, despite the high labour costs of knapsack spraying compared to other application methods such as boom spraying from vehicles. Consequently, over 90% of the total insecticide costs comprised labour costs in our analysis. Spray labour costs were estimated as $417/ha, assuming 25 knapsack sprays were needed to cover 1 ha, with each full knapsack spray requiring 20 minutes of a person's time and staff costs of $50/h. The cost of insecticide and adjuvant was estimated at $40/ha (<10% of the total spray costs). No allowance was made for the small costs of equipment or staff training, as nurseries would already possess and use this equipment and capability.

The total area of irises in New Zealand that might require spray protection from *A. nonstriata* was hard to estimate. Nurseries will have stock plantings for harvesting rhizomes and cut flowers for sale, although a component of the latter will be imported. We roughly estimated that there might be

[2] Univoltine – has one generation per year

a total of 20 ha of nursery/amenity and cut-flower plantings of irises in New Zealand that might need insecticide protection, but in the sensitivity analyses to cover uncertainties we increased this to 50 ha and 100 ha.

The need to apply insecticide to protect ornamental irises was assumed to match the base analysis trajectory for biocontrol effectiveness. Thus, if biocontrol was 50% effective against *I. pseudacorus*, we assumed that it would also be affecting 50% of the area of ornamental irises, which would then need protecting using insecticide.

In summary, to calculate a cost for protecting ornamental irises, we took the spray costs per hectare calculated above for 2025, and multiplied this by the number of hectares predicted to require insecticide protection. For each year, the number of hectares requiring protection was obtained by multiplying the number of hectares of ornamental irises (e.g. 20 ha in the base analysis) with the percentage success value for biocontrol predicted for that year in the base analysis logistic model (solid line in Figure 3).

4.5 Present value analysis and the benefit:cost ratio

To calculate an overall benefit:cost ratio for economic analyses spread over a number of years, each annual cost or benefit figure needs to be discounted back to 2025 to represent a present value (PV). Each annual *I. pseudacorus* control cost, biocontrol cost or non-target cost, from 2025 to 2045, was thus discounted back to 2025 at the selected annual, real discount rate of 2%, following New Zealand Treasury guidelines (The Treasury 2025).

The present PV of biocontrol benefits was then calculated as the cumulative PV of annual *I. pseudacorus* control costs (2025–45) *without* biocontrol, less the cumulative PV of annual control costs (2025–45) *with* biocontrol (i.e. including the costs of the biocontrol programme plus the potential non-target costs). The benefit:cost ratio is then this overall PV biocontrol benefit divided by the overall PV biocontrol costs. In the sensitivity analysis, a discount rate of 8% was used, again following New Zealand Treasury guidelines (The Treasury 2025).

5 Results

5.1 Control costs for *I. pseudacorus* in New Zealand

Data collated from local government authorities and the Department of Conservation in New Zealand indicated that the total annual control cost for *I. pseudacorus* in New Zealand was $321,000 in 2024. Using a logistic growth model, we predicted this would rise to $870,000 by 2045 (solid line, Figure 4), the final year of the current economic analysis, and to $950,000 by 2054 (the year by which the cost is predicted to approach the asymptote). The asymptote of the logistic growth model was set at a maximum annual control cost for *I. pseudacorus* for New Zealand of $1,000,000. All the data presented here and in Figure 4 are at 2025 rates.

