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RESEARCH

Sowing the seeds of wildlife-friendly gardening: does a garden biodiversity assessment promote uptake of pro-biodiversity gardening behaviours?

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Abstract
Residential gardens have the potential to support native biodiversity across cities. Certification programmes designed to motivate residents to perform pro-biodiversity gardening actions require a formal process of garden biodiversity assessment. We evaluated whether a garden biodiversity assessment process was effective at motivating pro-biodiversity gardening behaviours. A one-off garden assessment accompanied by feedback was trialled on 89 residents in 2020/2021. Four years later we surveyed this group and a matched control group to determine whether the assessment had a motivating and long-lasting positive effect on pro-biodiversity gardening. Results were mixed: while 57% reported the assessment did not influence subsequent gardening decisions, 38.5% confirmed that the assessment process had motivated the changes they made and 56% said it helped them understand at least a little better how they could enhance biodiversity in their garden. This understanding was positively associated with how useful they rated their tailored feedback but was not associated with their biodiversity score. The two groups didn't differ in the extent to which biodiversity enhancement was considered when making changes, and a larger proportion of the control group made biodiversity-positive changes. The number of changes made was not associated with age, income, education, years at the address, bird knowledge, or environmental engagement, but was positively associated with their nature connection score. While we provide some evidence to support the use of biodiversity assessments, ongoing support in the form of collaborative partnerships between gardeners and local government could be more effective at achieving favourable biodiversity outcomes.

Keywords Residential gardens · Nature relatedness · Garden assessment · Bird knowledge · GardenStar · Native

Introduction

Urban green spaces provide humans with a wide range of social benefits and support essential ecological processes (Aronson et al. 2017; Delahay et al. 2023). While often small in size, domestic gardens/yards are green spaces that can play important roles in supporting biodiversity as well as mental health, general well-being, social cohesion and food production (Chalmin-Pui et al. 2021; De Bell et al. 2020; Galhena et al. 2013; Schram-Bijkerk et al. 2018). Residents can carry out pro-biodiversity behaviours in their gardens, such as planting to support pollinators and the creation of wildlife habitat (Beumer and Martens 2016; Soga et al. 2017). Since domestic gardens make up relatively large proportions of cities (Colding et al. 2006; Loram et al. 2007; Mathieu et al. 2007), gardening practices can have a

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significant impact on city-wide biodiversity. However, the potential for domestic gardens to support biodiversity is subject to the "tyranny of small gardening decisions" (Dewaelheyns et al. 2016). Understanding the motivations behind gardening practices is useful then in developing strategies that assist or persuade residents to manage their gardens for biodiversity. If successful, city-wide biodiversity could be enhanced through the cumulative impact of many small gardening actions (Beumer and Martens 2016; Dewaelheyns et al. 2016; Goddard et al. 2013; Mata et al. 2021).

Every resident who manages a garden is unique, their decisions shaped and informed by a plethora of factors, including priorities, aesthetics, cultural backgrounds and a range of socio-demographic factors (Freeman et al. 2021; Larson et al. 2022; Van Den Berg and Van Winsum-Westra 2010; Varga-Szilay et al. 2024). Research on domestic gardens, which has mostly taken place in western Europe, North America and Australasia, has identified creative expression, food production, health, and social and spiritual connection as significant motivators (Cattivelli 2023; Murtagh and Frost 2023; van Heezik et al. 2012). Plant preferences can be very diverse, often driven by aesthetic traits of the plants, such as flower size and foliage colour (Kendal et al. 2012). Social norms and expectations from neighbours can reinforce gardening practices such as traditional lawns and manicured gardens (Larson and Brumand 2014; Nassauer et al. 2009; van Heezik et al. 2012). Consequently, outcomes for biodiversity conservation, particularly with respect to native species, are variable across gardens and neighbourhoods.

Gardening practices that specifically support biodiversity are increasing in popularity (Davies et al. 2009; Larson et al. 2022; Pham et al. 2022). Motivations for pro-biodiversity gardening (PBG) are also diverse, but additionally include personal enjoyment of wildlife, a connection to nature and a sense of responsibility to protect it (Clark et al. 2019; Goddard et al. 2013), while barriers to uptake of PBG can be family wellbeing and care (e.g., room for children's play and family gatherings), social norm conformity and self-efficacy (García-Antúnez et al. 2023; Home et al. 2019; Samus et al. 2023a). In their study across several European countries, Coisnon et al. (2019) found that older, more educated, politically left-leaning women living in larger households were more likely to perform specific actions, such as leaving space for wild animals, or avoiding planting non-native plants. Degree of environmental engagement, knowledge about common species, aesthetics and maintenance concerns also influenced the attractiveness of different PBG actions in Canada and New Zealand (Conway 2016; van Heezik et al. 2020).

Goddard et al. (2013) suggested several strategies for generating greater uptake of PBG, including better provision of information, financial incentives, education of children, community initiatives, collaborations between neighbours, and also wildlife garden certification schemes. Garden certification schemes are voluntary programmes where gardens are assessed against specific criteria to verify whether they meet certain standards for wildlife, biodiversity or other environmental goals. They require a formal process of assessment, followed by certification by an authorised authority. In doing so, they promote and recognise gardens that meet the specified criteria, such as planting native species, creating habitat resources for wildlife, and reducing harmful practices like excessive irrigation and pesticide use (Fogel et al. 2023; Pham et al. 2022). Through the process of assessment and subsequent certification, these programmes aim to motivate and guide gardeners. However, evaluations of the ecological effectiveness of both the process of assessment and the subsequent certification are rare (Pham et al. 2022), as are evaluations of the extent of behaviour change in response to the assessment process. A recent review by Fogel et al. (2023) highlighted the need for further research into the conservation outcomes of garden assessment and certification programmes.

