The socio-ecological benefits of wildlife gardening

Laura Mumaw and Luis Mata

Cover photo by Luis Mata. Hoverfly approaching a cut-leaved daisy. Taken on April 2020 at the Greenlink Box Hill Indigenous Nursery (Box Hill North, City of Whitehorse, Melbourne).

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Report prepared for Gardens for Wildlife Victoria

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by

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Executive summary

This research adds new evidence to a growing body of work on urban human–nature relationships in two interconnected areas: the links between human wellbeing and biodiversity, and the importance of urban gardens and gardeners to sustaining indigenous biodiversity. Through an online survey we examined the motivations, characteristics, wildlife gardening choices, and activities of 294 wildlife gardeners, alongside their wildlife observations and the wellbeing benefits they attribute to their wildlife gardening. Ecologically we documented the associations between indigenous plant species commonly used in wildlife gardening and the insect pollinators found on their flowers over the course of a year.

Our key findings and associated implications include:

Wildlife gardening has personal, social and ecological meanings for participants associated with emotional connections and wellbeing. Associations with biodiversity conservation and social connections are more strongly felt by wildlife gardening program leaders and volunteers. Wellbeing is experienced in six key domains: sense of purpose, experiential wellbeing, self-development, self-esteem, place attachment, and social connections. While these feelings have been found with gardening and environmental volunteering, this study quantitatively demonstrates their association with caring for nature via urban wildlife gardening. Our findings point to the importance of supporting wildlife gardening in governmental policies at all levels for biodiversity, wellbeing, and community building purposes.

Indigenous plant species used for wildlife gardening in greater Melbourne are predominantly associated with indigenous rather than introduced insect pollinator species. Thirty-six indigenous and seven introduced insect species were documented interacting with the flowers of the 37 studied indigenous plant species. Most indigenous plant species are providing floral resources for both

indigenous and introduced species, but a few are associated only with one group or the other. The mean number of introduced pollinator species per plant species studied varied from 0 to 4, while the mean number of indigenous pollinator species varied from 1 to 21. The findings corroborate the fundamental role indigenous plant species play in providing resources for pollinator species, particularly indigenous ones, and emphasise the important role wildlife gardens and gardeners can play in supporting both the biodiversity of pollinators and the function of pollination in urban environments.

Wildlife gardeners are motivated to attract or support many taxa, particularly birds, bees and butterflies. These are the same taxa they observe to increase in both numbers and diversity after they begin wildlife gardening, helping to reward and sustain their wildlife gardening efforts. Wildlife gardeners choose a wide range of plant flower colours, leaf colours and growth forms. Their preferences often align with high pollinator richness, but with notable exceptions. Selecting particular plant species on the basis of their known associations with indigenous insect pollinator species will help wildlife gardeners to attract/support particular insect pollinators. Recommendations are made for indigenous plant palettes that support a high diversity of indigenous insect pollinators, including by flower colour and growth form. Recommendations are also made for indigenous plant palettes suited to specific indigenous insect pollinators.

Acknowledgements

We acknowledge the First Nations people of the lands in what we now call the State of Victoria and thank them for their caring for country for thousands of years before us.

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Finally, a big thanks to all the wildlife gardeners who participated in this study!

Contents

1 Background

Human health is linked to biodiversity

Human health is linked to biodiversity across time, landscapes and human activities of various types and sizes (Isbell et al., 2017). While humans receive benefits – physical, spiritual, and emotional wellbeing – from nature (Jax et al., 2018), this requires its ongoing care. Increasingly evidence is emerging that acts of caring for nature themselves can provide the carers' with wellbeing benefits (Maller, Mumaw and Cooke, 2019).

We have limited understanding about the diverse human, ecological, and human-nature interactions occurring in urban residential settings, along with their ecological and social impacts. Below we outline some of these relationships, focusing on urban gardens and urban residents' interactions with nature at home and in their neighbourhoods.

Cities and their gardens are important for urban biodiversity

We know that cities can contribute to sustaining biodiversity by offering various species places to shelter, forage, reproduce, find refuge, and adapt to changing conditions (Spotswood et al., 2021). Urban landscapes are highly fragmented, with diverse land uses and landowners and managers. Domestic gardens can make up at least half of the green space in cities (Cameron et al., 2012) and in major Australian cities host almost half of urban tree cover (Hurley et al., 2020). Of particular interest is the potential of gardens to help support insect pollinators (Hall et al., 2017; Baldock et al., 2019), which are showing dramatic losses globally (Powney et al., 2019) and support a vital function both for agriculture and biodiversity conservation.

Wildlife gardening can support and improve biodiversity

Gardening in a way that focuses on sustaining indigenous (locally native) species amongst a wide variety of other species is called wildlife gardening (Mumaw and Mata, 2022; Figure 1.1). Wildlife gardening activities include planting indigenous species, removing environmental weeds, retaining mature trees and remnant vegetation, planting in layers from groundcover to canopy, and adding habitat elements like shelters, nesting sites, and water features (Gardens for Wildlife Victoria, 2021). To be meaningful at a landscape scale, wildlife gardening needs to complement the other urban green spaces and nature stewardship activities of public land managers, such as councils, and other private land managers including residents and businesses (Goddard, Dougill and Benton, 2010; Aronson et al., 2017). Even small-scale planting activities can have a large positive effect on the number, diversity and interactions of insects associating with those plants over time (Mata et al., 2021).

Wildlife gardening can improve human wellbeing and connections to nature, place, and people

There are clear connections between experiencing urban green spaces and having feelings of wellbeing (Mensah et al., 2016). In one study prompting adults to record daily the good things they noticed in urban green spaces (including but not limited to their gardens), the most common response was wonder at encountering wildlife in everyday settings (McEwan et al., 2020). Residential gardeners describe wellbeing from their gardening that include connecting with others and community, reduced stress and anxiety and improved mood, and connecting with one's garden and nature, observing and enjoying the living creatures and interactions they observe (Soga, Gaston and Yamaura, 2017; Ambrose et al., 2020). Wildlife gardening participants reveal that additionally, they express benefits derived from the stewardship focus of their gardening, including learning and sharing biodiversity stewardship skills and knowledge, a sense of purpose from and contribution to helping wildlife and the environment (Mumaw, 2017; Mumaw, Maller and Bekessy, 2017; Raymond et al., 2019; Diduck et al., 2020) and attachments to place (Mumaw and Mata, 2022; Figure 1.3).

Figure 1.1. An excellent example of a wildlife garden. Photo by Richard Kelly.

Knowledge gaps

While previous research shows what habitat improvement activities wildlife gardeners undertake (Mumaw, 2017; Mumaw and Bekessy, 2017), it remains unclear what the impacts of these activities are for particular species. There are anecdotal accounts that gardeners notice more wildlife, particularly insects, after they begin wildlife gardening, and that their observations strengthen motivation to continue (Mumaw, 2017). However, little is documented about the relationships between wildlife gardening, observing flora and fauna in the garden, participating in related citizen science activities, and the social and subjective wellbeing benefits participants receive. The only quantitative study on the wellbeing and social connection benefits of wildlife gardening to our knowledge contains data from one Australian program (Mumaw and Mata, 2022).

Purpose of this research

This report addresses research commissioned by Gardens for Wildlife Victoria to:

Explore the motivations, garden/gardening activities, planting choices, wildlife observations, environmental activities, demographics, neighbourhood environmental character, and proximity to bushland patches of wildlife gardeners.

Identify features of wellbeing and connections with community, nature, and place that wildlife gardeners attribute to their wildlife gardening.

Document associations between locally native plant species commonly used in wildlife gardening and insect pollinators.

Describe relationships between wildlife gardener motivations, activities, and planting choices and the achievement of specific insect pollinator goals.

Recommend indigenous plant palettes to achieve various insect pollinator goals.

Recommend tools for assessing the social and ecological benefits of wildlife gardening.

Figure 1.2. Gum tree providing habitat for a pair of tawny frogmouths. Photo by Richard Kelly.

The findings will expand our knowledge about the social and wellbeing impacts of wildlife gardening; improve understanding of how wildlife gardening can support the critically important ecological function of pollination, particularly in relation to indigenous species; and support urban biodiversity stewardship knowledge and practice.

Research approach

This research was commissioned in 2019 prior to the onset of COVID and COVID-related restrictions throughout 2020. This required modifying the original approach to adhere to lockdown restrictions. The research involved:

An online survey of wildlife gardeners associated with or involved in wildlife gardening programs being developed or operated by Gardens for Wildlife Victoria participants. Statistical analysis was used to ascertain the

Figure 1.3. Wildlife gardening provides opportunities for connections with people and place. Photo by Richard Kelly.

gardening preferences and activities of participants, their observations of wildlife, the range and strength of benefits they derive from these activities, and other factors. An additional question was asked about the impact of COVID lockdowns on the respondents' wildlife gardening efforts and neighbourhood wildlife observations.

Observations and photographic documentation of insects and insect pollinators interacting with the flowers of a suite of indigenous plant species over the course of a year at four plant nurseries supplying wildlife gardening programs.

Details are provided in Chapters 2 and 3 respectively.

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2 Social research methods and findings

Social research methods

Online survey

We developed a survey (a link to the survey will be included here) with a series of questions about what wildlife gardening means to participants, their gardening preferences, the time spent and the type of activities they conduct in their garden, their perceptions about the diversity of wildlife living in and visiting their garden, the locally native plant species they have added to their garden since they started wildlife gardening, and where they acquired these species.

Another part of the survey invited participants to respond to different facets of personal wellbeing and connections associated with their wildlife gardening experiences. We also asked what other environmental care activities they undertook as a result of wildlife gardening.

Finally, we asked whether and how participants were involved in wildlife gardening programs, how long they have been wildlife gardening, and a few demographic questions, including the environmental character of their surroundings.

Survey distribution

Between November 2020 and early February 2021, we invited (1) Gardens for Wildlife Victoria members and Facebook group participants and (2) participants of municipal wildlife gardening programs associated with Gardens for Wildlife Victoria and their Facebook groups to take the survey. Gardens for Wildlife Victoria members are developers and managers of municipal wildlife gardening programs. Wildlife gardening program participants are generally residents of that municipality; some are business owners doing wildlife gardening on their business properties. Facebook participants of both Gardens for Wildlife Victoria and municipal wildlife gardening programs are people interested in wildlife gardening but not necessarily members of Gardens for Wildlife Victoria or the programs.

Two hundred and forty nine (249) persons took the survey although not everyone answered all the questions. Approximately 200 respondents answered most questions.

Demographics of respondents

Households

Over three quarters of respondents described their households as couples, almost equally split between those with and without children (Figure 2.1).

Ninety two per cent of respondents said they lived in houses with the remaining 8% in units, townhouses and apartments.

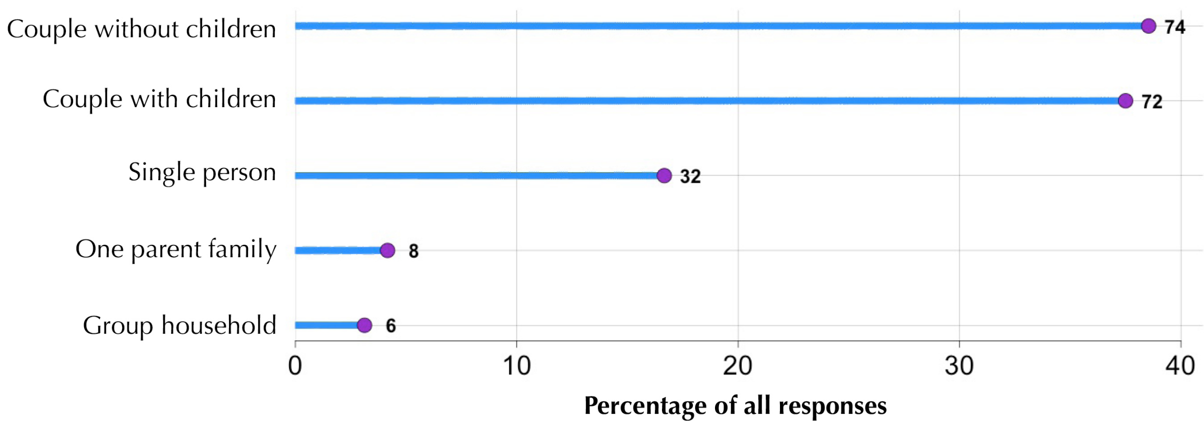

Figure 2.1. Respondents' description of their households.