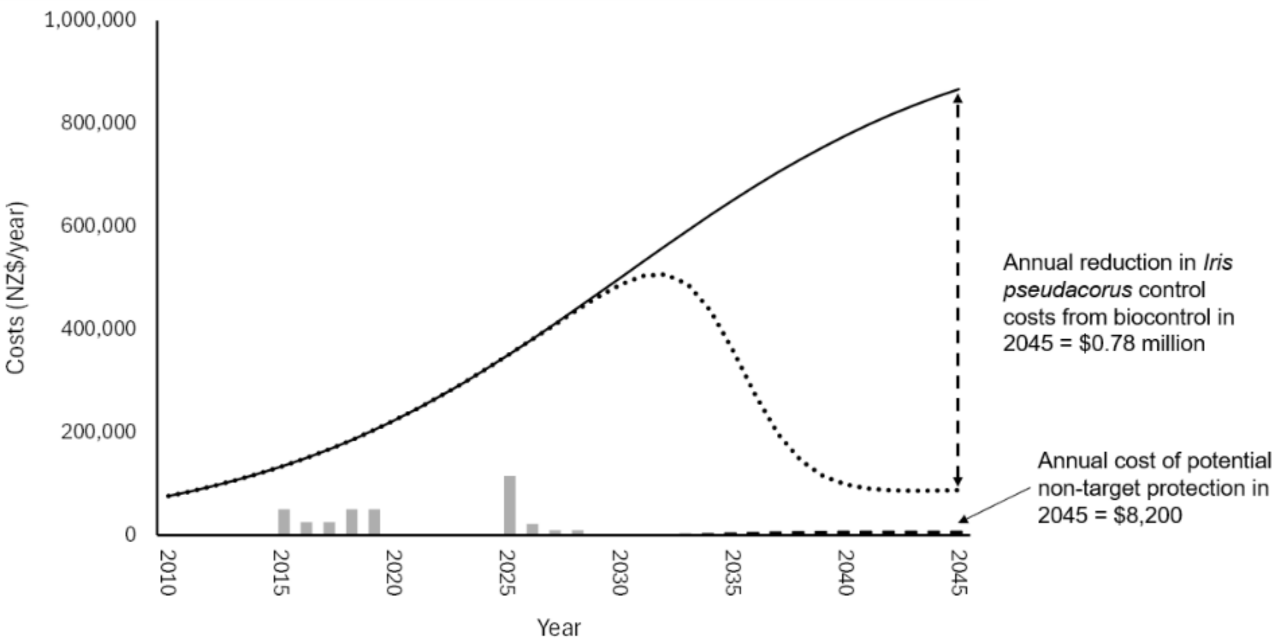

Figure 4. The annual costs of *I. pseudacorus* control in New Zealand from 2010 to 2024 and projected forward to 2045, assuming no biocontrol takes place (solid line) and with successful biocontrol (dotted line).

Notes: The dashed line represents the annual saving in *I. pseudacorus* control costs predicted to occur in 2045. The annual costs of undertaking a biocontrol programme are shown in grey bars. No non-target impacts of the biocontrol agent on ornamental irises are expected, but in the unlikely event that some attack occurs, the annual costs of preventing such damage by applying insecticides are relatively small (black bars). All figures at 2025 rates.

5.2 Cost and effectiveness of the biocontrol programme

The actual or predicted annual costs of the biocontrol programme, undertaken from 2015 out to 2028, varied from around $10,000 up to $115,000, depending on the type and scale of the activities undertaken (grey bars; Figure 4). The peak cost was expected to occur in 2025, associated with the build-up to the first agent releases anticipated in 2027. Total costs associated with the introduction of one agent, *A. nonstriata*, were predicted to be $357,000, incurred from 2015 to 2028. All these figures are at 2025 rates.

The effectiveness of biocontrol was represented by reductions in *I. pseudacorus* control costs. Thus, as biocontrol effectiveness increases logistically over time (Figure 3), there is a symmetric reduction in annual *I. pseudacorus* control costs (dotted line; Figure 4). The difference between the solid (no biocontrol) and dotted (with biocontrol) lines in Figure 4 is the predicted saving in *I. pseudacorus* control costs for any given year. For the base analysis, annual savings start slowly, reaching 10% of control costs by 2032 (5 years after the first releases of the biocontrol agent) and increase following the logistic model to reach $0.78 million by 2045 (90% of *I. pseudacorus* control being saved annually). This scale of annual benefit of $0.78 million is then ongoing, requiring no further investment. As the biocontrol benefits accumulate after 2045, the current benefit:cost ratio will gradually rise (see below).

5.3 Non-target impacts

Although considered unlikely to materialise, the risk of some non-target impact of *A. nonstriata* on ornamental irises could not be ruled out. Thus, an annual cost of insecticide application to prevent possible damage to ornamental irises from *A. nonstriata* was built into the overall economic analysis. It was assumed that any non-target damage would mirror the effectiveness of the agent against the target weed.

Given the relatively low costs of the insecticide treatments proposed to control *A. nonstriata* on ornamental irises ($417/ha in 2025), the national costs associated with preventing non-target damage were relatively low. They started at <$100 in 2028, rising logistically to around $5,000 by 2035/36, and starting to level off at just over $8,200 in 2045 (black bars; Figure 4). These represented only about 1–2% of the annual saving in *I. pseudacorus* control costs from biocontrol in each year. Put another way, in the unlikely event of non-target impacts occurring, the total predicted cost of protecting ornamental irises from 2025 to 2045 was $0.086 million. This is only 1.2% of the predicted total gain of $7.2 million in reduced *I. pseudacorus* control costs over the same period.