A number of behaviour change models have been used to encourage pro-environmental behaviours (Rau et al. 2022): they identify the factors that influence the intention to perform a behaviour, in order to tailor interventions to address those factors. For example, Samus et al. (2023) found that perceived behavioural control was the strongest predictor of wildlife gardening behaviour, while social norms also played a role. There are a number of well-used behaviour intervention types, including providing general or tailored information, providing feedback, goal setting, social influence, nudging towards more desirable behaviour, gamification, policies and structural measures (Abrahamse 2019). Combinations of interventions are most effective, by targeting more than one barrier, such as providing tailored information together with feedback (Rau et al. 2022). Thomas-Walters et al. (2023) found behaviour change can occur even in response to short-term efforts if multiple intervention types are used.

In this study we evaluate the impact of the process of assessment per se on subsequent self-reported PBG practices, using a garden biodiversity assessment tool designed in Aotearoa New Zealand (GardenStar; van Heezik et al. 2023). The intervention types we used included tailored information, goal setting, and feedback that had a normative component. At the end of 2020 and start of 2021, the GardenStar assessment was applied to 89 residential properties. The process involved a site visit for assessment purposes by the assessor, and a questionnaire on garden management practices (van Heezik et al. 2023). Feedback included their garden's overall biodiversity score out of a possible 100 (goal setting), their score relative to other people's scores in the study (the normative component), along with scores for each of the four main categories, with tailored suggestions regarding how to improve any of these categories: permeable surface extent, habitat quality, habitat management, and connectivity between vegetation both inside and in neighbouring areas outside the evaluated property (Suppl. Mat. A).

Four years later we engaged with this group again to evaluate: (1) whether the garden biodiversity assessment process helped them better understand what they needed to do to make their garden more biodiverse; (2) how they found the feedback they received (i.e., useful, motivating, interesting, confusing, de-motivating); (3) whether having their garden evaluated influenced their decisions to make changes in their gardens; (4) whether they had made any changes that might positively impact biodiversity, and if yes, what sort of changes were made; (5) whether there were any downsides to changes made; and (6) reasons for not making any changes. These questions allowed us to evaluate whether the biodiversity assessment process per se can generate lasting changes in gardening behaviours. We also identified socio-demographic and other factors influencing uptake of PBG in this group and in another "control" group that did not have their gardens assessed. There was no formal certification of these gardens by an authorised authority, therefore our study focuses on the influence of the process of assessment and tailored feedback on subsequent gardening behaviours. On-site assessments, which are a requirement of certification schemes, were identified in Australia, as a potential means of engaging individuals who might otherwise be disinterested in pro-biodiversity gardening (Shaw and Miller 2016).

Methods

Surveys and recruitment

Two surveys were created in Qualtrics. One survey link was sent to the 89 residents who had had their gardens evaluated previously using the GardenStar garden biodiversity assessment tool (referred to subsequently as the assessment group; Suppl. Mat. B) followed by a personalised reminder email two weeks and a month later, during February and March 2025. A link to another survey (the control group; Suppl. Mat. C) was advertised through neighbourhood Facebook groups during February and March 2025 in the same urban areas where the "assessment group" was assessed in 2020/21, i.e., Dunedin and the Wakatipu Basin, Aotearoa New Zealand. The control group was surveyed to account for potential society-wide changes in attitudes and values concerning PBG that might have occurred during the four-year period. The surveys were approved by the University of Otago Human Ethics Committee (24/0656). Each survey consisted of three sections: the first collected information on the participants that has been shown to influence gardening behaviours (i.e., demographic data such as age, gender, socioeconomic background), the second asked about changes made in their gardens and the reasons for making them, and the third focused on the participants' relationships with nature.

Additionally, in the survey sent to assessment group, the second part of the survey included questions relating to (1) the evaluation and feedback of results, (2) information on any changes they had subsequently made, (3) why they had made changes to increase biodiversity, and (4) whether there were any downsides to having made those changes.

Open fields were provided to cater for actions and reasons not listed. In the second part of the survey sent to the control group, participants were asked the same questions but without those relating to the assessment of four years ago. All participants who ticked the question asking whether they had made any changes to their garden in the last four years had the opportunity to identify which of 12 potential changes they had made to benefit biodiversity: ticked options were summed into a "Biodiversity Actions" score. These changes included planting native shrubs, grasses and trees (Tartaglia and Aronson 2024), allowing dead wood to remain on the ground (Seibold et al. 2018), mowing their lawns less frequently (Unterweger et al. 2017), reducing their use of pesticides (Barratt et al. 2015; Fardell et al. 2022; Muratet and Fontaine 2015; Toledo-Hernández et al. 2016), specifically creating habitat for wildlife or providing resources (Delahay et al. 2023; Gaston et al. 2005; Harris et al. 2021), keeping their cat indoors either at night or 24/7 (Fardell et al. 2023; Galão et al. 2025; Pavisse et al. 2019), planting for pollinators (Majewska and Altizer 2020), and controlling pests on their property. Controlling pest species such as rats (*Rattus* spp), hedgehogs (*Erinaceus europaeus)*, and brushtail possums (*Trichosurus vulpecula*) is commonly encouraged in New Zealand, as these invasive species have detrimental impacts on native wildlife and are also the subjects of a nationwide programme to eliminate invasive predators from the landscape (Russell et al. 2015). Nine actions each contributed one point to the overall "Biodiversity Actions score", and the following three contributed two points as they were deemed to comprise a more significant contribution: they had planted 3 or more native trees, they had planted 3 or more native grasses and shrubs', they kept their cat/s indoors all the time. The maximum possible score was 15, and scores ranged between 1 and 11.