Age

The greatest proportion of respondents who answered this question said they were aged between 35-49 (30%), followed by those 50-59 (22%), 60-69 (22%) and 70-84 (19%) (Figure 2.2). Those aged between 25 and 34 made up only 7%. In comparison to the age structure of the Victorian population between 25 and 84, the sample is older (with the exception of the 35-49 year old group); there is a much smaller proportion in the youngest age group (Table 2.1).

Country of childhood

The great majority of respondents (84%) said they grew up in Australia, a greater proportion than the 67% the Australian 2016 census shows were born in Australia (Australian Bureau

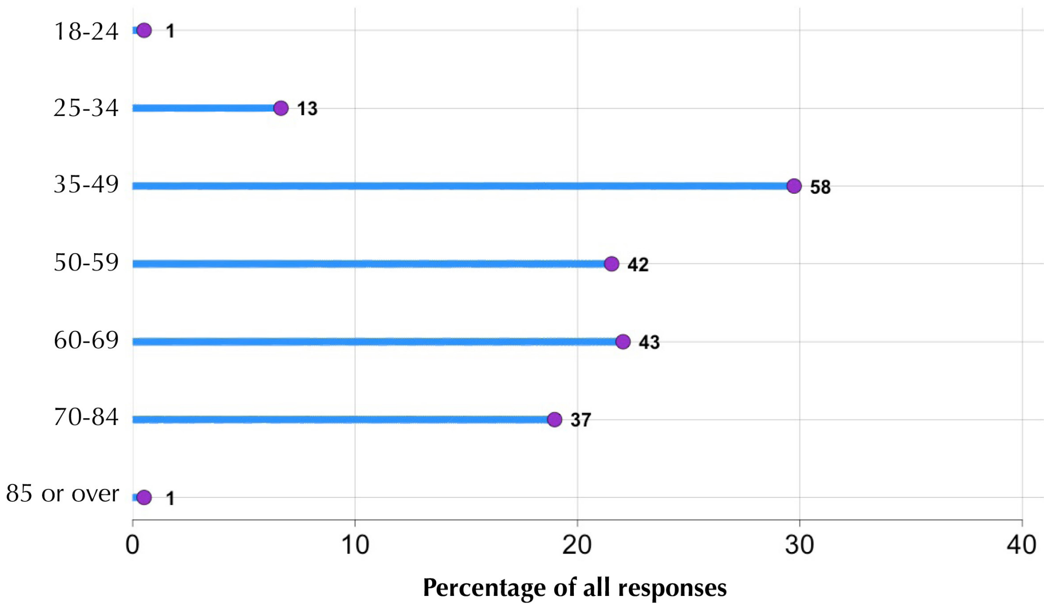

Figure 2.2. Age of respondents.

Table 2.1. Proportion of participants by age group.

Age category	Survey sample (%)	Victorian population (%)[1,2]
25-34	7	23
35-49	30	31
50-59	22	19
60-69	22	15
70-84	19	13

[1] Percentage of total population between ages of 18 and 84

[2] Source: ABS, 2016 census

of Statistics, 2017). The minority who grew up elsewhere had done so in diverse other countries (Figure 2.3).

Location of residence

The greatest proportion of respondents (close to 40%) lived in the City of Knox (Figure 2.4). This reflects the large number of participants in the Knox gardens for wildlife program (over 1000 at the time of the survey), which has been operating the longest (15 years) and has more participants than any other program associated with Gardens for Wildlife Victoria.

Environmental character of respondents' surroundings

Property surroundings

The great majority of respondents (80%) lived in urban or suburban surroundings, and the remaining 20% in rural or natural surroundings. In future we recommend better defining and distinguishing urban from suburban surroundings.

Proximity to nearest bushland patch

The great majority of respondents (72%) lived within 10 minutes walking distance to the nearest bushland patch (Figure 2.5).

Respondents' involvement in wildlife gardening

Length of time involved in wildlife gardening

Respondents had been involved in wildlife gardening from under two years to more than 40 years (Figure 2.6). While

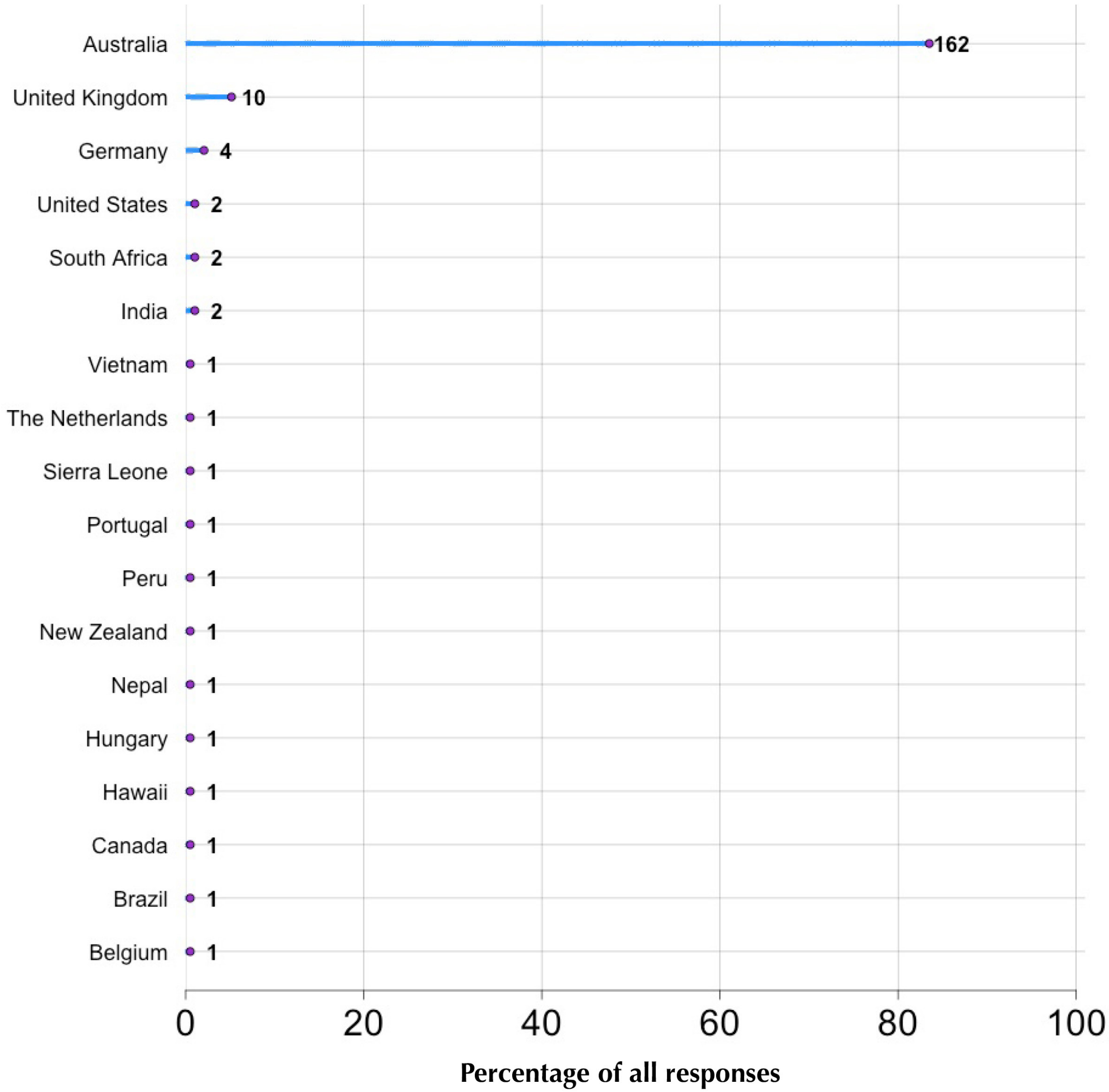

Figure 2.3. Place respondents grew up.

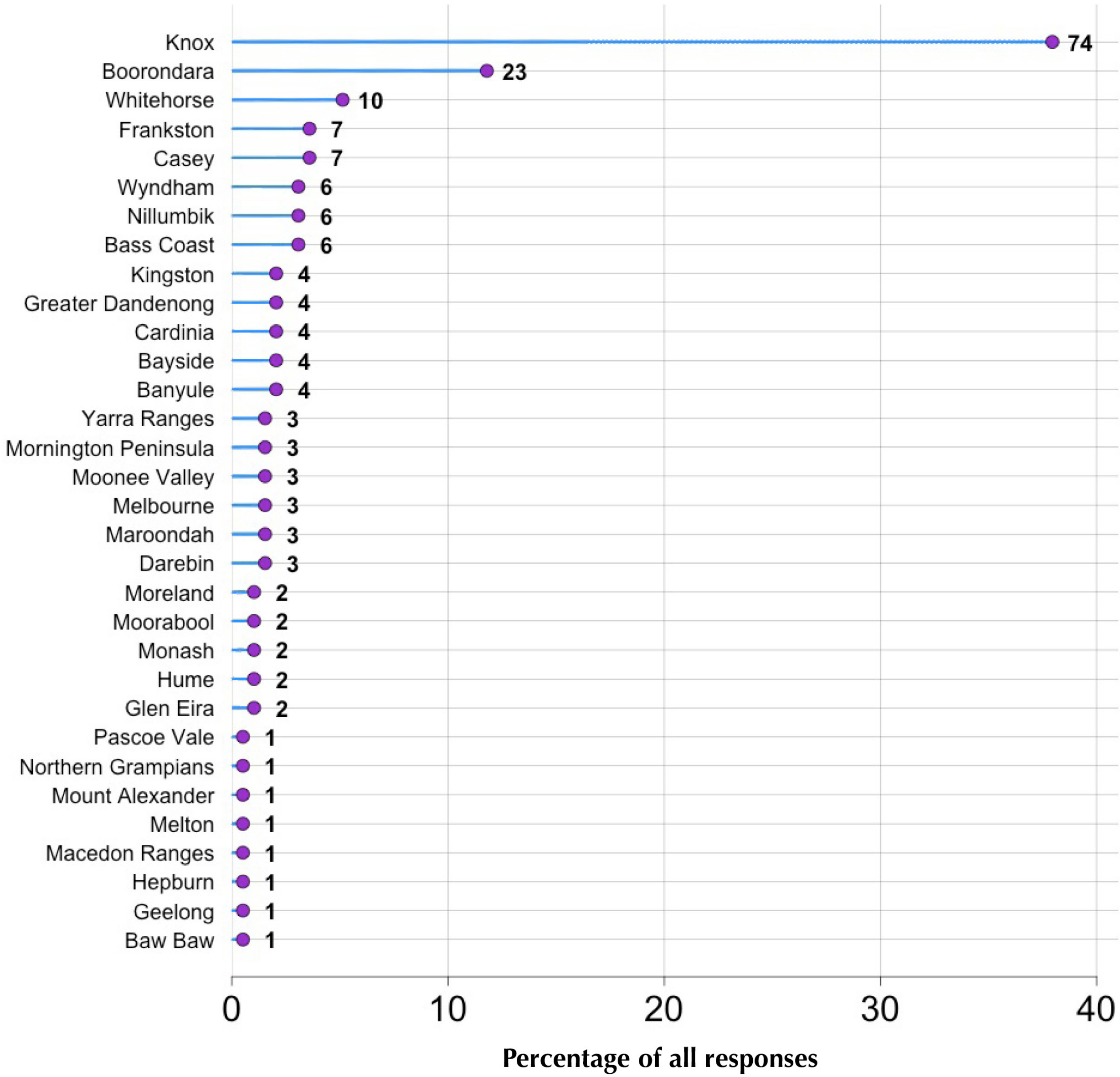

Figure 2.4. Respondents' Local Government Area of residence.

about 40% have been doing it for 5 years or less, and 32% for 6-10 years, about 28% claim to have done it between 16 to over 40 years.