5.4 Present value analysis and the benefit:cost ratio

Present value (PV) figures enable calculation of benefit:cost ratios using annual losses/costs incurred over the 20 years from 2025 to 2045. The calculated PV of *I. pseudacorus* control costs from 2025 to 2045 without biocontrol (with all future annual costs discounted back to 2025) was $10.7 million. With biocontrol, the PV of *I. pseudacorus* control costs were reduced to $5.3 million. The potential benefit of biocontrol PV of $5.4 million was then reduced by the PV of $0.064 million required to protect non-target species, and the PV $0.16 million for biocontrol (excluding pre-2025 costs as ‘sunk’). The resulting benefit:cost ratio was 33:1.

5.5 Sensitivity analyses

In sensitivity testing (Table 2), the predicted annual reduction in *I. pseudacorus* control costs in 2045 ranged from $0.6 million to $0.9 million with most parameter adjustments. However, when the effect of biocontrol was reduced to 50% (from 90%), the predicted annual reduction in control costs in 2045 was $0.4 million. In the extreme example where sensitivity test parameters were simultaneously combined in a worst-case scenario, the predicted annual reduction in control costs in 2045 was $0.35 million

The predicted cost of non-target impacts also remained below $10,000 per year in 2045 in nearly all the testing, with the unsurprising exception of the scenarios where the non-target area requiring control was increased. Even then, the non-target costs remained at less than 10% of the reduction in *I. pseudacorus* control costs (Table 2), resulting in little overall effect on benefit:cost ratios, which remained at over 30:1.

Increasing the discount rate to 8% only affected the PV calculations, so this adjustment only affected the benefit:cost ratio in row 2 of Table 2, bringing it down from 33:1 (base analysis) to 14:1.

Benefit:cost ratios were moderately affected by adjustments to biocontrol parameters, but always stayed strongly positive (Table 2). Changing the biocontrol costs by 0.5× or 2× had approximately pro-rata effects on the benefit:cost ratios. Altering the rapidity or final success level of biocontrol also had only moderate effects on the benefit:cost ratios.

In an extremely unlikely worst-case scenario situation where all the sensitivity test parameters were combined so that they had their maximum negative effects, the benefit:cost ratio remained positive but was reduced to 2:1 (example 7 in Table 2). This extreme test is largely of theoretical interest only, and we consider it unrealistic so do not discuss it further.

Overall, excluding the worst-case scenario, the benefit:cost ratio in the sensitivity analyses ranged between 14:1 and 67:1.

Table 2. The results of sensitivity analyses, showing the predicted reductions in *I. pseudacorus* control, the predicted non-target control costs (absolute and percentage), and the benefit:cost ratio in the year 2045

	Sensitivity test adjustment	Annual saving in *I. pseudacorus* control costs, 2045	Non-target control costs, 2045	Non-target costs as % of savings, 2045	Benefit:cost ratio
1	Base analysis	$779,409	$8,213	1.1%	33:1
2	Discount rate 8%	$779,409	$8,213	1.1%	14:1
3a	*I. pseudacorus* costs ×0.5	$625,627	$8,213	1.3%	23:1
3b	*I. pseudacorus* costs ×2	$884,353	$8,213	0.9%	42:1
4a	Biocontrol costs ×0.5	$779,409	$8,213	1.1%	67:1
4b	Biocontrol costs ×2	$779,409	$8,213	1.1%	16:1
5a	Biocontrol success slower	$774,353	$8,159	1.1%	24:1
5b	Biocontrol success faster	$780,113	$8,220	1.1%	42:1
5c	Final biocontrol success 50%	$433,203	$4,565	1.1%	20:1
6a	Non-target area 50 ha	$779,409	$20,531	2.6%	32:1
6b	Non-target area 100 ha	$779,409	$41,063	5.3%	31:1
7	Combined test (2+3a+4b+5c+6b)	$347,730	$22,823	6.6%	2:1

Note: See text for details of sensitivity test adjustments.

6 Discussion

This study was initiated because it became clear that the flea beetle, *A. nonstriata* is an *Iris* specialist and that the predicted risk to specific groups of *Iris* species or cultivars could not be further refined with additional testing in a contained environment. We thus assumed that attack of ornamental irises, should the flea beetle be released in New Zealand, is possible. Instead of conducting additional host range testing, we opted to assess the balance of beneficial economic impacts of the biocontrol programme on the target weed and the undesirable economic impacts to growers of ornamental irises in the eventuality that non-target feeding occurs following the release and establishment of *A. nonstriata*.