The third section explored the participants' relationships with nature, which is known to influence environmental behaviours (Kiesling and Manning 2010; Lin et al. 2017). The NR-6 Nature Related score (Nisbet et al. 2009), which measures cognitive, affective (emotional), and experiential aspects of connection with nature, indicating the extent to which individuals' relationships with nature are part of their identity, was used alongside questions on the extent to which biodiversity is a consideration when managing their gardens and membership of any environmental initiative. Nature relatedness was positively associated with greater vegetation cover in urban gardens in Brisbane, Australia (Lin et al. 2017), and environmental identity, measured using the EID scale, predicted ecological gardening behaviour in the US (Kiesling and Manning 2010). To assess awareness of sources of information on PBG, participants were asked to list resources of information on PBG that they used. The assessment group had not received any information about resources in their feedback. Finally, participants were presented with a quiz requiring them to name and indicate the native/non-native status of images of 10 relatively common urban birds. Knowledge about birds has been associated with some garden care characteristics (Varga-Szilay et al. 2024). Responses requesting bird names were open-field (see Suppl. Mat. B & C). Each answer was summed to provide a Bird Knowledge score with a maximum score of 20.

Statistical analyses

Frequencies of options ticked were compared between groups using Chi-squared tests. A general linear model and logistic regressions were performed in SPSS (v28) to identify parameters (age, income, NR-6 score, level of education, membership of an environmental group, knowledge of local birds, years at the address (previous research suggests that garden tenure can influence current vegetation structure and management practices) and in the case of the assessment group, original GardenStar score, usefulness of feedback) associated with the Biodiversity Actions Score, and yes/no responses in the case of logistic regression. Only uncorrelated variables were used in the models ($r<0.6$; Hosmer & Lemeshow, 2000); consequently, 'years in New Zealand' was removed as it was correlated with 'age ($r=0.615$). All variables were checked for normality using q-q plots, and the variable 'years at address' was transformed. Characteristics of the control and assessment groups were compared using an independent samples t-test and Kolmogorov-Smirnov goodness-of-fit test (D).

Results

Survey respondent characteristics

Forty-one of the original 89 (46%) in the assessment group who had their gardens evaluated in 2020/2021 responded to the survey, and the control group comprised 128 respondents. Fifteen of the control group completed only section 1 and were removed from the analysis (total $n=113$). Five did not complete the bird quiz and were retained. All of the assessment group completed the survey. Respondents occasionally left one or two questions unanswered, resulting in different sample sizes for different analyses.

The assessment group were significantly older than the control group and scored higher in the bird recognition quiz (Table 2) but there was no difference between the groups in level of education (D (7,7)=0.43, $p=0.426$), income (D (73,3)=0.67, $p=0.6$), years at the address and NR-6 score (Table 1).

Impacts of the biodiversity assessment and feedback

The GS participants with assessment group received feedback in 2020/21 which included their garden biodiversity score and suggestions on how to improve their score. Nearly half (46.3%, $n=19$) of the assessment group couldn't recall how their garden had scored when assessed four years previously, 31.7% ($n=13$) thought their garden had scored "moderately", 14.6% ($n=6$) thought "high", and 7.3% ($n=3$) "low". The mean score of the group that couldn't recall their scores ($\bar{x}=28.4$, SD=8.5, $n=19$) was significantly lower than the group who recalled their scores as high (($\bar{x}=45.6$, SD=6.4, $n=6$) ($F_{3,41}=11.777$, $P<0.001$, $\eta^2=0.488$, $R^2_{adj}=0.447$; Tukey HSD, $p<0.001$)). Mean scores of those who recalled scoring low ($\bar{x}=18.1$, SD=4.6, $n=3$) were lower than those who recalled scoring moderately ($\bar{x}=35.6$, SD=6.4, $n=13$; Tukey HSD, $p=0.01$). Among those who could recall their score ($n=21$), 76% ($n=16$) thought it was about right, 20% ($n=4$) thought it was too low and 4.8% ($n=1$) too high. Of those who answered the question "Did participation in GardenStar influence your subsequent decisions to make changes to improve biodiversity in your garden?", 12 (57.1%) answered "no" and nine (42.9%) answered "yes". The remainder could not recall. Reasons for not making changes are shown in Fig. 1a. There was no difference in the original GardenStar scores between the group that answered "yes" ($\bar{x}=30.8$, SD=9.56, $n=9$) or "no" ($\bar{x}=31.3$, SD=10.29, $n=12$; $t_{19}=-0.101$, $p=0.921$) and no correlation between the original GardenStar score and the Biodiversity Actions score (Pearson's $r=0.160$, $p=0.337$, $n=41$).

Table 1 Characteristics of survey respondents: assessment group (residents who had their garden assessed four years earlier) and control group (residents from the same locality who had not had their gardens evaluated)

Variables	Mean ± SEM (number of responses to question)		Test statistic	*P* value
	Assessment $n=41$	Control $n=128$		
Age (years)	58.3 ± 2.04 (41)	50.1 ± 1.27 (111)	$t_{165} = -3.350$	0.001
Years at address	13.5 ± 1.57 (41)	11.9 ± 1.01 (110)	$t_{163} = -0.723$	0.471
Bird quiz score	17.1 ± 0.42 (41)	17.0 ± 0.33 (105)	$t_{138} = 2.032$	0.044
NR-6 score	4.3 ± 0.09 (41)	4.2 ± 0.07 (111)	$t_{142} = -0.315$	0.753
Education	Percent ($n=41$)	Percent ($n=128$)		
Post-graduate degree	39.0% (16)	38.1% (45)		
Graduate Diploma	19.5% (8)	8.0% (9)	D = 0.43	0.426
Bachelor degree	24.4% (10)	20.4% (28)		
Trade certificate	7.3% (3)	10.6% (15)		
Year 9–13	2.4% (1)	13.3% (16)		
Year 8 or below	0.0% (0)	0.9% (2)		
Other	7.3% (3)	4.4% (8)		
Income	Percent ($n=41$)	Percent ($n=128$)		
			D = 0.67	0.600
Comfortably meets needs	65.9% (27)	50.8% (65)		
Only just enough	29.3% (12)	39.1% (50)		
Doesn't meet needs	2.4% (1)	3.1% 99)		

Frequency distributions are compared using the Kolmogorov-Smirnov goodness-of-fit test (D)

When asked whether the garden assessment improved their understanding of what they would need to do to make their garden more biodiverse, most reported "a little/somewhat" ($X^2 = 11.54$, df = 2, $p < 0.01$; Fig. 1b). Whether respondents gained a better understanding was not associated with education ($F_{1,25} = 0.105$, $p = 0.751$) or their original GardenStar score ($F_{1,25} = 1.001$, $p = 0.328$), but it was positively associated with how they rated the usefulness of the feedback on their score (GLM; $F_{1,25} = 9.009$, $p = 0.007$; $\eta^2 = 0.291$; $R^2_{adj} = 0.197$).