Mode of involvement in wildlife gardening

Of the 194 respondents who answered questions related to their involvement in wildlife gardening programs (Question 18 in survey), 45% were not involved in a wildlife gardening program, 30% were participants in wildlife gardening programs, and 25% were program leaders or volunteers of wildlife gardening programs (Figure 2.7). These different modes of involvement allow us to consider how they may affect people's meanings, motivations, and perceived benefits of wildlife gardening.

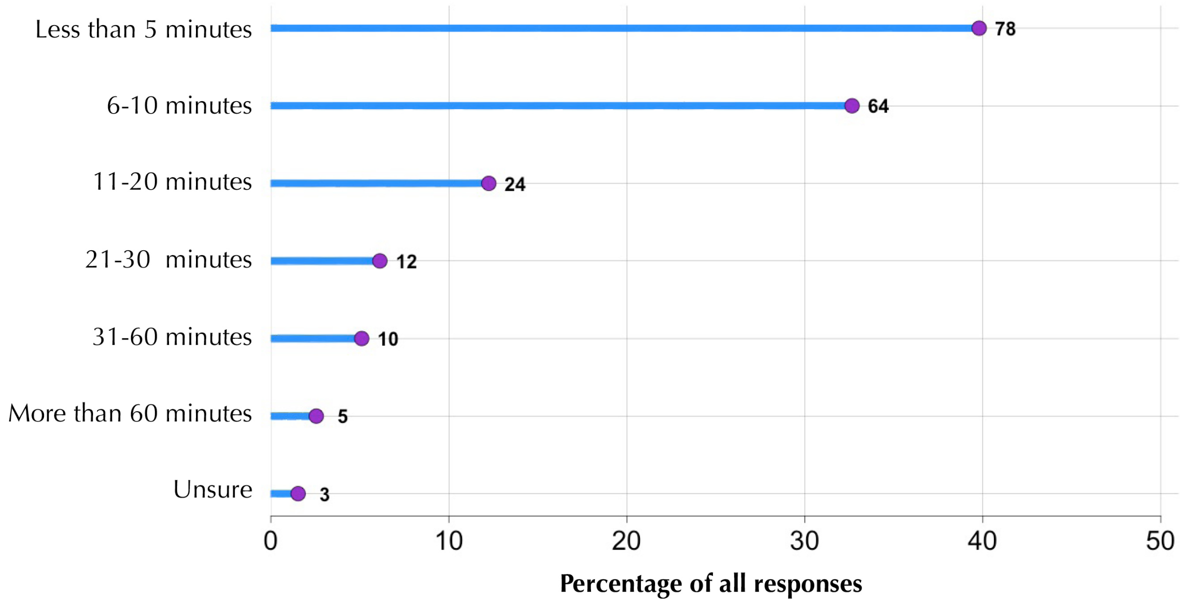

Figure 2.5. Proximity of respondents' gardens to nearest bushland patch.

Frequency of garden visits

Respondents visited their gardens at different frequencies for different purposes. Figure 2.8 shows how frequently respondents visited their gardens to relax and/or experience nature, wildlife garden, garden more generally, or conduct citizen science activities. Respondents overwhelmingly visited their gardens daily (>80%) to relax and/or experience nature. This is a greater frequency than found in the Victorians Value Nature study, which surveyed a representative sample of over 3000 Victorians in terms of gender, age, and metro (Melbourne) versus regional (rest of Victoria) residents according to ABS statistics (Meis-

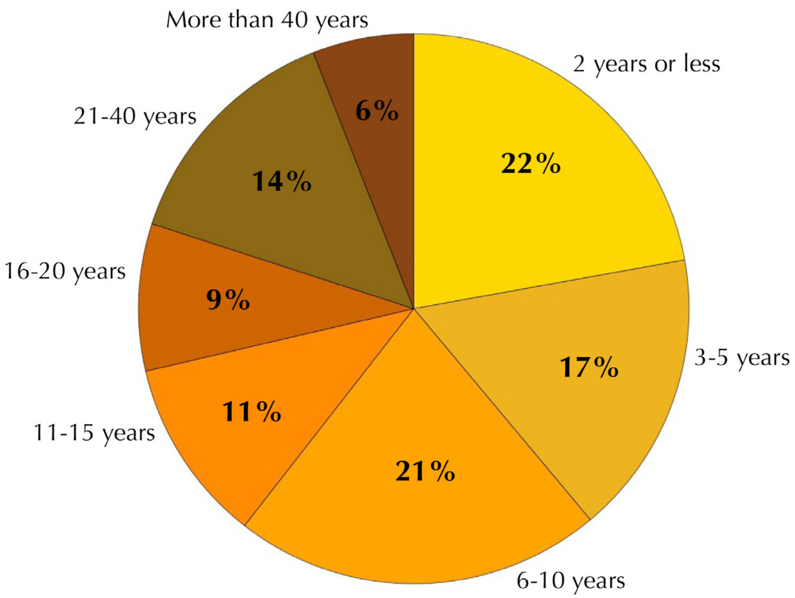

Figure 2.6. Time involved in wildlife gardening.

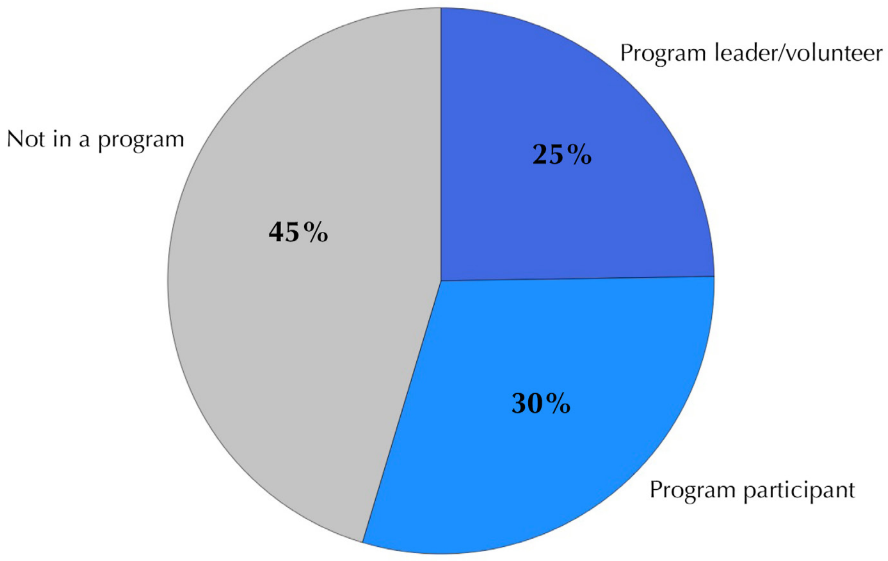

Figure 2.7. Mode of wildlife gardening.

Harris et al., 2019). In this study, 60% of respondents said they spent time in nature at least once a week (32% every day or every other day), and when 'spending time in nature', 42% said they spent most time in their own gardens (Meis-Harris et al., 2019).

Seventy per cent of our study's respondents visited their gardens daily or weekly to wildlife garden (30% daily) and 80% to garden more conventionally (40% daily). Only 40% of respondents visited their gardens to make observations and/or contribute to citizen science, with about 15% doing this daily, 10% weekly, 10% monthly, and 7% annually. The Victorians Value Nature survey showed that a similar 40% of Victorians engaged in citizen science, but less frequently – 8% often, 12% sometimes, and 20% rarely (Meis-Harris et al., 2019).

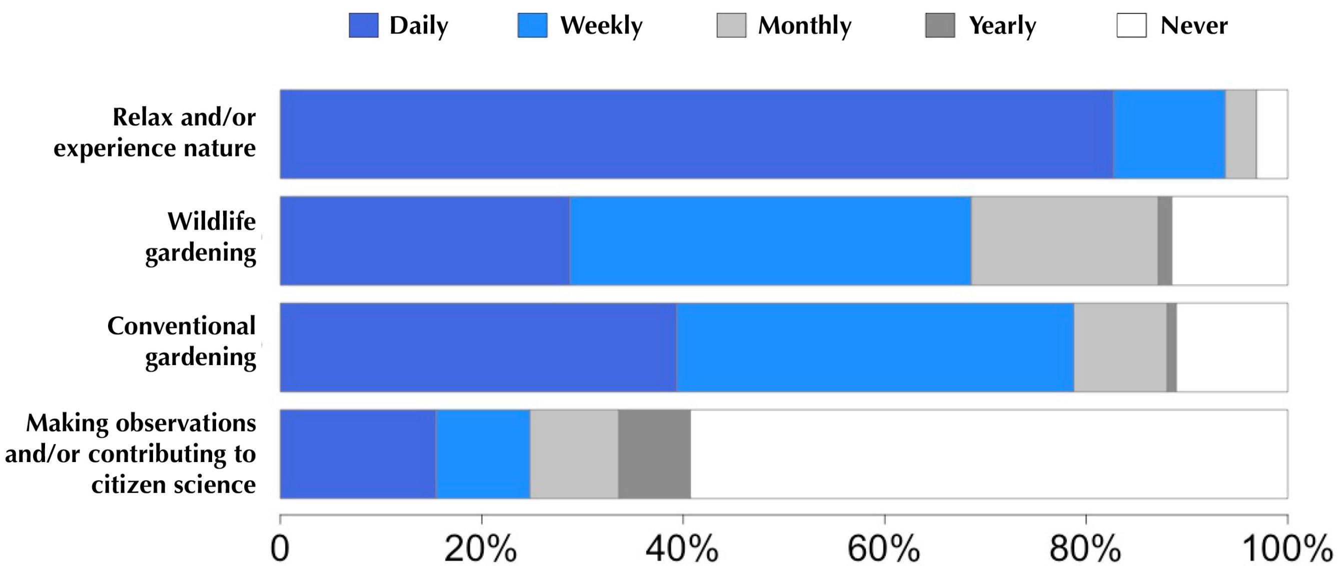

Figure 2.8. Frequency of visiting garden for different activities.

Social findings

In this section we discuss findings that have primarily social significance. Survey findings with more direct implications for plant and animal taxa and associated wildlife gardening motivations and activities are discussed in Chapter 4.

Wildlife gardening has personal, ecological, and social meanings

Figure 2.9 shows what meanings three groups of respondents ascribe to wildlife gardening. These groups were: program leaders/volunteers, program participants, and those not involved in a program. The most frequently agreed meanings for all groups (>80%) reflect 1) personal benefits (e.g. attracting wildlife to or experiencing wildlife in my garden – Figure 2.9a-b) and 2) benefits for native species (e.g. supporting native plants and animals – Figure 2.9c-f). When the social concept of 'being part of a community effort' to preserve native species is introduced (Figure 2.9 g), there is still over 80% agreement from program leaders/volunteers but slightly less (approx. 70%) agreement from program participants and non-participants.