Sensitivity tests with individually varied parameters showed that the benefit:cost ratio was substantially affected by the cost of the biocontrol programme. The highest benefit:cost ratio of 67:1 was achieved if biocontrol costs were halved, and a much lower ratio of 16:1 was achieved when biocontrol costs were doubled. It is plausible to assume that the cost of the biocontrol programme will end up doubling over time, because we have predicted from the outset of the programme that a second agent is likely to be required. We also acknowledge that the cost of the current phase of the programme is at the mid to lower end of the scale, thanks to the collaboration with South Africa, who are also pursuing a programme against *I. pseudacorus*. Should a second agent indeed be required for New Zealand, the same collaboration with South Africa is expected to keep the cost of the programme within the same range as the current phase.

We note that the high sensitivity of the benefit:cost ratio to the cost of the biocontrol programme reflects the fact that the programme is being pursued at a relatively early stage of *I. pseudacorus* invasion, when control costs are still modest compared to the cost of developing the biocontrol programme. If the biocontrol programme were to be initiated after *I. pseudacorus* had spread to occupy a greater share of its potential range and control costs had escalated, then the cost of developing biocontrol would have been considerably smaller in relative terms, and the benefit:cost ratio would have been less sensitive to changes in these costs.

Increasing the real discount rate to 8% also had a large impact on the benefit:cost ratio, reducing it to 14:1. The higher discount rate is suggested by the New Zealand Treasury for commercial projects. Classical biocontrol programmes such as the biocontrol programme against *I. pseudacorus* fall under the definition of a non-commercial project and have a long time-lag between the costs of development being incurred and the benefits being realised. Hence, the use of the lower non-commercial Treasury discount rate of 2% is justified (Katz 2024).

Adjusting the modelled pace of biocontrol impacts on *I. pseudacorus* such that the reduction in weed control costs become slower or faster led to benefit:cost ratios ranging from 24:1 to 42:1. In reality it is hard to predict how rapidly a biocontrol programme will operate, so these positive benefit:cost ratios are encouraging. Similarly, the final level of success achieved in terms of reductions in weed control costs are hard to predict. In this case, the modelling predicts that a reduction in biocontrol effectiveness from 90% to 50% leads to a drop in the benefit:cost ratio from the baseline level of 33:1 down to 20:1. Again, this test still leaves the benefit:cost ratio encouragingly positive.

Increasing the area of commercial ornamental iris affected by non-target attack generated only small changes in the benefit:cost ratios, because the non-target costs were always relatively low compared to the benefits from biocontrol. When considering the area of commercial irises susceptible to non-target attack it is important to note that some groups of cultivated irises, such as Louisiana irises (*I.* ser. *hexagonae*) and tall-bearded irises (*I. germanica*) were unsuitable for *A. nonstriata* development (McGrannachan 2025). We do not know what proportion of the area of cultivated irises in New Zealand is planted in irises of these groups, which would not require any control measures.

While we cannot rule out the possibility of *A. nonstriata* damage to ornamental irises, some evidence, both anecdotal (see Appendix) and scientifically tested, suggests that damage to ornamental irises will be minimal and easily managed. Feedback from iris growers in Europe (the native range of *I. pseudacorus* and *A. nonstriata*) has overwhelmingly indicated that *A. nonstriata* is *not* a problematic pest of ornamental irises and control is unnecessary. Of the nine European growers contacted, only one respondent from Germany noted attack of *A. nonstriata* on ornamental irises (*I. sibirica* and *I. barbata*) but added that the flea beetle's presence was infrequent (years apart) and easily controlled with one application of an approved insecticide. In the UK, *A. nonstriata* does not appear to be a problem on *Iris* for the home gardener: out of the many thousands of entomological enquiries to the free advisory service offered by the Royal Horticultural Society since 1918, around 200 have been on *Iris*, and *A. nonstriata* was identified only three times: twice in the 1930s and once in 2009. Most damage reports on *Iris* are from other arthropods (A. Salisbury, The UK Royal Horticultural Society, personal communication). Furthermore, out of the 17 species of *Iris* included in the host range testing, certain *Iris* groups did not support development of *A. nonstriata* (e.g., Louisiana and tall-bearded irises; McGrannachan 2025), which indicates that they are unable to sustain beetle populations and any damage on their cultivars is likely to be transient.