Of the two-thirds of the assessment group (69.2%) who could recall the feedback they received after having their garden assessed, most found it either interesting, useful or motivating, but four people found the feedback discouraging (Fig. 1c). Among the 22 participants who had had their garden evaluated and had made changes since the evaluation to increase their garden's biodiversity ($n=22$), most had been influenced to some extent by some aspect of the garden evaluation, whether it was just participation, learning or motivation to achieve a higher score (Fig. 1d). Over half (59.1%, $n=13$) of 22 participants listed a range of other reasons for making changes, from a personal interest in biodiversity, to information they had read, community initiatives and conversations with family and friends. One wrote that the garden evaluation showed them they were on the right track, but that it didn't motivate them more. There was no significant correlation between participants' original GardenStar scores and their Biodiversity Actions Score (Pearson's $R = 0.160$, $p = 0.337$).

PBG across both control and assessment groups

There was no significant difference between the assessment and the control group in the extent to which respondents reported that biodiversity enhancement was a consideration when making changes to their gardens ("rarely" and "not at all" were combined into one category due to low sample sizes; $X^2 = 3.485$, df = 3, $p = 0.323$). The majority of both groups ($n = 111$ responses) reported biodiversity enhancement was a frequent consideration or the primary driver behind their actions (Fig. 2a).

While a large proportion of respondents from both groups reported they had made changes to their garden or the management of their garden in the last four years that might positively impact biodiversity (79.9%, $n = 154$), a significantly larger proportion of the control group answered yes to this question (Control: 88.5% [100/113]; Assessment: 60.5% [23/38]; Wald z = 3.85, $p < 0.001$, with a higher proportion of the control group engaged in all activities (Fig. 2b).

When the different changes that people indicated they had made were summed into the Biodiversity Actions score, there was no significant effect of age ($F_{1,106}$, = 0.216, $p = 0.642$), education, ($F_{1,106} = 0.016$, $p = 0.901$), years at the address ($F_{1,106} = 0.124$, $p = 0.726$), income ($F_{1,106} = 0.677$, $p = 0.510$), whether they belonged to an environmental organisation ($F_{1,106} = 0.295$, $p = 0.588$), or bird knowledge ($F_{1,106} = 0.726$, $p = 0.396$) on the score. However, both the NR-6 score ($F_{1,106} = 5.037$, $p = 0.027$, $\eta^2 = 0.049$) and the group (Control mean score = 4.49, SD = 3.17, $n = 128$; Assessment mean score = 2.08, SD = 2.80, $n = 40$; $F_{1,106} = 29.771$, < 0.001; $\eta^2 = 0.235$) were significant (R^2 adjusted = 0.229).

Respondents were offered several options they could tick when asked why they decided to make changes that would increase biodiversity in their gardens, as well as an open-ended question ("community initiatives" and