For the term 'contributing to biodiversity conservation' (Figure 2.9 h), almost 80% of program leaders/volunteers agree while this drops to 70% for program participants and non-participants. Similarly, for ecological concepts such as 'providing habitat links to native bushland' (Figure 2.9i) receives agreement from over 80% of program leaders/volunteers, dropping to 70% from program participants and 60% for non-participants. 'Helping to maintain the quality of surrounding bushland' (Figure 2.9k) received less than 60% agreement from program leaders/volunteers and participants and about 45% from non-program participants. Wildlife gardening can improve the quality of bushland by reducing environmental weeds in gardens that can spread to bushland, but this potential relationship is probably not well known or considered by the general public. One respondent provided this comment:

> "I don't live anywhere near bushland, so the 'stepping stones' type questions unfortunately don't apply"

and another:

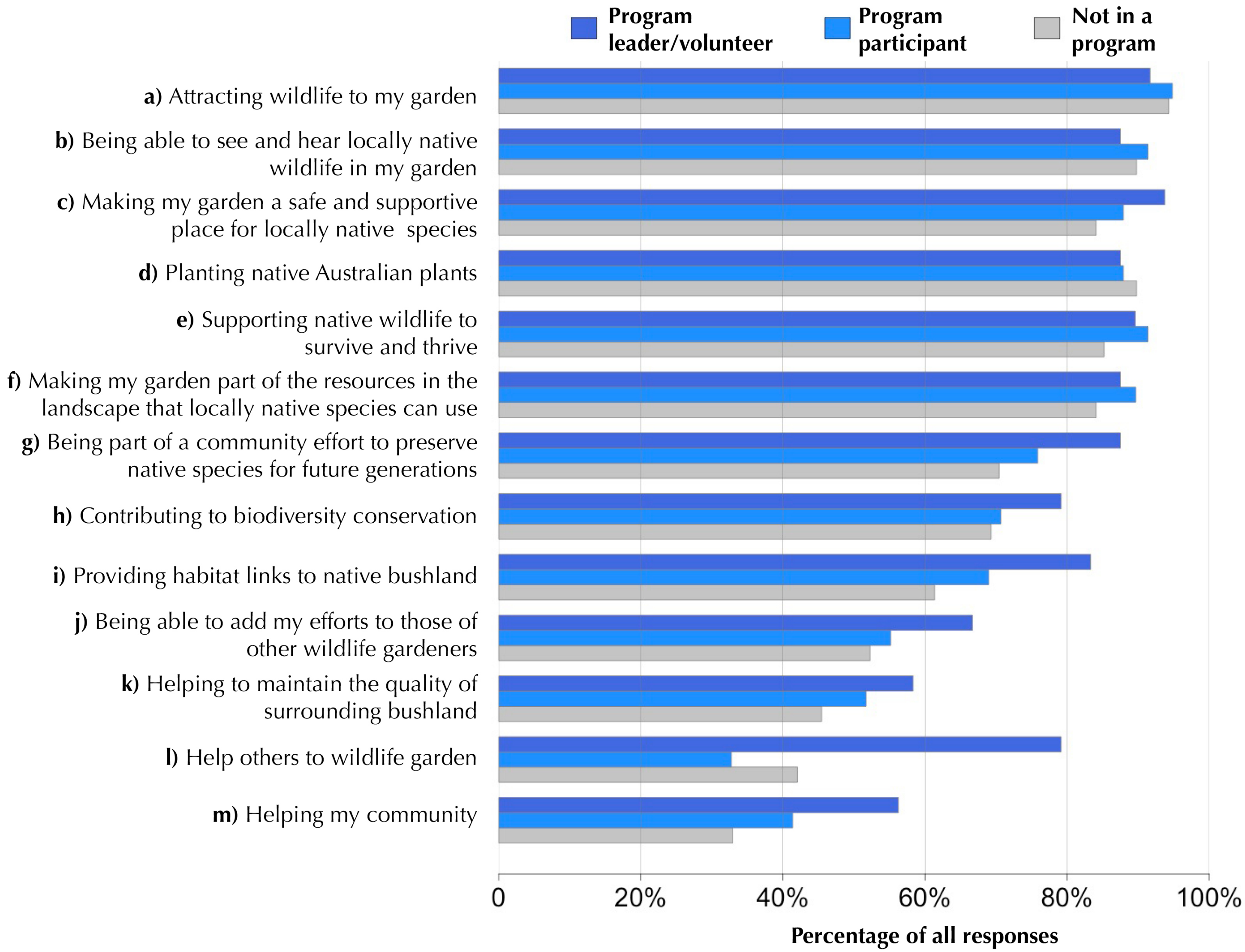

Figure 2.9. Meanings of wildlife gardening for those involved in different ways. LEA: Leader or volunteer of program; PAR: Participant in a program; NOT: Not a participant or leader/volunteer of a program.

> "the only reason I didn't click 'habitat links' and 'surrounding bushland' is because we are somewhat distant from our nearest park that would support wildlife and I'm unclear whether our garden would be on any travel-routes. However I would love to think birds and animals are using our garden to link to native bushland".

The social meanings of wildlife gardening (Figure 2.9j, l-m) receive the least agreement from all three segments of wildlife gardeners, with program leaders and volunteers providing the highest levels of agreement. The meaning 'adding my efforts to those of other wildlife gardeners' (Figure 2.9j) gets agreement from 50% of program participants and non-participants, but drops to 35-40% from these respondents for 'helping others to wildlife garden' (Figure 2.9l) and 'helping my community (Figure 2.9m).

Fifty respondents provided comments in the 'Other' box. Many comments added detail to choices the respondents had already ticked including personal experiences, e.g. the various wildlife that had visited their properties. In relation to biodiversity conservation, one respondent commented:

"So little is done by state and federal government levels to protect and conserve biodiversity that it is up to the ordinary citizen to keep our biodiversity alive".

Some new concepts were introduced; the greatest number (10) related to indigenous species and caring for country, for example:

> "I go beyond planting just native Australian plants, I strongly preference local indigenous plants".

> "Celebrating local flora and creating a sense of place that is uniquely Australian or city-specific".

> "It is my duty to look after nature, considering the life nature gives me. I'm not of aboriginal descent, but in a sense, it is my connection to country too".

In this vein two respondents respectively added 'seed collection' and 'propagating rare and native food plants'.

Another eight respondents added comments related to wellbeing and experiencing nature, for example:

> "It gives me a sense of achievement"

and:

> "All of the above [meaning choices] apply but it's also key in managing my mental state and stress levels. I get more back than I give as I'm a human in my native habitat and it just feels right".

> "Sitting outside at night seeing all that my garden offers to all the night life. eg micro bats, possums, powerful owls, tawny frogmouths. Listening to the crickets n cicadas. Not to mentioning the birds who visit during the day, the skinks n spiders".

> "I am bedridden but still collaborator with my gardening husband and daughter. I can observe much of the back garden and dam/orchard area through the bedroom windows".

Four additional respondents commented about learning about nature and indigenous species.

Meanings can be thought of as social representations in that they reflect 'a system of values, ideas and practices that are used by social groups to understand a phenomenon' (Buijs et al., 2012). Meanings related to human connections with nature are underpinned by broader societal understandings and debates, but also reflect the concepts of groups to which the users belong or adhere to, and the contexts within which the meaning is considered (Buijs et al., 2012; De Kleyn, Mumaw and Corney, 2020). People often use informal language that they are familiar with to describe their experiences and meanings for nature and its components, rather than less familiar, specialised concepts (De Kleyn, Mumaw and Corney, 2020). For example, a term such as 'biodiversity conservation' may not be chosen by someone because a person ascribes a narrow meaning to it (e.g. saving a rare charismatic species), or characteristics (such as being a 'greenie') that they do not espouse (De Kleyn, Mumaw and Corney, 2020). This may help explain why some of the more technical or 'loaded' meanings received less agreement. Additionally, the public seem to focus on individual animals and trees and their emotional connection to them when considering nature management, in contrast with professional foci on conserving species, habitats and ecosystem health (Buijs and Elands, 2013).

We found, unsurprisingly, that some of the meanings agreed to more strongly by program leaders and volunteers than other groups are embedded in the definitions, understandings and practices of the network to which they belong, Gardens for Wildlife Victoria. Gardens for Wildlife Victoria puts strong emphasis, including in workshops and training for program leaders and volunteers, on engaging residents in wildlife gardening to improve habitat for locally native species and support habitat protection and improvement. It also emphasises fostering social connections and wellbeing, and nurturing native biodiversity as part of a community effort (Gardens for Wildlife Victoria, 2021a, 2021b).

Wildlife gardening provides personal, social, and place-related forms of wellbeing

We used subjective (the opinion of respondents rather than independent assessors) wellbeing measures in the survey. Subjective measures are widely accepted and used in policy and wellbeing research (Ryff and Keyes, 1995; Ryan and Deci, 2001; Dolan and Metcalfe, 2012; La Placa, McNaught and Knight, 2013). They include global measures such as 'quality of life', measures relating to emotions (e.g. 'in a better mood'), eudemonic (eudaimonic) measures relating to purposefulness, self-development and self-esteem (e.g. 'feel a sense of purpose to my gardening', 'am learning new things'), measures relating to place attachment, and measures relating to social connections (e.g. 'feel a part of the neighbourhood community').

All of these wellbeing elements have been previously associated with various human-nature connections and interactions (Russell et al., 2013; Capaldi et al., 2015; Basu, Hashimoto and Dasgupta, 2020), including environmental enhancement and care (Maller, Mumaw and Cooke, 2019), gardening (Soga, Gaston and Yamaura, 2017), and wildlife gardening (Raymond et al., 2019; Mumaw and Mata, 2022).

Respondents agreed or strongly agreed with a diverse array of feelings and connections as a result of wildlife gardening (Figures 2.10-2.11). Ninety per cent or more agreed or strongly agreed with items in the categories of experiential wellbeing, self-development, self-esteem, sense of purpose, and place attachment (Figure 2.10a-i; Figure 2.11a-b, d-e). This included high levels of agreement with wellbeing from and learning more about nature; sense of purpose and satisfaction from wildlife gardening; feeling motivated to continue wildlife gardening; and feeling attached to one's garden, local nature and wildlife – all predominantly centred around self.

Less respondents agreed or strongly agreed with receiving benefits associated with social connections, ranging from 'helping the community' and 'sharing my wildlife gardening experiences' – nonetheless still high at over 75% (Figure 2.11c, g), down to approximately 55% agreeing that they feel connected with other wildlife gardeners (Figure 2.11h) and just under 50% feeling a part of the neighbourhood community (Figure 2.11i).

For those elements respondents only strongly agreed with, we see broadly similar patterns to those elements with which respondents agreed or strongly agreed, but with some interesting distinctions. For those 13 elements with which 90% or more of respondents agreed or strongly agreed (associated with experiential wellbeing, self-development, self-esteem, sense of purpose, and place attachment but not social connections), feeling wellbeing from experiencing nature (Figure 2.10d) now stands out from the others with the highest per cent of respondents – almost 80% strongly agreeing. Feeling a sense of purpose to my gardening (Figure 2.10a) comes next with close to 70% strongly agreeing.

The next three elements with which respondents strongly agreed (approx. 61-63%) were 'feel in a better mood' (Figure 2.10e), 'feel attached to my garden' (Figure 2.11d), and 'feel that I am helping wildlife (Figure 2.10b). Seven of the remaining high-scoring elements received strong agreement from between 50-60% of respondents (Figure 2.10c, g-i; Figure 2.11a-b, e), with 'feel satisfied with life', strongly agreed to by about 47% of respondents (Figure 2.10 f).

Feeling attached to my neighbourhood the place (Figure 2.11f) and the four socially related elements (Figure 2.11c, g-i) received strong agreement from between 20-40% of respondents; only 13% strongly agreed that as a result of wildlife gardening they feel a part of the neighbourhood community (Figure 2.11i).