6.1 Study assumptions

The study included several key assumptions, which are detailed below.

6.1.1 Selection of the end year of analysis, 2045

The year 2045 was selected as the end point because 20 years from the present (2025) gives plenty of time for biocontrol impact to build up to a postulated maximum, or close enough to it, even at a hypothetical 'slow' rate.

6.1.2 Rate of increase in control costs of *I. pseudacorus*

The logistic model for increasing costs of *I. pseudacorus* in New Zealand was selected because *I. pseudacorus* spread here is likely to follow a logistic pattern, and control costs will likely follow *I. pseudacorus* spread, at least early on. Although we do not know what the final extent of *I. pseudacorus* might be in New Zealand, our logistic model is for stakeholder control costs (rather than spread), and these were assumed to reach an asymptote at $1,000,000 per year (at 2025 rates) based on current levels of investment in weed management. Higher levels of annual investment in control of a single weed species were considered unlikely given councils' and the Department of Conservation's need to control a suite of environmental weeds and pests. The figure climbs to around $1.6 million in the year 2045 (at 2045 rates).

While the accuracy of stakeholder control costs for 2010 and 2024 could be challenged, we worked under the assumption that if stakeholders were investing heavily in *I. pseudacorus* control then we would have heard from them when they were approached to provide input. Thus, we interpreted lack of information/response to be evidence of little/no expenditure (see also Appendix). Costs were varied in the sensitivity tests to account for this assumption.

6.1.3 Non-target impacts

If non-target impacts on ornamental irises do eventuate, then the beetle can be managed with insecticide treatment. Assumptions in this category are therefore split into three: the total area of commercial irises that may be susceptible to non-target impacts, the cost per unit area for chemicals and equipment, and labour costs per unit area treated.

Scale of area to treat

We assumed that the increase and asymptote of area requiring protection against non-target impacts will follow the same trajectory as biocontrol effectiveness against the target weed. We estimated the maximum nursery area of commercial iris growing in New Zealand to be 20 hectares. We came to this estimate by assuming that nurseries for producing rhizomes for sale can fit 10 iris pots per square metre, or 100,000 per hectare. We assumed that if, on average, one-quarter of the adult population in New Zealand buy one pot/rhizome/bulb packet per year, this would total 500,000 pots/rhizomes/bulb packets, or 5 hectares.

We then estimated the cut flower iris industry at 8 million cut stems per year (one to three stems per bunch at one to three bunches per adult per year), giving 4 hectares (at 200 stems per square metre per year). While some cut stems off-season may come from imported material, we exclude this material from the analysis because it is unexposed to the biocontrol agent while in New Zealand. Council and gardener plantings of irises were also excluded from the area estimate because they are unlikely to be treated for the beetle. Rather, they are more likely to be replaced by alternatives. We also recognise that specialist nurseries have stock area, and at least one of these at Amazing Iris Gardens is 2.5 hectares. Thus, rounding up, we came to the figure of 20 hectares. To cover for considerable uncertainties in these estimates, we increased the area estimate to 50 hectares and 100 hectares in the sensitivity analysis.

Cost per hectare of chemicals and equipment

There are multiple options for insecticides. We assumed a contact synthetic pyrethroid (e.g. lambda-cyhalothrin). This active ingredient is recommended for control of flea beetles, and we have used it effectively against leaf-feeding beetles in exclusion experiments in field conditions (Peterson et al. 2020; Groenteman R, unpublished). At a small scale this ingredient costs around $150/L to cover 25 ha at the recommended application rate of 4 mL/ha. An adjuvant may also be required and would add a minor cost to the chemical ingredients.

We assumed that existing spraying equipment will be used by nurseries, and so no cost is associated with purchasing new equipment. For small-scale applications we assumed knapsack sprayers will be used. In larger applications (considered unlikely), other options such as quad bikes can be used, and would be cheaper on a per hectare calculation.

Cost per hectare of labour

We assumed that if insecticide treatment is needed it will be performed by nursery staff at a rate of $50/hour (rather than contractors). If using a 15 L knapsack, which covers 400 m^2, the labour component of such a treatment would total $416.67/ha (20 minutes per knapsack load, 25 loads per hectare). *A. nonstriata* is univoltine and its feeding damage on foliage is distinctive. We therefore assumed one well-timed treatment per year will suffice to control the beetle.