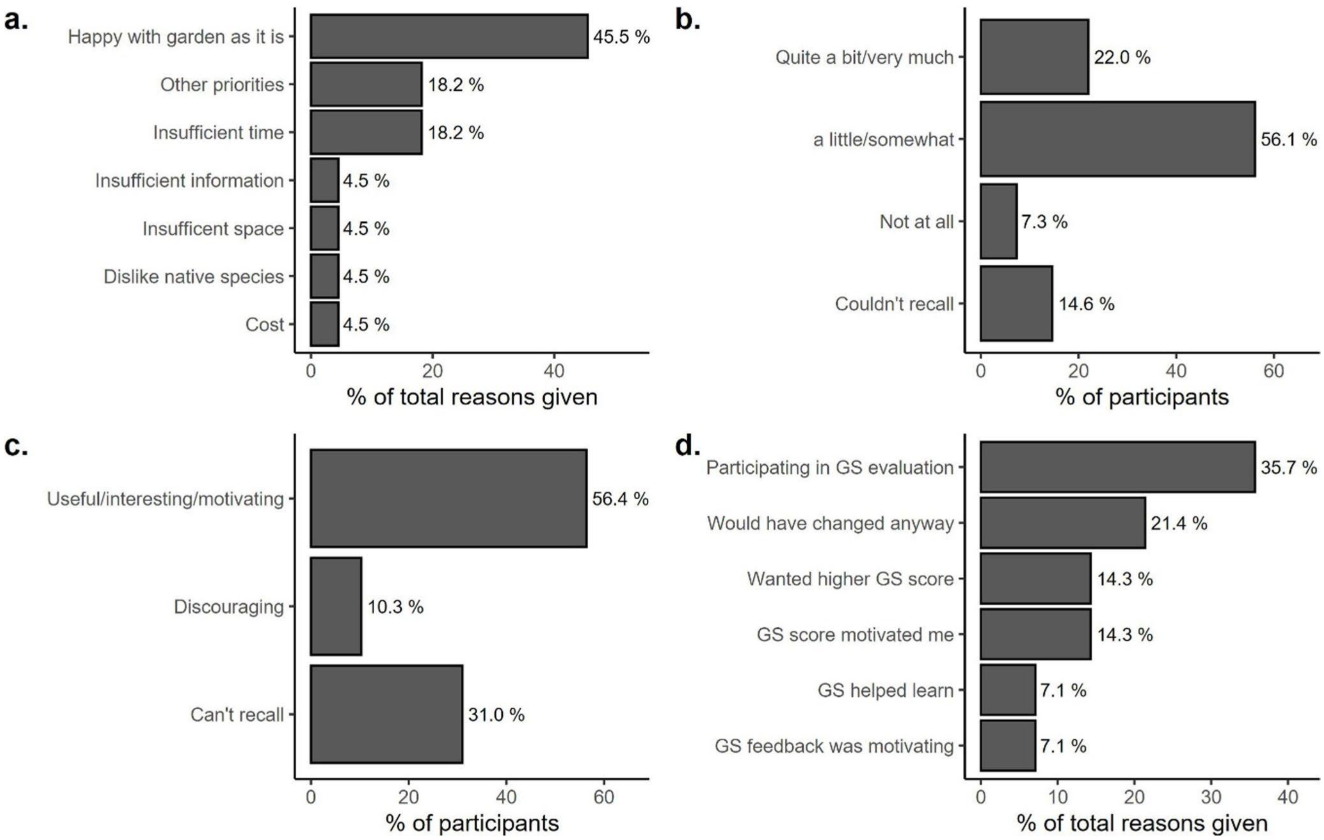

Fig. 1 Responses of participants who had their garden assessed using the garden evaluation tool to (**a**) why they did not make changes to enhance biodiversity in their gardens ($n=22$ reasons from 16 participants); (**b**) whether the assessment improved their understanding of what they would need to do to make their garden more biodiverse ($n=41$); (**c**) how they found the feedback they received after the assessment ($n=41$); (**d**) among those who had subsequently made changes, whether the garden assessment motivated them to make changes to increase their garden's biodiversity ($n=14$ reasons from eight participants)

"conversations" were combined, as were "TV/radio/online" and "books, magazines" due to low sample size in the assessment group). There was no significant difference between the control and the assessment group in the reasons why they had made changes ($X^2=0.504$, df=2, $p=0.777$). The most common reason across both groups was a personal interest in biodiversity (Fig. 2c).

When asked whether respondents had talked to others about changes they had made, 33.8% (n=52) replied "yes", 24.0% (n=37) thought 'maybe' but couldn't recall, and 16.2% (n=25) said "no". Among those who answered "yes", 43.2% (n=16) thought they might have influenced someone else's gardening. In response to the open form question asking how they had influenced others, respondents describe communicating their experience through their role in their community, and social networks.

> I am a teacher at our local kindergarten so I spoke to many whānau [extended family] and tamariki [children] about my garden and what they were doing at their houses. I don't know if I influenced anyone, but I was certainly inspired by others.

> I share photos with media, outreach groups, etc.

> "I talk with other enthusiasts. Our shared interests probably motivate all of us to act.".

Participants reported these interactions as positive.

> People like that I only plant native species.

> I talk with other enthusiasts. Our shared interests probably motivate all of us to act.

Respondents were also asked if there were any downsides to the changes they had made. Of the 121 responses to this question, 22.3% replied "yes". Among those who elaborated on their response ($n=24$) the most frequently reported downside was more weeds and maintenance ($n=8$), and