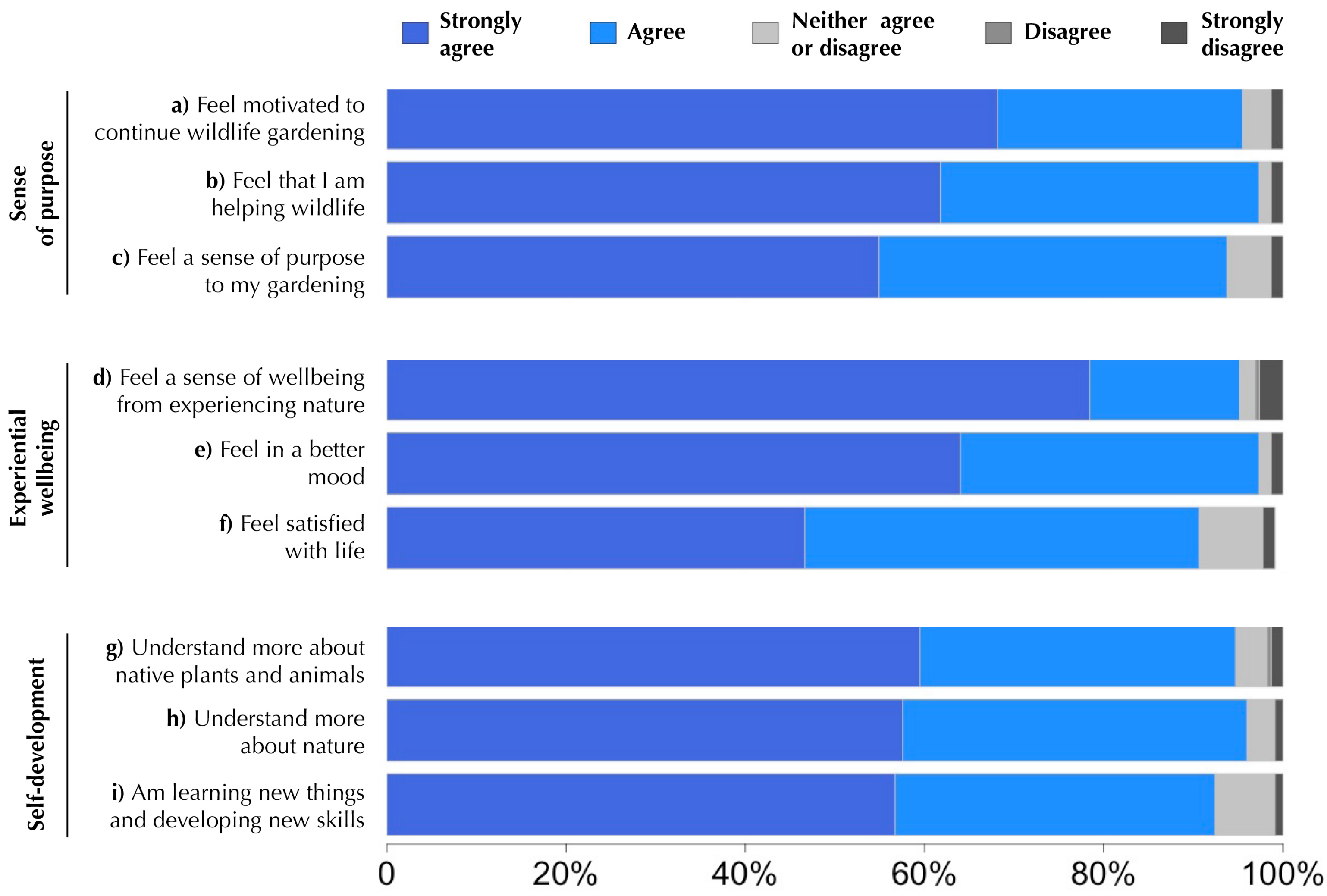

Figure 2.10. Feelings and connections as a result of wildlife gardening, part I.

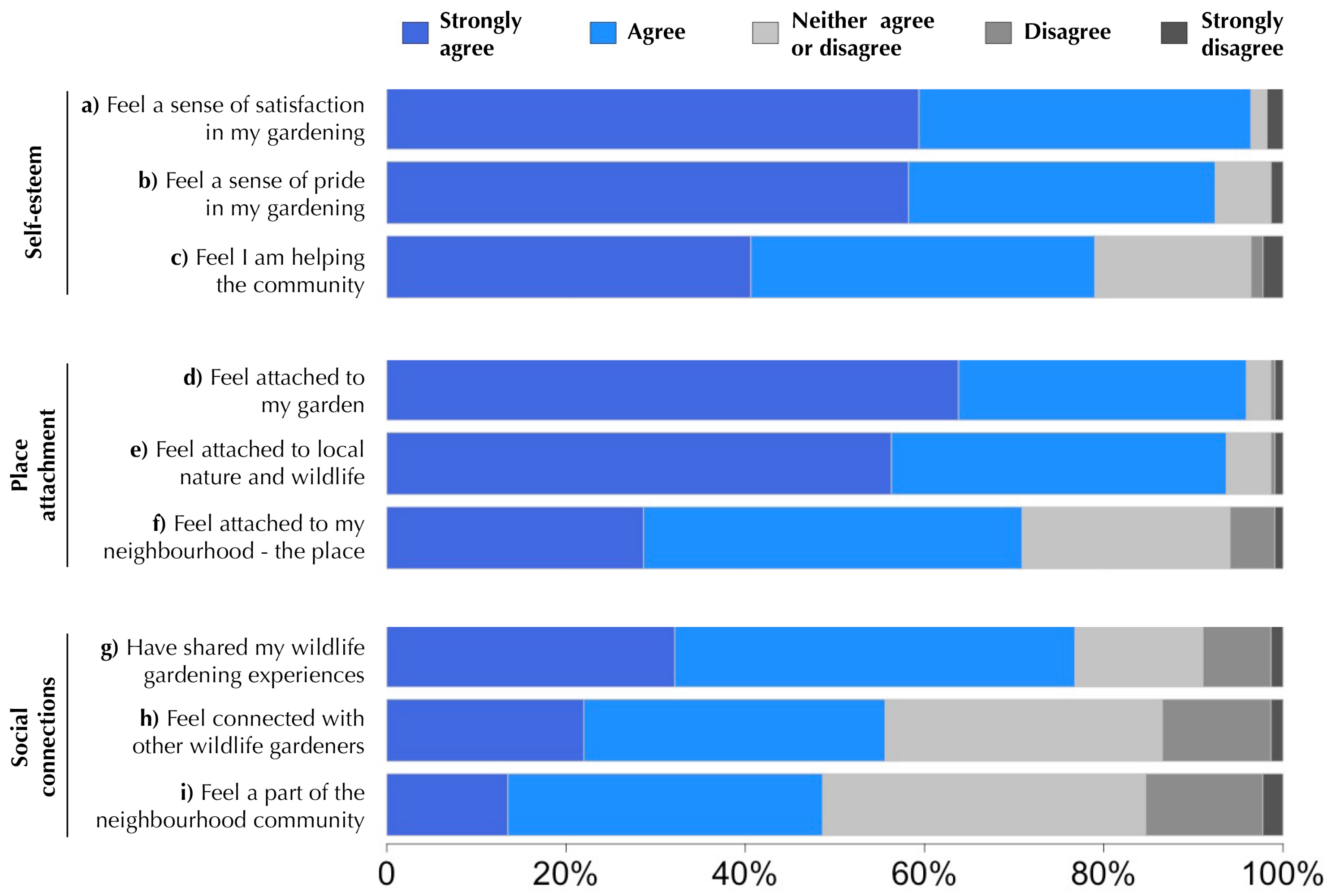

Figure 2.11. Feelings and connections as a result of wildlife gardening, part II.

Social connections are more strongly felt / shared by program leaders and volunteers

Of the four wellbeing elements involving social connections (Figure 2.11c, g-i), there are strong levels of agreement with 'feel I am helping the community' and 'have shared my wildlife gardening experiences'. Figure 2.12 shows the different levels of agreement with social connections from wildlife gardening for respondents involved either as 1) program leaders/volunteers, 2) program participants, or 3) those not involved in a program. Program leaders/volunteers more strongly agree with all four elements than the other two groups. This result is similar to the greater agreement program leaders/volunteers show for social meanings of wildlife gardening. As described in that section, this result is unsurprising given that the Gardens for Wildlife Victoria network promotes engagement of the community in wildlife gardening and its social benefits (Gardens for Wildlife Victoria, 2021a, 2021b). The importance of the social dimensions of wildlife gardening to Gardens for Wildlife Victoria program leaders/developers has been found in other research (Mumaw and Raymond, 2021).

Interestingly, those not involved in wildlife gardening programs show greater levels of strong agreement than program participants for all four social measures, and overall agreement with two of the measures ('feel connected with other wildlife gardeners', 'feel a part of the neighbourhood community' – Figure 2.12). Further exploration of how and why this might be so is warranted. This may be related to the fact that non-program participants are more heavily involved in Friends groups, citizen science, and community planting events than program participants (Figure 4.28).

In terms of neighbourhood relations, wildlife gardening activities can be at odds with neighbours' gardening practices. Previous studies of wildlife gardening program participants have shown that activities such as retaining large mature trees or removing environmental weeds can conflict with neighbours' views and gardening approaches, and program participants manage this in different ways (Mumaw and Bekessy, 2017).

Wellbeing results compare with other types of pro-environmental behaviours

There is growing quantitative evidence of a positive link between pro-environmental behaviours, life satisfaction, and eudemonic wellbeing (Laffan, 2020). Laffan's large-scale study across four years of a representative sample of British adults showed that being involved in pro-environmental behaviours (recycling, buying eco-friendly products, encouraging other people to protect the environment, environmental volunteering and being a member of a conservation or environmental organisation) were all associated with overall life satisfaction although they seemed to be far more closely related to how worthwhile individuals consider their behaviours to be (Laffan, 2020). In our study, engaging in wildlife gardening was somewhat more associated with a sense of purpose to their gardening and satisfaction in helping wildlife than feeling 'satisfied with life' more broadly.

Of the few quantitative studies specifically focused on the subjective wellbeing benefits gained by 'hands on' environmental volunteers (outside of wildlife gardening), one found that individuals involved in conservation land management in rural Victorian communities reported feeling higher levels of general health, safety in their local communities, and overall wellbeing than non-participants (Moore, Townsend and Oldroyd, 2006). In another quantitative study, ecological restoration volunteers working in groups on reserves in greater Chicago ranked satisfaction from their restoration work highest for meaningful action and fascination with nature, followed by participation in a group (Miles, Sullivan and Kuo, 2000).

Quantitative research on the benefits of Australian Landcare (volunteers in community-based groups practicing sustainable land management and environmental conservation) was conducted by KPMG (2021). Survey respondents (1000) were almost equally split between those who lived in major Australian cities (48%) and those in remote and regional communities. Since being involved in Landcare they felt more connected to the natural environment (93% agree of which 57% strongly agree) and more connected to other people (90% agree of which 40% strongly agree). Half felt that their mental health had moderately or strongly improved, of which 17% felt it had strongly improved.

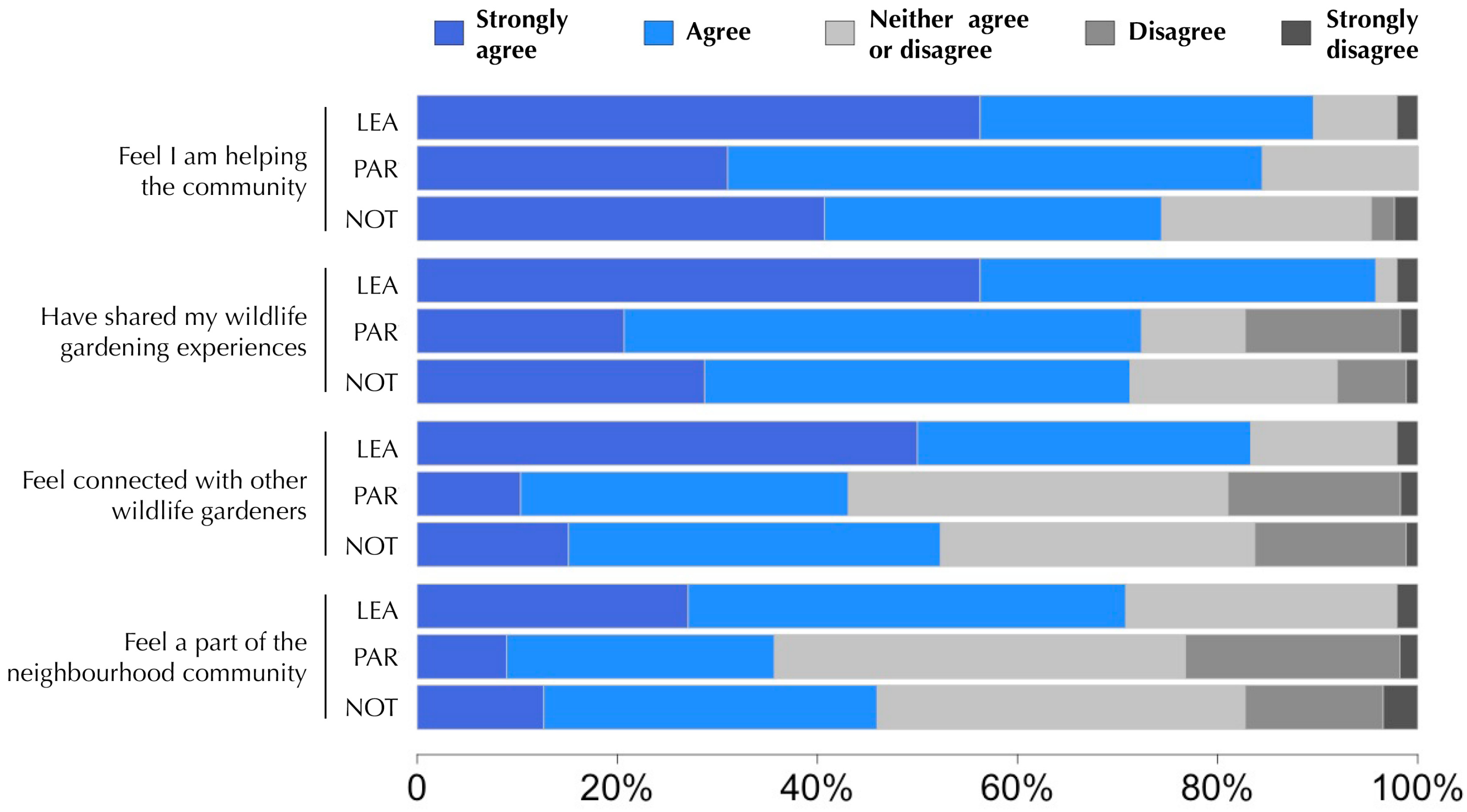

Figure 2.12. Social connections from wildlife gardening for those involved in different ways. LEA: Leader or volunteer of program; PAR: Participant in a program; NOT: Not a participant or leader/volunteer of a program.