6.1.4 Biocontrol costs/effectiveness

Cost of biocontrol programme

We base our analysis on the assumption of one biocontrol agent for *I. pseudacorus*. An additional agent is accounted for as a scenario of doubling biocontrol costs in the sensitivity analyses. Past and future budget estimates have been calculated in the same way we have calculated them in previous peer-reviewed benefit:cost analyses for individual weed targets (Fowler et al. 2016; Fowler, Barringer et al. 2023)

Effectiveness of the biocontrol programme

Effectiveness in the context of this study is defined as reduction in costs of *I. pseudacorus* control. We assumed logistic population increase and spread of the beetle. A large-scale release effort is likely to speed up the earlier phase to faster than a logistic model. Our base model assumes 90% reduction in control costs when the beetle peaks, and this was dropped to 50% reduction in the sensitivity analysis. We assumed that even at high effectiveness of biocontrol there will remain situations where control by other means will be applied, hence 90% as the maximum effectiveness.

6.1.5 Present value analysis – discount rates

The current Treasury recommendation (up to October 2024) was for a discount rate of 5.0% for most projects (Katz 2024), but more recent recommendations have changed to 2% for non-commercial projects and 8% for commercial projects (with 8% and 2%, respectively, for sensitivity tests) (Reddell 2025; Treasury 2025). The figures of 2% and 8% are real discount rates and exclude inflation, so are appropriate for the current analysis.

7 Conclusions

While non-target impacts to ornamental irises from the yellow flag iris flea beetle, *A. nonstriata*, are highly unlikely, it is not possible to guarantee that they will not occur. Should such non-target impacts eventuate, we estimate that the costs of controlling beetles in iris nurseries will remain negligible in comparison to the benefits in reduced costs of managing the weed as a result of successful biocontrol.

One aspect we have left out of this economic impact assessment is the likely environmental damage and costs from spraying in nurseries or ornamental plantings, which are likely to be minimal compared with continued herbicide use to control *I. pseudacorus* as an environmental weed, often in wetlands or riparian habitats. There is no commonly agreed method to monetise the value of such environmental damages. We consider that our overall estimate of benefits from biocontrol is therefore conservative.

8 Recommendation

Based on the strongly positive benefit:cost ratios in this economic impact assessment, we recommend that the application to release *A. nonstriata* as a biocontrol agent for *I. pseudacorus* should proceed.

9 Acknowledgements

This project was funded by the National Biocontrol Collective and by the Ministry for Primary Industries' SFF Futures 'Multi-weed biocontrol' grant #S3F20095. We thank regional councils and the Department of Conservation for providing figures for *I. pseudacorus* control costs, and Pike Stahlmann-Brown and Angela Bownes for comments on earlier drafts.

Declaration of the use of generative AI / AI-assisted technologies

No generative AI or AI-assisted technologies were used in the analysis and preparation of this report.

10 References

Auckland Regional Council 2007. Auckland regional pest management strategy 2007–2012. https://www.bionet.nz/assets/Uploads/Auckland-Regional-PEst-management-strate-2007-2012.pdf

Bay of Plenty Regional Council 2011. Keeping pests out: regional pest management plan for the Bay of Plenty 2011–2016. https://www.boprc.govt.nz/media/121976/operativeregionalpest_managementplanfor2011-2016webversion.pdf

Burrows GE, Tyrl RJ 2001. Toxic plants of North America. Hoboken, NJ, Wiley-Blackwell.

Cooper MR, Johnson AW 1984. Poisonous plants in Britain and their effects on animals and man. London, HM Stationery Office.

DiTomaso JM, Kyser GB 2016. Shoreline drizzle applications for control of incipient patches of yellowflag iris (*iris pseudacorus*). Invasive Plant Science and Management 9: 205–213.

Environment Canterbury Regional Council 2011. Canterbury regional pest management strategy 2011–2015. https://www.ecan.govt.nz/data/document-library?ids=1505973

Fowler SV, Barringer, J, Groenteman, R, Humphries G 2023. Biocontrol of St John's wort (*Hypericum perforatum*) provides huge ongoing benefits to New Zealand agriculture. New Zealand Journal of Agricultural Research 68: 308–320

Fowler SV, Gourlay AH Hill R 2016. Biological control of ragwort in the New Zealand dairy sector: an ex-post economic analysis. New Zealand Journal of Agricultural Research 59: 205–215.