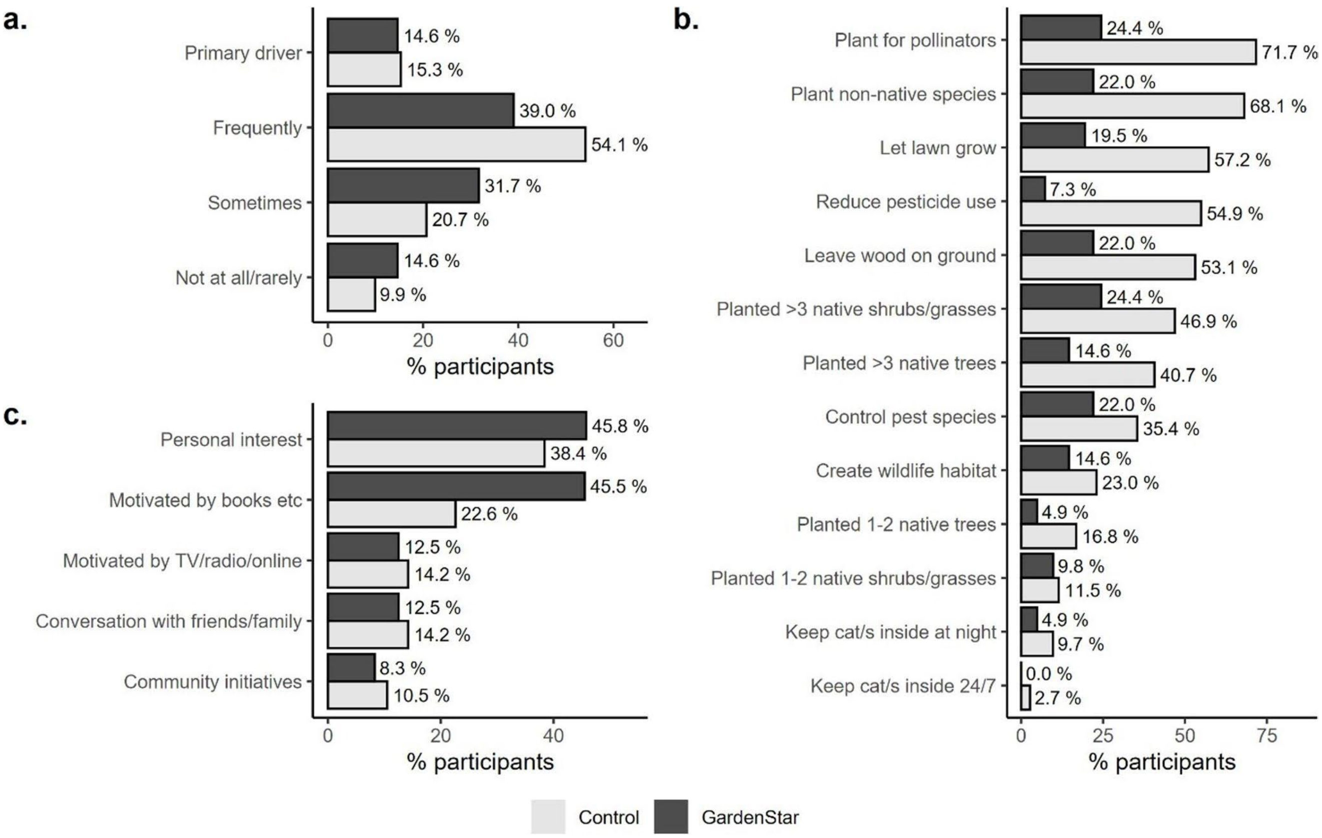

Fig. 2 Assessment ($n=41$) and control ($n=128$) groups' responses: (**a**) the extent to which biodiversity enhancement influenced their actions in their gardens; (**b**) the proportions of each group engaging in biodiversity-enhancing garden activities in the past four years; (**c**) reasons for making changes to enhance biodiversity

concerns about messiness ($n=3$), followed by an increase in insects perceived as pests (Table 2).

Discussion

Here we have shown that participation in a process of garden biodiversity assessment can improve a resident's understanding of what they need to do to improve biodiversity in their garden, yet when compared to a control group, we found no evidence that it enhanced decision-making in a garden context, nor did it lead to greater uptake of biodiversity-friendly garden strategies. Despite this, both groups in this study showed a high level of biodiversity awareness when managing their gardens, with over half (53.4%) reporting that biodiversity was a frequent consideration and another 14.6% stating that it was a primary driver behind making changes in their gardens.

We do provide some weak evidence that people who have a stronger connection to nature are inclined to undertake a larger number of actions. Nature-relatedness has been positively associated with greater vegetation cover in urban gardens in Australia (Lin et al. 2017). In the USA Kiesling and Manning (2010) found that environmental identity, measured using the EID scale, predicted ecological gardening behaviour. In a previous New Zealand study, gardens of residents who were more environmentally oriented (measured using the New Ecological Paradigm) tended to support more structurally complex vegetation (van Heezik et al. 2013). Although the evidence from our study was weak, it does provide further support for the relationship between a connection to nature/environmental orientation and the likelihood of PBG activities.

We found no association between the extent to which people undertook pro-biodiversity actions in their garden and various socio-demographic factors or levels of biodiversity knowledge, including age, level of education, years at their address, income, membership of environmental organisations, or bird knowledge. This is surprising as these factors have been identified as significant predictors of environmental behaviours in many other studies (Coisnon et al. 2019; Otto and Kaiser 2014; Varga-Szilay et al. 2024), although the relationship between garden landscaping preferences and income can be complex (Kirkpatrick et al. 2007; Larsen and Harlan 2006; Meléndez-Ackerman et al. 2014). Knowledge of wildlife was identified previously as a factor

Table 2 Responses from 24 participants when asked about downsides to changes they had made to enhance the biodiversity in their gardens categorised into themes with quotes illustrating each theme

Examples	Theme
"We get more weeds and need to spend a lot of hours in the garden maintaining it. It's also quite pricey." "Have a more visually messy garden and is way more upkeep involved rather than just mowing the lawn once a week which used to be there." "The weeds grow very well now and I limit my spraying so weed more." "I was unable to fully eradicate some pernicious weeds like Convolvulous, ivy and Muehlenbeckia which now grow through some of my new plantings." "I now have to do more weeding to keep the undesirable plants down. I need to water the garden more regularly." "It looks a mess." "Longer grass makes the property look messier than I prefer."	Messiness & additional maintenance ($n=11$)
"A lot more insect activity and bugs eating my veges, we are completely organic now. Reoccurring infestations of sooty mould." "Trying to use more natural methods of insect control on vege seedlings has been challenging and not always as successful." "Not using pesticides means more bugs - but that's ok." "A lot more spiders. Some might see this as a good thing." "More insects does mean a higher chance of being stung by a bee when the lawn is longer however, we manage this by being careful and wearing shoes or sandals on the lawn. Also, we used a hugelculture system when we built a new strawberry raised garden bed. This has introduced a lot of slaters so we have to be quick to get the fruit. Not major issues, just minor inconvenience." "More spiders and parasitic wasps coming into the house"	More insects ($n=7$) & other pest species ($n=1$)
"I let the grass on our verge grow, it looks good for a bit but not for long. We mow the edges to make it look managed but I feel judged. We think we will remove some grass and plant native grasses or wildflowers instead."	Neighbourhood norm & cues to care ($n=1$)
"Native trees and shrubs grow slowly."	Slow growth of native plants ($n=1$)
"Only in that I realised how non-environmentally friendly gardening can be - plastic pots, plastic weed mats, plastic water storage, soil in plastic bags. plastic compost bins. It's hard to increase biodiversity in the garden without single use plastic - it shouldn't be, but alternatives are not necessarily accessible to busy and low-income people."	Single-use plastics ($n=1$)
"More grass pollen, makes my eyes itch"; "Minor downside but it's uglier mid-progress, looking forward to plants filling out"; "My husband and I disagree about how much more of our property I can plant!!"	Other ($n=4$)

positively associated with plant richness in gardens in New Zealand (van Heezik et al. 2013). Regarding income, even though 40.9% of participants in this study reported they either only had just enough to get by (37.0%) or not enough (3.9%), only two respondents cited cost as a reason for not making changes. Some activities that support biodiversity such as mowing less often and reducing pesticide use do not cost anything, and native plants can often be acquired at small expense through community-based initiatives.