Our research results are in accord with those studies, with the overwhelming majority of respondents agreeing with having connections to nature and feeling a sense of purpose to their wildlife gardening. This research provides more detail in relation to elements of self-esteem, self-development, motivation, and learning associated with wildlife gardening, which will be further analysed. Unsurprisingly, the environmental volunteers working in groups feel they gain stronger social connections from their nature stewardship activities. Gardens for Wildlife Victoria program leaders and volunteers who work with each other and program participants also feel connected to other wildlife gardeners.

Implications

The social findings of this research have several implications. First, the wellbeing results confirm quantitatively and with the largest and most diverse sample of wildlife gardeners to date, that wildlife gardening provides an array of subjective wellbeing found in previous research (Raymond et al., 2019; Mumaw and Mata, 2022). This has overarching policy significance given the universally accepted importance of fostering wellbeing and social connections. Global studies have shown the importance of wellbeing associated with self-esteem (pride), learning new things, purpose and self-direction – irrespective of the field(s) in which these are achieved – and that fulfilling these needs contributes to one's feelings of wellbeing independently of whether other needs such as safety, security, food and shelter are met (Tay and Diener, 2011).

Second, the findings of this research point to supporting wildlife gardening in social and ecological policies at all government levels for wellbeing alongside environmental purposes. Feeling energised and satisfied from carrying out activities powerfully contributes to empowering individuals to continue on a self-motivated basis (Thomas and Velthouse, 1990). Building community capacity involves building the energy, skills and resources 'to solve collective problems and improve or maintain the wellbeing of a given community' (Chaskin, 2001, p 295). European research shows that people act for nature not only because nature means something to them, but because acting for nature is meaningful and makes a difference; eudemonic value is key to energizing and shaping committed action for nature and should be a key pillar of nature conservation policy (van den Born et al., 2018). The wellbeing results from this study show how wildlife gardening engenders motivation to continue, and provides added evidence to previous studies that wildlife gardening programs can build community capacity and empowerment for environmental stewardship, of high value in the urban context (Mumaw, Maller and Bekessy, 2019; Jones et al., 2021). Other research shows that a network such as Gardens for Wildlife Victoria reinforces the motivation of program leaders and developers to continue their program work and boosts their feelings of empowerment (Mumaw and Raymond, 2021).

Third, this research adds to evidence that at the neighbourhood or property level, there are strong relationships between place attachment, personal wellbeing, social connections, and connections to nature (Raymond, Brown and Weber, 2010; Russell et al., 2013; Basu, Hashimoto and Dasgupta, 2020). As this research shows, respondents are strongly attached to their gardens, local nature and wildlife. Wildlife gardening programs can harness these personal connections from a social and ecological perspective. Moreover, this research shows that the rewards from wildlife gardening align with very high levels of motivation to continue, as shown in previous qualitative research For example, the Gardens for Wildlife Victoria garden visit reinforces the importance of a particular garden as well as its surrounds, landscape, and other wildlife gardeners. Garden guides can link the strong emotional connections individuals can have with individual animals and trees (Buijs and Elands, 2013) to broader concepts of habitat linkages and biodiversity conservation. Consideration can be given by each program to how to respond to local needs, aspirations, and resources, such as places of particular cultural, social or ecological significance.

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3 Ecological research methods and findings

Ecological research methods

Plant-insect pollinator interactions survey

Our plant-insect pollinator interaction surveys were conducted at four sites in Greater Melbourne, Victoria, Australia, which were centered around the project's four participating indigenous plant nurseries (Table 3.1). The original intention was to focus the surveys on the indigenous plant species grown within the nurseries, but this was later expanded to include indigenous plant species occurring in the nurseries' adjacent greenspace(s). The number of species surveyed in and around each of the four nurseries varied from four to 25 (Table 3.1). We imposed one important condition for plants surveyed outside of the nursery: the targeted plant individual to be surveyed had to be grown from nursery material, therefore guaranteeing its locally indigenous provenance.

We conducted our surveys over the period of a whole year; specifically, we visited the nurseries and their adjacent greenspaces a total of 23 times from 9 April 2020 to 4 April 2021. The original plan was to visit each site every 4-5 weeks across the year, but this became unfeasible due to COVID19 pandemic restrictions. In the end, we visited each site every 7-13 weeks.

At each site and during each visit we surveyed one to four individuals of each indigenous plant species (forbs, lilies, climbers, and shrubs) that were in flower. For species being grown in tubestock trays within the nursery, we considered a 'plant individual' as those tubestock plants growing in one or more (adjacent) trays. In total, we surveyed 36 indigenous plant species – including six that were only identified to genus level – across the four sites, comprising 17 forbs, three lilies, two climbers, and 14 shrubs (Table S1.1). These plant species had white (13), blue/violet (8), yellow (13), and pink/red (2) flowers (Figure 3.1). The surveyed plants also comprised a range of phylogenetic clades (a group of species that share a common ancestor and all its evolutionary descendants) across the plant branch of the tree of life – two liliod monoocts, three basal eudicots, 19 superasterids, and 12 superrosids – spread across 16 plant families (Table S1.1).

Our surveys were specifically designed to document any observed interactions between the above mentioned flowering plant species and a diverse range of insect pollinators and other flower-visiting insect species – henceforth pollinators for brevity. We only documented an interaction when the pollinator was actively observed touching the flower's reproductive organs. The studied pollinators were represented by 43 indigenous and introduced ant, aphid, bee, beetle, butterfly, fly, grasshopper, heteropteran bug, lacewing, moth, and wasp taxa (Table S1.2; Figures 3.2 and 3.3).

Plant-pollinator interactions were recorded using a variation of the direct observation survey methodology developed by Mata, Vogel and Bolitho (2020). Each survey consisted of three time periods of four, three, and three minutes, respectively. During each period, the surveyor actively observed the plant's flowers

Table 3.1. Indigenous plant nurseries where plant-insect pollinator interaction were surveyed.

Site name | Nursery	Associated greenspace(s)	Suburb	Municipality	Nº plant species surveyed
Bili Nursery	Gill Reserve and Walter Reserve	Port Melbourne	Port Phillip	18
Frankston Indigenous Nursery	Reserves within nursery site	Seaford	Frankston	4
Greenlink Box Hill Nursery	Bushy Creek Reserve	Box Hill North	Whitehorse	25
Knox Environment Society Indigenous Nursery	Wally Tew Reserve	Ferntree Gully	Knox	19

Figure 3.1. Flowers of the plant species surveyed in this work.

Figure 3.2. Indigenous pollinators and other flower-visiting insects observed during the study.

Figure 3.3. Introduced pollinators and other flower-visiting insects observed during the study.

and noted down the first sighting of any pollinator that came in touch with the flower's reproductive organs (i.e. carpels and stamens).

To complement this direct observation method, we also photographically recorded as many of the observed interactions as possible using a digital single-lens reflex camera equipped with a 100 mm macro lens. We posteriorly uploaded all photographic records to iNaturalist and benefited from the platform's community identification systems to check and validate the accuracy of our 'on the wing' field identifications. For consistency all plant-pollinator surveys were conducted by the same researcher (L. Mata). Surveys were conducted on clear, sunny days with less than 50% cloud cover, and discontinued if rain developed or if wind speed was greater than 5 m/s.

Statistical modelling

To assess whether indigenous pollinators were more common than introduced ones and how their species richness varied amongst the studied indigenous plant species across the four nurseries, we analysed our data with a three-level hierarchical metacommunity occupancy model (Kéry and Royle, 2016). Plant species was the unit of analysis for drawing inferences on pollinator species occupancy (i.e. whether a species is was observed to interact with the flower or not). Spatial (individuals of the same plant species sampled in different sites) and temporal (same or different individual of a given plant species sampled at different times) replication was used to draw inference on detection probability. We structured the model around three levels: one for species occupancy; a second for species detectability; and a third to treat the occupancy and detection parameters for each species as random effects (Kéry and Royle, 2016). A fully detailed description of our modelling approach can be found in Mata and colleagues (2021).

Ecological network

To illustrate the network structure of the study's plant-pollinator interaction dataset and highlight specific interactions between indigenous plant species and pollinators, we organised the data into two plant species by pollinator taxa matrices to generate: (1) a plant-bee network; and (2) a plant-butterfly network. In both cases cell values, and therefore the interaction strength between plants and pollinators, represented the number of times the bee or butterfly taxa were recorded interacting with each plant species. We visualised the networks as chord diagrams using Circos (Krzywinski et al., 2009).

Ecological findings

In total, we documented 825 plant-pollinator interactions between 36 indigenous plant species (Table S1.1) and 43 insect species (Table S1.2). The most frequently surveyed plant species was hop goodenia *Goodenia ovata*, accounting for 14.3% of all plant individuals surveyed. It was followed by sticky everlasting *Xerochrysum viscosum* and cut-leaf daisy *Brachyscome multifida*, which accounted for 8.2% and 7.5%, respectively, of all plant individuals surveyed. The European honeybee *Apis mellifera* was the most frequently observed pollinator – it participated in 16.8% of all recorded interactions. It was followed by sweat bees and hoverflies, which participated in 15.4% and 12.1%, respectively, of all recorded interactions.

Pollinator communities associated with indigenous plant species are predominately composed of indigenous rather than introduced species

We documented approximately five times more indigenous (36) than introduced (7) pollinator species in our study. Introduced species included the African carderbee *Pseudoanthidium repetitum*, aphids (family Aphididae), the cabbage white *Pieris rapae*, the dronefly *Eristalis tenax*, the European honeybee, European wasps (genus Vespula), and greenbottle flies (genus Lucillia). Our model estimates indicate that any particular plant species in our study was associated with 3.6 times more indigenous than introduced pollinator species (Figure 3.4a; Table S1.3). The mean number of introduced pollinator species per plant species varied from 0 to 4; whereas the mean number of indigenous pollinator species varied from 1 to 21, with approximately half of the studied plant species being associated with more than four indigenous pollinator species (Figure 3.4b; Table S1.4).

Our results indicate that communities of pollinators and other flower-visiting insects associated with indigenous plant species in Melbourne are predominately composed of indigenous rather than introduced species. This finding aligns well with our previous study of insect communities in Melbourne's greenspaces (Mata et al., 2021), as well as with studies from urban environments in other continents (Goertzen and Suhling, 2014; Sing et al., 2016; Brown and Hartop, 2017). A couple of the introduced species, however, such as the European honeybee and the cabbage white, were relatively common and widespread, which is consistent with previous studies (Threlfall et al., 2015; Mata et al., 2021). The European honeybee's ubiquitousness may be a direct consequence of urban beekeeping and may be associated with negative effects on indigenous bees (Egerer and Kowarik, 2020; Prendergast and Ollerton, 2021).