Fowler SV, Groenteman R, Paynter Q.2023. The highs and the lows: a cost benefit analysis of classical weed biocontrol in New Zealand. BioControl 69: 253–267. doi: 10.1007/s10526-023-10225-2.

Fuller TC, McClintock E 1986. Poisonous plants of California. Berkeley, CA, University of California Press.

Gedebo A, Froud-Williams RJ 1998. Seed biology of *Impatiens glandulifera, Typha latifolia* and *Iris pseudacorus*. 10th EWRS Symposium on Aquatic Weeds 1998, Lisbon. Pp. 55–58.

GISD (Global Invasive Species Database) 2025. Species profile: *Iris pseudacorus*. http://www.iucngisd.org/gisd/species.php?sc=873 (accessed 9 July 2025).

Grieve M 1971. A modern herbal. New York, NY, Penguin, Dover Publications.

Iris flea beetle *Aphthona nonstriata* 2025. NatureSpot. https://www.naturespot.org/species/irish-flea-beetle (accessed 27 May 2025).

Jaca TP, Mkhize V 2015. Distribution of *Iris pseudacorus* (Linnaeus, 1753) in South Africa. BioInvasions Records 4: 249–253.

Jacobs J, Pokorny M, Mangold J, Graves-Medley M 2011. Biology, ecology and management of yellow flag iris (*Iris pseudacorus* L.). Bozeman, MT, Montana State University Extension.

Jarvis PJ, Fowler SV, Paynter Q, Syrett P 2006. Predicting the economic benefits and costs of introducing new biological control agents for Scotch broom *Cytisus scoparius* into New Zealand. Biological Control 39: 135–164.

Johnson B 2025. Increasing use of biodiesel could fuel canola explosion. AgAlert. https://www.agalert.com/california-ag-news/archives/march-21-2007/increasing-use-of-biodiesel-could-fuel-canola-explosion/ (accessed 27 May 2025).

Katz A 2024. The public sector discount rate: time for a rethink? Asymmetric Information. https://nzae.substack.com/p/public-sector-discount-rate-katz (accessed 26 May 2025).

King County Noxious Weed Control Program 2009. Best management practices: yellow-flag iris (*Iris pseudacorus*) Iridaceae. In: Noxious weeds – weed control information. Seattle, WA, King County Department of Natural Resources and Parks, Water and Land Resources Division, Noxious Weed Control Program. https://www.nwcb.wa.gov/images/weeds/yellow-flag-iris-control_King.pdf (accessed 9 July 2025).

Lui K, Butler M, Allen E, Snyder J, da Silva B, Brownson B, Ecclestone A 2010. Field guide to aquatic invasive species: identification, collection and reporting of aquatic invasives in Ontario waters (3rd edn). Peterborough, ONT, Canada, Ministry of Natural Resources.

McGrannachan C 2025. Host range testing of *Aphthona nonstriata* (Goeze) (Coleoptera: Chrysomelidae) for biological control of *Iris pseudacorus* in New Zealand. Manaaki Whenua Contract Report LC4615, prepared for the National Biocontrol Collective and the Ministry for Primary Industries.

McGrannachan C, Barton J 2019. Feasibility of biological control of yellow flag iris, *Iris pseudacorus*. Manaaki Whenua – Landcare Research Contract Report LC3487, prepared for Waikato Regional Council.

Morgan VH, Berent L, Fusaro A 2025. *Iris pseudacorus* L.. U.S. Geological Survey. Non-Indigenous Aquatic Species Database, Gainesville, FL, and NOAA Great Lakes Aquatic Nonindigenous Species Information System, Ann Arbor MI. https://nas.er.usgs.gov/queries/greatlakes/FactSheet.aspx?SpeciesID=1115&PotentiPo=N&Type=0 (accessed 9 July 2025).

Northland Regional Council 2017. Northland Regional Pest and Marine Pathway Management Plan 2017–2027. https://www.nrc.govt.nz/media/uhudlio4/northland-regional-pest-and-marine-pathway-management-plan-2017-2027.pdf

Paynter Q, Fowler SV, Hayes L, Hill RL 2015. Factors affecting the cost of weed biocontrol programs in New Zealand. Biological Control 80: 119–127

Peterson PG, Merrett MF, Fowler SV, Barrett DP, Paynter Q 2020. Comparing biocontrol and herbicide for managing an invasive non-native plant species: efficacy, non-target effects and secondary invasion. Journal of Applied Ecology 57: 1876–1884.

Phillips R, Foy N 1992. Herbs. London, Pan MacMillan.