The variable "years at the address" was included in analyses to account for potential legacy effects. At the scale of the neighbourhood, land cover in the form of tree canopies rather than herbaceous or grassy areas, is better predicted by previous, rather than current, socio-economic and lifestyle characteristics (Boone et al. 2010). A short period of residence could mean that current residents who want to enhance biodiversity engage in a wider range of pro-biodiversity activities to transform their garden into a site that reflects their values, while those in residence for much longer may be less likely to make changes because they are content with their garden as it is, which was the most commonly cited reason when asked why respondents hadn't made any changes. Despite a range of years of residence (< 1–53 years for the assessment group; <1–45 years for the control group), this variable was not significant.

We did not ask for information on ethnicity, but the region sampled has predominantly Pākehā (New Zealand European; 85% at 2023 census (StatsNZ 2025) populations. Other regions in Aotearoa New Zealand have higher proportions of Māori, Asian and Pasifika peoples, and caution should be exercised when generalising our results to other populations. Further research across diverse communities could explore the significance of PBG in these groups and identify whether access to nature could be made more equitable through PBG campaigns tailored to different communities.

A large proportion of respondents had made biodiversity-supporting changes to their gardens during the 4-year time period (81.7%), somewhat higher than was reported by (Larson et al. 2022) in the USA, where 60% of survey respondents had added "plants or other features that attract wildlife and pollinators" to their gardens. While we tried to minimise bias by targeting general neighbourhood groups rather than specific gardening or environmentally focused groups and offering a financial incentive, the very high proportion of respondents engaging in pro-biodiversity activities suggests some bias due to our method of recruitment (self-selection). However, we did use the same recruitment method to recruit the assessment group four years previously.

The most popular activities residents had engaged in during the 4-year period were planting for pollinators and planting native grasses, shrubs and trees. The popularity of the former could be because this can be achieved using colourful non-native species that are aesthetically pleasing and often preferred (Hanson et al. 2021; Kendal et al. 2012). Nevertheless, there is a growing demand for native plants in the USA (Gillis and Swim 2020), where urban, college-educated and younger participants are more likely to be native plant adopters (Torres et al. 2024). Larson et al. (2022) also found planting natives was the most popular change people made to their gardens to increase value for wildlife and suggested this would only increase in popularity in the future. The popularity of native planting in our study could reflect the impact of campaigns by many organisations and initiatives promoting native planting for biodiversity in New Zealand.

Some participants noted negative consequences from making changes benefiting biodiversity, with the most common concern being an increased number of insects, which were reported as problematic if residents were also growing vegetables. There is potential for improved education around insect species and the roles they play in gardens, as our impression from comments and interactions is that some residents misidentify insect species, attributing destructive roles to many "innocent" insects. It is becoming more commonly recognised that invertebrates build the foundation to ecosystem functioning, and an increasing number of community outreach and science communication initiatives have been implemented successfully to combat invertebrate misconceptions and promote greater appreciation of their ecological importance globally (Howe n.d; New 2024).

The other two main negative consequences mentioned were the extra work involved in weeding and maintaining more diverse plantings, and an increase in messiness, which also led to them to feeling disapproval from neighbours. The latter sentiment can be attributed to implicit neighbourhood norms, as alluded to by one respondent who wrote "We mow the edges to make it look managed but feel judged", as well as the impact of broader cultural norms on individual preferences (Nassauer et al. 2009). Neighbourhood norms most dramatically affected preferences for front yard designs in the USA (Gillis and Swim 2020; Larson and Brumand 2014; Nassauer et al. 2009) and were recurrent themes in a Copenhagen study of engagement in PBG (García-Antúnez et al. 2023), but there was little evidence for a strong influence of social norms in this study. Interestingly, the one resident who "felt judged" in this study used "cues to care", a strategy that signals deliberate management (Li and Nassauer 2020). Social exchange of information was significant in our study, with 31% of respondents reporting communication with others about the changes they had made, introducing the opportunity for mimicry across neighbourhoods through inspiring others to follow suit. This is a phenomenon reported by Goddard et al. (2013), who also pointed out that social pressure to maintain a neat garden is not a barrier for those who are passionate about wildlife.

Efficacy of the garden assessment process

While the garden assessment tool (GardenStar) was designed with the aim of incentivising residents to enhance native biodiversity in their urban properties, we found no evidence that either the process of the assessment or the feedback received resulted in positive biodiversity outcomes over and above what was reported from the control group. In many ways the control group showed more engagement in activities promoting native biodiversity and reducing impacts on biodiversity. It is possible that the knowledge gained through participating in the garden assessment, and the opportunity to reflect on gardening practices, might have changed how participants perceived their motivations and actions. For example, participants could be more aware of the range of pro-biodiversity activities they could be doing and also the reasons that they are not doing certain actions (e.g., competing garden uses), which might cause them to undervalue their actions relative to the control group. Future research to address this could reassess participants' gardens and compare the result to the description provided by the participants. Alternatively, the assessment group could have been better able to demarcate the previous four years since their assessment, compared to the control group which could have included actions prior to the four-year period. The existing relationship with the assessment group participants too might mean that this group was more conservative in their recollection, while the control group may have been more liberal.

Despite the lack of any clear biodiversity benefit arising from the assessment process, there were many positive aspects reported by a significant number of the assessment group members. Nearly three-quarters reported that the assessment had improved their understanding of how their gardening practices could contribute to biodiversity, although for most this was only a little. These people were more likely to have rated the feedback they received at the time of their evaluation as useful, either because they felt better informed, or it was interesting or motivating. The feedback on their score was the only important factor influencing how well their understanding had improved, however, it was not motivating for all: while 84% found the feedback useful, interesting or motivating, or a combination of these, 16% ($n=4$) found it discouraging, and over half (57%) reported that it did not influence their decisions to make changes to enhance biodiversity. It is likely that people who were already knowledgeable and committed to improving their garden's biodiversity were less likely to be influenced by the evaluation. That four participants found the feedback discouraging suggests a need to reconsider how feedback is communicated.