Plant species hosted very different numbers of pollinator species

Our model estimates indicate that any particular plant species in our study was associated with approximately eight pollinator species (Figure 3.5; Table S1.3). This mean number of pollinator

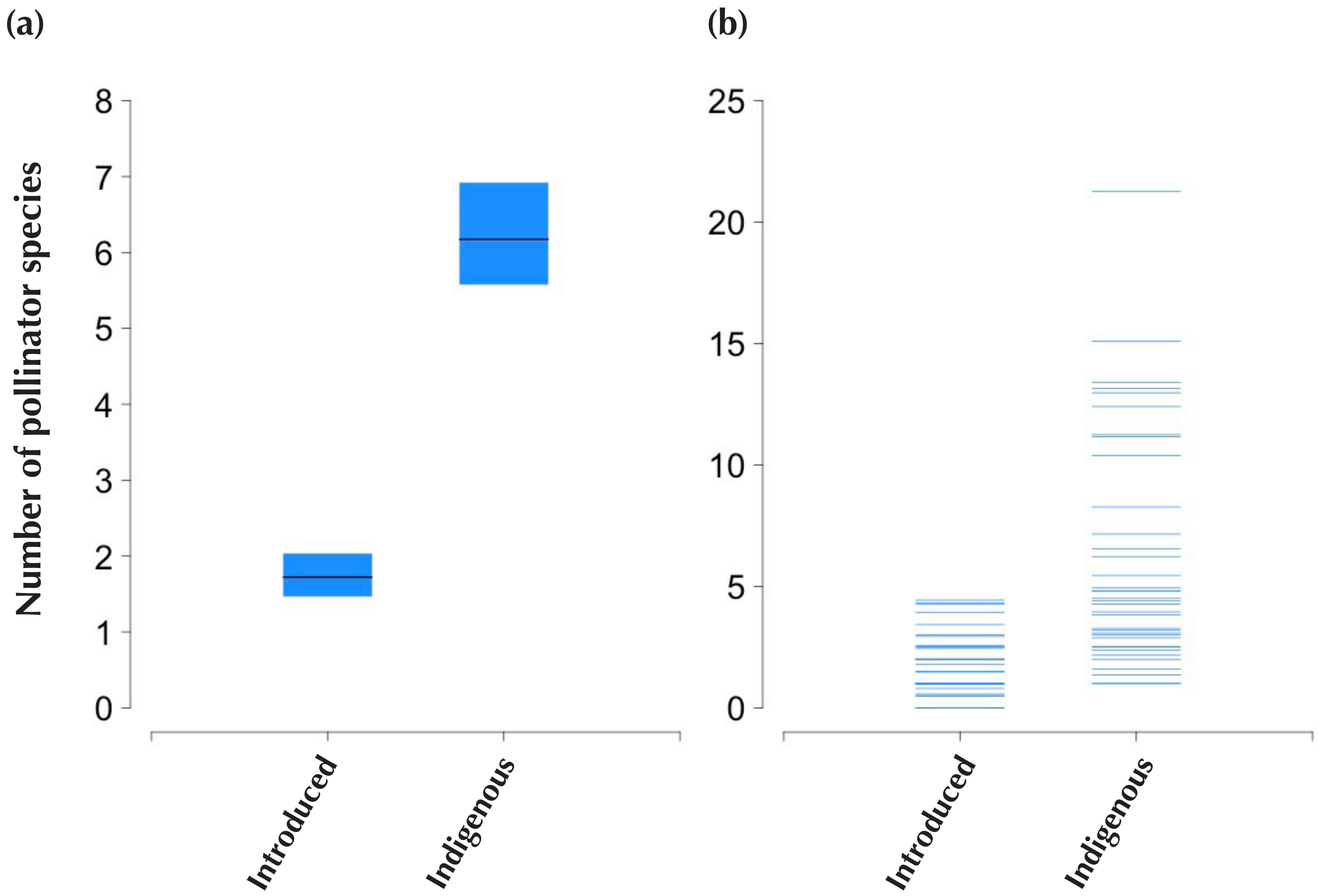

Figure 3.4. (**a**) Estimated number of introduced and indigenous pollinator species across all studied plants. Dark horizontal lines represent mean estimates. Blue boxes represent 95% credible intervals. (**b**) Mean estimated number of introduced and indigenous pollinator species for each plant species surveyed in this study.

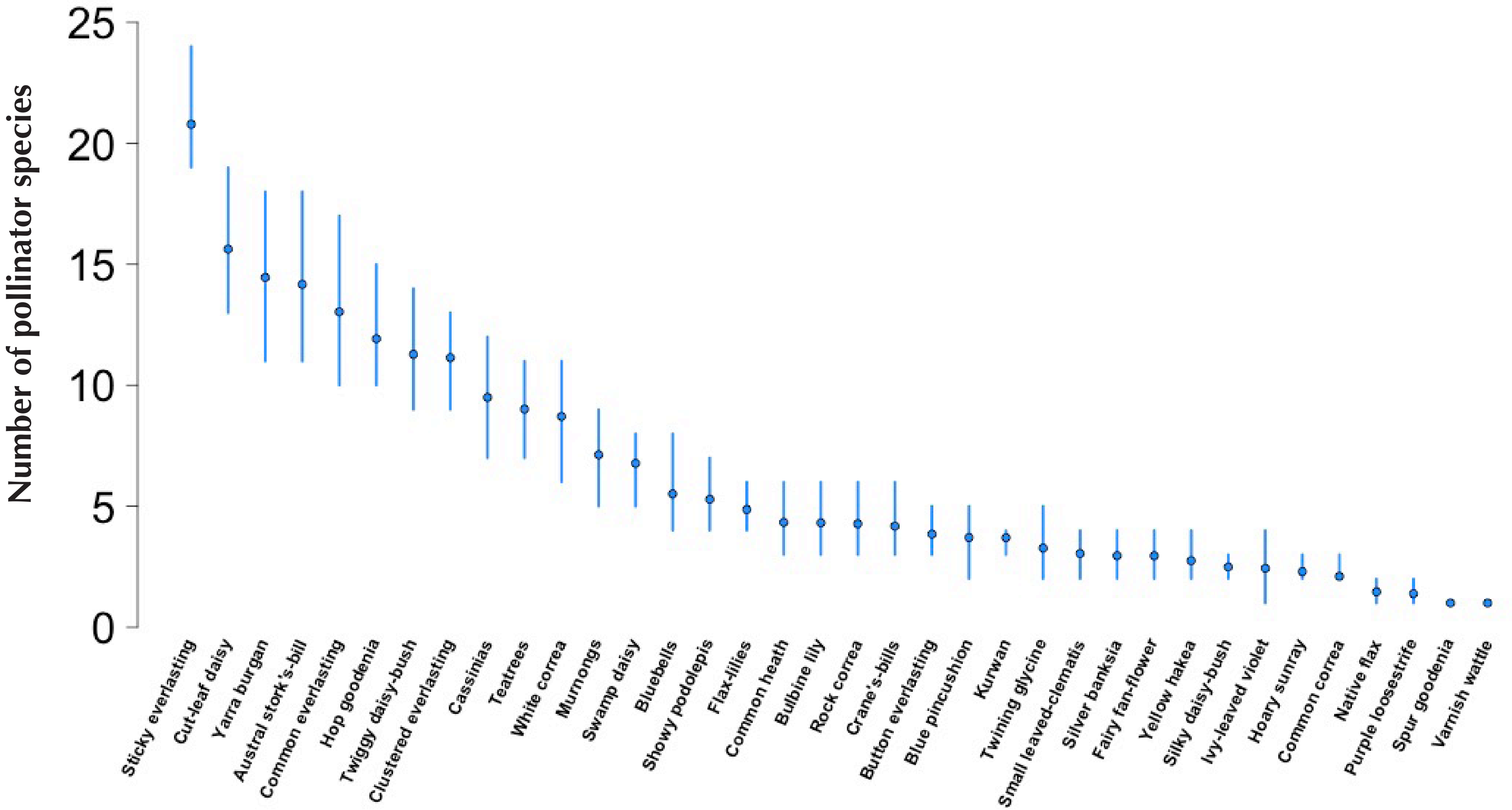

Figure 3.5. Estimated number of pollinator species by plant species. Dark dots represent mean estimates. Blue lines represent 95% credible intervals.

species by plant species varied substantially from one species to another (Table S1.4). The species with the highest mean number of associated pollinators were sticky everlasting and cut-leaf daisy with approximately 25 and 19 associated pollinators, respectively (Figure 3.5; Table S1.4). On the other side of the spectrum, spur goodenia *Goodenia paradoxa* was associated with a single pollinator (Figure 3.5; Table S1.4).

Our results indicate that indigenous flowering plant species in Melbourne are associated with a taxonomically diverse community of pollinators and other flower-visiting species. While our study did not attempt to assess the associations between the range of studied pollinators and non-indigenous plant species – whether indigenous to Australia/Victoria but not to Melbourne or fully introduced to Australia –, it substantiates or complements previous studies highlighting the fundamental role that indigenous plant species play in providing resources for pollinator species, particularly indigenous ones (Salisbury et al., 2015; Threlfall et al., 2017; Mata, Vogel and Bolitho, 2020; Mata et al., 2021). Importantly, our findings emphasise the opportunity presented by indigenous plant species to promote the biodiversity of pollinators and other flower-visiting species in urban environments. We hope our study encourages and inspires wildlife gardeners, as well as others responsible for managing public and private greenspace, to incorporate into their practice the ample range of indigenous plant species that we have shown here as having the capacity to attract and support pollinators and other flower-visiting insects.

Pollinator and plant species were linked in a complex network of ecological interactions

We documented 298 interactions between 31 indigenous plants and seven bee taxa (Figure 3.6), which represent over 36% of all recorded interactions. Approximately 53% of the interactions in this network were established with indigenous bee taxa, including blue-banded bees, leafcutter bees, masked bees, wolly sweat bees, and the green-and-gold nomia. The remaining interactions (~47%) were established with two introduced species: the European honeybee and the African carderbee.

On the other hand, the plant-butterfly network was structured by 158 interactions between 19 indigenous plants and six butterfly taxa (Figure 3.7). These interactions represent approximately 19% of all those recorded across the study. Approximately 60% of the interactions in this network were established with