Probst C, McGrannachan C, Morton S, McGrath Z, White R, Cartier A 2022. Invertebrates and fungi associated with yellow flag iris, *Iris pseudacorus* L., in New Zealand. Manaaki Whenua – Landcare Research Contract Report LC4111, prepared for the National Biocontrol Collective and the Ministry for Primary Industries.

Reddell M 2025. Bad advice on public sector discount rates. Croaking Cassandra. https://croakingcassandra.com/2025/04/29/bad-advice-on-public-sector-discount-rates/ (accessed 26 May 2025).

Sandenbergh E, Gervazoni P, Grewell B, Franceschini C, Minuti G, McGrannachan C, Stiers I, Coetzee J 2024. Biology of invasive plants 7: *Iris pseudacorus* L. (Iridaceae). Invasive Plant Science and Management 18: (e6).

Sarver M, Treher A, Wilson L, Naczi R, Kuehn FB 2008. Mistaken identity? Invasive plants and their native look-alikes: an identification guide for the mid-Atlantic. Dover, DE, Delaware Department Agriculture.

Sutherland WJ 1990. Biological flora of the British Isles – *Iris pseudacorus* L. Journal of Ecology 78: 833–848.

Syngenta 2025. Karate Zeon – insecticide. https://www.syngenta.co.nz/product/crop-protection/insecticide/karate-zeon (accessed 27 May 2025).

Tarasoff CS, Streichert K, Gardner W, Heise B, Church J, Pypker TG 2016. Assessing benthic barriers vs. aggressive cutting as effective yellow flag iris (*Iris pseudacorus*) control mechanisms. Invasive Plant Science and management 9: 229–234.

Tasman District Council, Nelson City Council 2012. Tasman-Nelson Regional Pest Management Strategy 2012–2017. https://www.tasman.govt.nz/document/serve/Existing%20Plan%20Part%201.pdf?DocID=27305

The Treasury 2025. Discount rates. https://www.treasury.govt.nz/information-and-services/public-sector-leadership/guidance/reporting-financial/discount-rates (accessed 6 August 2025).

The West Coast Regional Council 2010. Regional Pest Plant Management Strategy for the West Coast 2010. https://www.bionet.nz/assets/Uploads/the-west-coast.pdf

Tu M 2003. Element stewardship abstract for *Iris pseudacorus* L. (yellow flag iris, water flag). Arlington, VA, Nature Conservancy. http://www.invasive.org/weedcd/pdfs/tncweeds/irispse.pdf (accessed 9 July 2025).

USDA-APHIS (United States Department of Agriculture – Animal and Plant Health Inspection Service) 2013. Weed risk assessment for *Iris pseudacorus* L. (Iridaceae). Technical Bulletin 1. https://www.aphis.usda.gov/plant_health/plant_pest_info/weeds/downloads/wra/Iris_pseudacorus_WRA.pdf (accessed 9 July 2025).

Waikato Regional Council 2014. Waikato Regional Pest Management Plan 2014–2024. https://www.bionet.nz/assets/Uploads/Waikato-Pest-Management-strategy.pdf

Weedbusters 2025. Yellow flag iris *Iris Pseudacorus*. https://www.weedbusters.org.nz/what-are-weeds/weed-list/yellow-flag-iris/ (accessed 12 February 2026).

Wildland Consultants 2011. Current extent and potential distribution of yellow flag iris in parts of the lower Waikato River catchment. Prepared for Department of Conservation and Waikato Regional Council.

Williams PA, Champion PD 2008. Biological success and weediness of existing terrestrial pest plants and aquatic weeds in Northland. Landcare Research Contract Report LC0708/080, prepared for Northland Regional Council.

Yousefi Z, Mohseni-Bandpei A 2010. Nitrogen and phosphorus removal from wastewater by subsurface wetlands planted with *Iris pseudacorus*. Ecological Engineering 36: 777–782.

Appendix – Supplementary information

More on the assumption about rate of increase in control costs

We acknowledge that it is unclear how successful current and future control efforts are and how they will affect *I. pseudacorus* costs and spread in New Zealand. Some councils suggest they have *I. pseudacorus* spread in check, while others recognise that it is increasing despite control efforts. Some councils may be further along the logistic increase in costs and may experience a lesser increase, while others have yet to begin control and experience the logistic increase. Either way, the cap on maximum control cost remains valid and is uncoupled from spread. Therefore, we argue that the logistic model for control costs is realistic.