There was no relationship between the GardenStar score received by participants and the number of pro-biodiversity actions performed subsequently, indicating that a low score didn't motivate this group to engage in more actions, and a high score was not associated with a maintained pattern of pro-biodiversity actions. Despite this the assessment process did motivate and influence the gardening choices of a small proportion of the people who participated in the exercise. In contrast, consistently and significantly higher proportions of respondents in the control group reported that they had considered biodiversity more frequently when managing their garden than did members of the assessment group, and had made changes that might positively impact biodiversity in the last four years, across almost all activities: the mean Biodiversity Actions score for the control group was over twice as high as that of the assessment group. Nonetheless, both groups had similar reasons for making changes to enhance biodiversity, the most important of which were a personal interest in biodiversity and being motivated by information that they had read from printed materials, content from online/TV/radio and conversations with family, friends and colleagues.

Very few evaluations of the efficacy of PBG programmes have been made, and unlike this study they focused on ecological parameters, comparing garden features or species diversity between certified and non-certified gardens. Widows and Drake (2014) evaluated the National Wildlife Federation's Certified Habitat™ programme in Florida, USA, comparing certified gardens to neighbouring and non-adjacent non-certified gardens, and found certified gardens offered wildlife habitat that was not available in non-certified gardens. They concluded that the programme was successful. In Texas, USA, a certified Texas Wildscape neighbourhood had higher bird diversity and species richness than an adjacent non-certified neighbourhood (Aurora et al. 2009). In Melbourne, Australia, Mumaw (2017) explored how a wildlife gardening programme, which involved an assessment by an assessor who advised on features of the garden and opportunities for conserving native species as well as providing participants with information on local activities and sources of information, affected participants' self-reported gardening behaviour. This model, which was effectively a partnership between a community group and local government, was deemed to be successful at developing land stewardship.

In their recent review of residential garden programmes in the USA, Fogel et al. (2023) found that due to the wide variation in how residents are contacted and enrolled into these programmes, the language on certification garden signs, and the support provided throughout the process, it is difficult to evaluate the relative success of programmes, with more research needed into their conservation outcomes. We suggest that the garden assessment component of the process of certification or scoring a garden should also be examined, especially if it results in a score which is assumed to act as a motivating factor, allowing residents to rank their garden against others, and to identify areas they can improve.

The garden assessment and feedback was designed to both educate residents and appeal to potentially motivating influences. Interviewing to determine garden management practices and measuring garden landcovers and features provided the opportunity for interactive dialogue between the resident and the assessor, facilitating knowledge exchange: this has been shown to be successful at promoting pro-biodiversity gardening among some residents (van Heezik et al. 2012). The inclusion of a comparison of each resident's garden scores against a distribution of other scores introduced a normative component which was found to be an effective communication tool for at least 20% of residents in a previous study (van Heezik et al. 2012). Schneider et al. (2019) also found when trialling their GartenApp that a common request by users was to see how their garden compared to others. However, others have found this approach less effective (Kirkpatrick et al. 2009) and variable between individuals (Fishbein 1992). Niemiec et al. (2021) compared efficacy-based to normative messaging and found the former more effective at increasing residents' willingness to engage and encourage others to participate in native plant gardening. In our study only a small number of residents were motivated by their GardenStar score ($n=2$) or by wanting a higher score ($n=2$), but this amounted to nearly a quarter (23.6%) of respondents.

Promoting environmental behaviours such as PBG is challenging and requires an understanding of the factors that affect individuals' intention to perform a behaviour, which include attitudes, social norms and perceived control (Ajzen 1991), as well as knowledge, and personal emotional investment (Hungerford and Volk 1990; Kollmuss and Agyeman 2002). Samus et al. (2023b) applied an extended version of the theory of planned behaviour, including nature connectedness, to predict engagement in gardening practices that support biodiversity in New Zealand. They found that the perception of having information and knowledge, as well as time, was the most important influencing factor, while also important were normative beliefs about friends, family, and environmentalists but not neighbours. The current study found a high level of engagement with pro-biodiversity activities and little evidence that neighbourhood norms strongly shaped PBG, with friends and family being a more important source of information, support and inspiration. A lack of information and time also emerged as important barriers to PBG.

Conclusions

The process of having one's garden evaluated for its biodiversity value using the GardenStar tool had some positive outcomes in terms of motivating residents, or reassuring them they were on the right track, but the assessment group reported engaging in fewer pro-biodiversity activities during the four-year period than the control group. The garden assessment did not yield the expected motivational outcomes for pro-biodiversity gardening, although there are likely nuanced biases between the two groups that would require further research to fully understand. The sample size in the assessment group was low: while we evaluated 89 gardens in the initial study, only 41 people responded to our follow-up current survey, which resulted in low numbers of responses in some categories. Moreover, the time period since the initial garden assessment could have been too long. On the one hand we were looking for long-term changes in behaviour, but unsurprisingly a significant proportion of the group had forgotten about their garden assessment.

Our groups were also biased towards residents already engaged in biodiversity-enhancing practices: tailoring recruitment strategies to facilitate equitable participation could address this (Pham et al. 2022). When implementing programmes to encourage uptake of PBG practices, the challenge lies in engaging the unengaged (Shaw and Miller 2016). It is possible that one-off assessments may be less effective, and ongoing engagement and support are necessary when promoting pro-biodiversity gardening practices. Effective communication between residents, community groups and local government was identified as important in nurturing competency and confidence with regard to where advice and materials could be obtained (Mumaw 2017), and in New Zealand interactive dialogue during a process of garden biodiversity inventory, that included informative feedback with a normative component, was effective in shifting attitudes of some residents towards prioritising native species in their gardens (van Heezik et al. 2012). If the GardenStar assessment tool was incorporated into a certification scheme, which was integrated into policy frameworks in Aotearoa New Zealand, it could be more effective if it were one of the resources of a partnership between community groups and local government, as well as ongoing advice, access to resources, and credible validation (Mumaw 2017).

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Declarations

Competing interests The authors declare no competing interests.

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