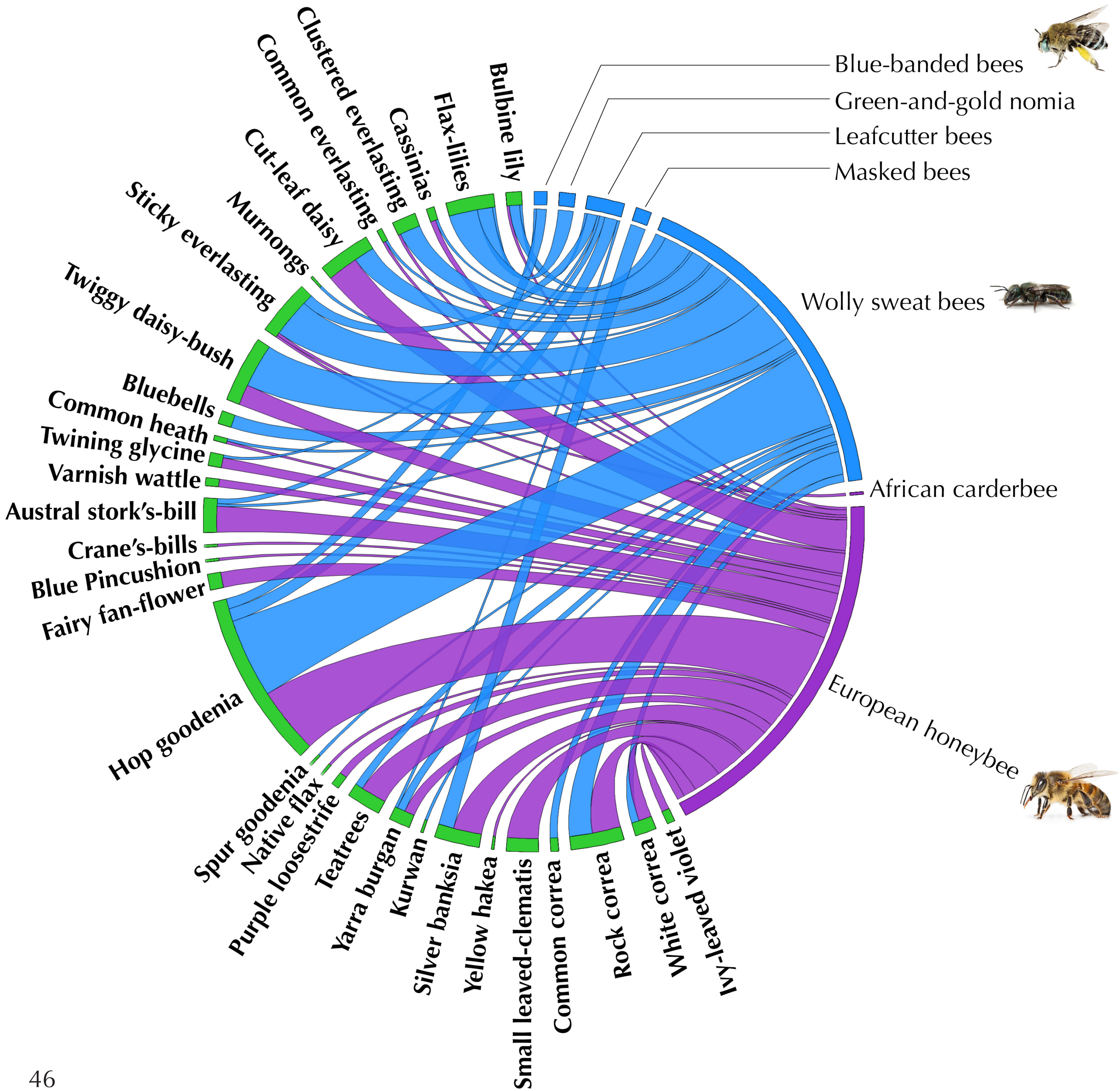

Figure 3.6. Network of interactions between the plant and bee species observed during the surveys. The width of the bands represents the strength of the interaction. Indigenous bee species are represented in blue and introduced species in purple. The thickness of each chord, or line connecting a bee taxa with a plant species, represents the frequency of observed interactions between them.

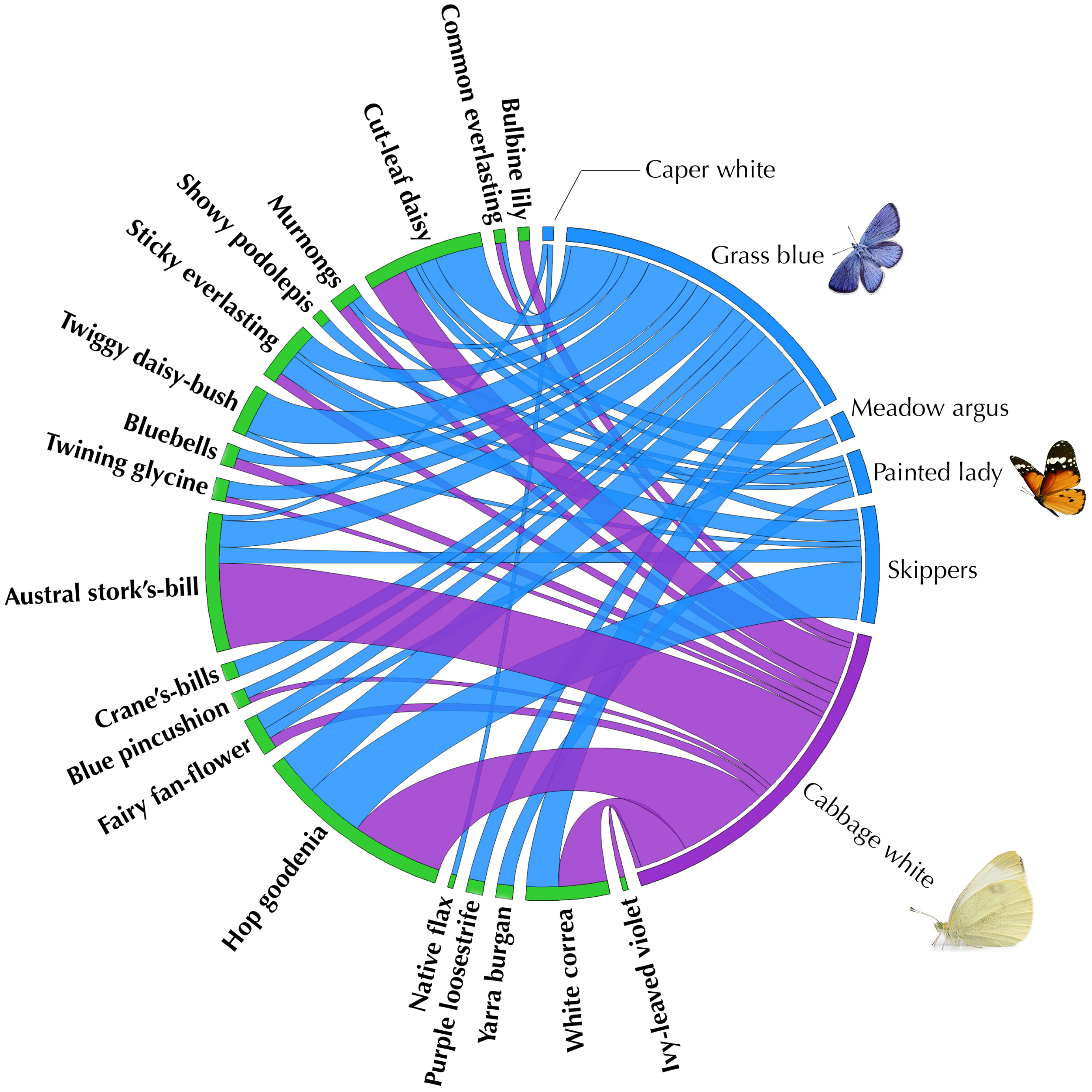

Figure 3.7. Network of interactions between the plant and butterfly species observed during the surveys. The width of the bands represents the strength of the interaction. Indigenous butterfly species are represented in blue and introduced species in purple. The thickness of each chord, or line connecting a butterfly taxa with a plant species, represents the frequency of observed interactions between them

indigenous butterfly taxa, including skippers, the caper white, the grass blue, the meadow argus, and the painted lady. The remaining interactions (~40%) were established with one introduced species: the cabbage white.

Taken together, these findings indicate that most indigenous plant species are providing floral resources for both indigenous and introduced bees and butterflies. Notable exceptions included (1) flax-lilies, spur goodenia, kurwan, and common correa, which were exclusively associated with indigenous bees; (2) showy podolepis, which was exclusively associated with indigenous butterflies; and (3) varnish wattle, yellow hakea, small-leaved clematis, and ivy-leaved violet, which were exclusively associated with introduced bees and/or butterflies. Our results further show that – while most pollinator species interact with a wide range of indigenous plant species – some bee and butterfly species only interact with a limited subset of the studied plant species. We note, for example, that blue-banded bees were only documented on flax-lilies and hop goodenia, a finding that aligns well with our previous and ongoing research (Mata et al., 2020; Mata, 2021). Another bee example that drew our attention were masked bees and the green-and-gold nomia, which only interacted with flax-lilies and silver banksia, respectively. Examples of specialised interactions between the studied indigenous plant species and butterflies include the caper white – which interacted exclusively with austral stork's-bill and native flax – and the meadow argus – which only interacted with cut-leaved daisy and fairy fan-flower.

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4 Socio-ecological findings

In this chapter we discuss social findings in relation to their potential ecological impact, and the implications and opportunities for wildlife gardening activities and programs.

Wildlife gardeners' plant choices are motivated primarily by attracting and/or supporting wildlife

Unsurprisingly, over 95% of respondents were motivated to attract and/or support wildlife (Figure 4.1). This suggests that,

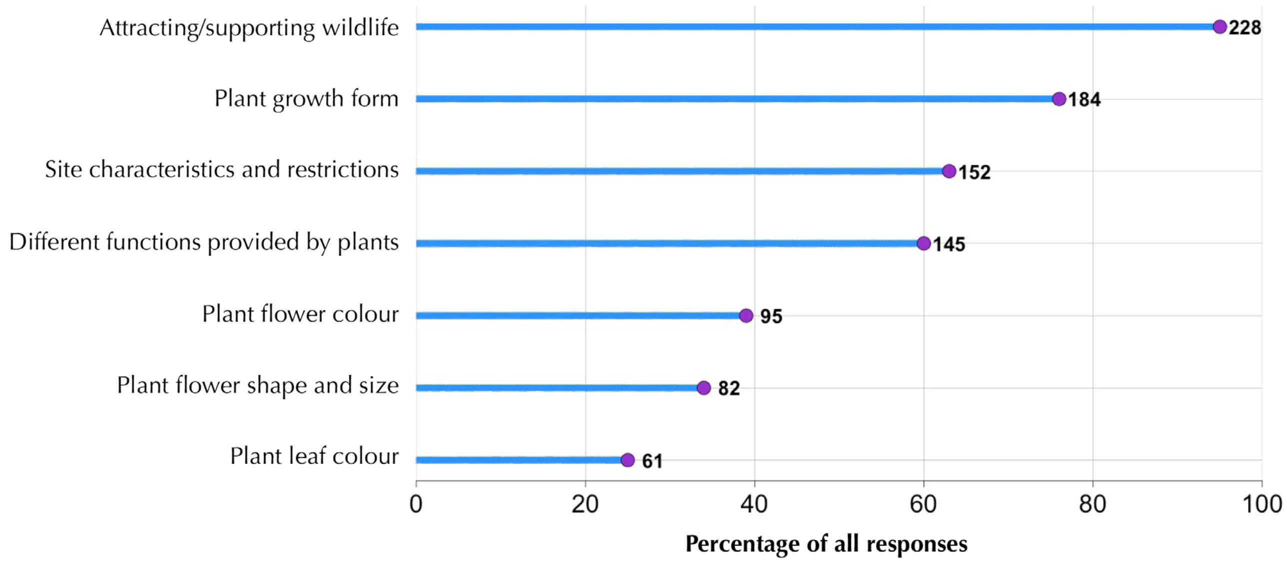

Figure 4.1. Motivations for respondents' planting choices.

if given information that certain plants attract or support forms of wildlife they are interested in, these gardeners will place these plants high on their planting choice list. Plant growth form influences planting choices of approximately 80% of respondents, followed by practical considerations, i.e. site characteristics and restrictions (~65%) and functions provided by the plants (~60%). However, plant functionality can also include supporting different forms of wildlife (Figure 4.5).

Less frequent motivators are plant flower colour (~40%), shape and size (~35%) and leaf colour (~25%) (Figure 4.1). Aesthetic elements such as plant flower colour, flower shape and size, and plant leaf colour, are known to be primary motivators for gardening choices (Kendal et al., 2012; Marco et al., 2010).

Wildlife gardeners are motivated to attract/support many animal taxa, particularly birds, bees, and butterflies

Survey respondents were motivated to attract and/or support a wide range of animal groups, with well over 95% choosing birds and insects (Figure 4.2). Those respondents selecting insects were asked which types motivated them. Almost 100% selected bees and butterflies, with approximately 90% choosing dragonflies and damselflies, followed closely by beetles (Figure 4.3). These results provide quantitative evidence for anecdotal reports of the popularity of birds, bees, and butterflies amongst wildlife gardeners. This popularity points to the suitability of these taxa as 'mascots' to promote programs, reinforced by the choices of these species in the logos of current wildlife gardening programs, selected through voting by community members or program volunteers (Figure 4.4). The findings also suggest that there are strong opportunities to promote insect biodiversity/conservation as a goal of wildlife gardening, and in particular, insect pollinators and pollination, a key group and function, respectively, for indigenous plant conservation.

Wildlife gardeners are also motivated by plant functionalities that support human amenity

Almost 60% of respondents noted that plant functions motivate their planting choices (Figure. 4.1). When given definitions of different functionalities to choose, respondents equally chose functionalities that support biodiversity – for example, a range of layers and diversity of habitats – and those that support

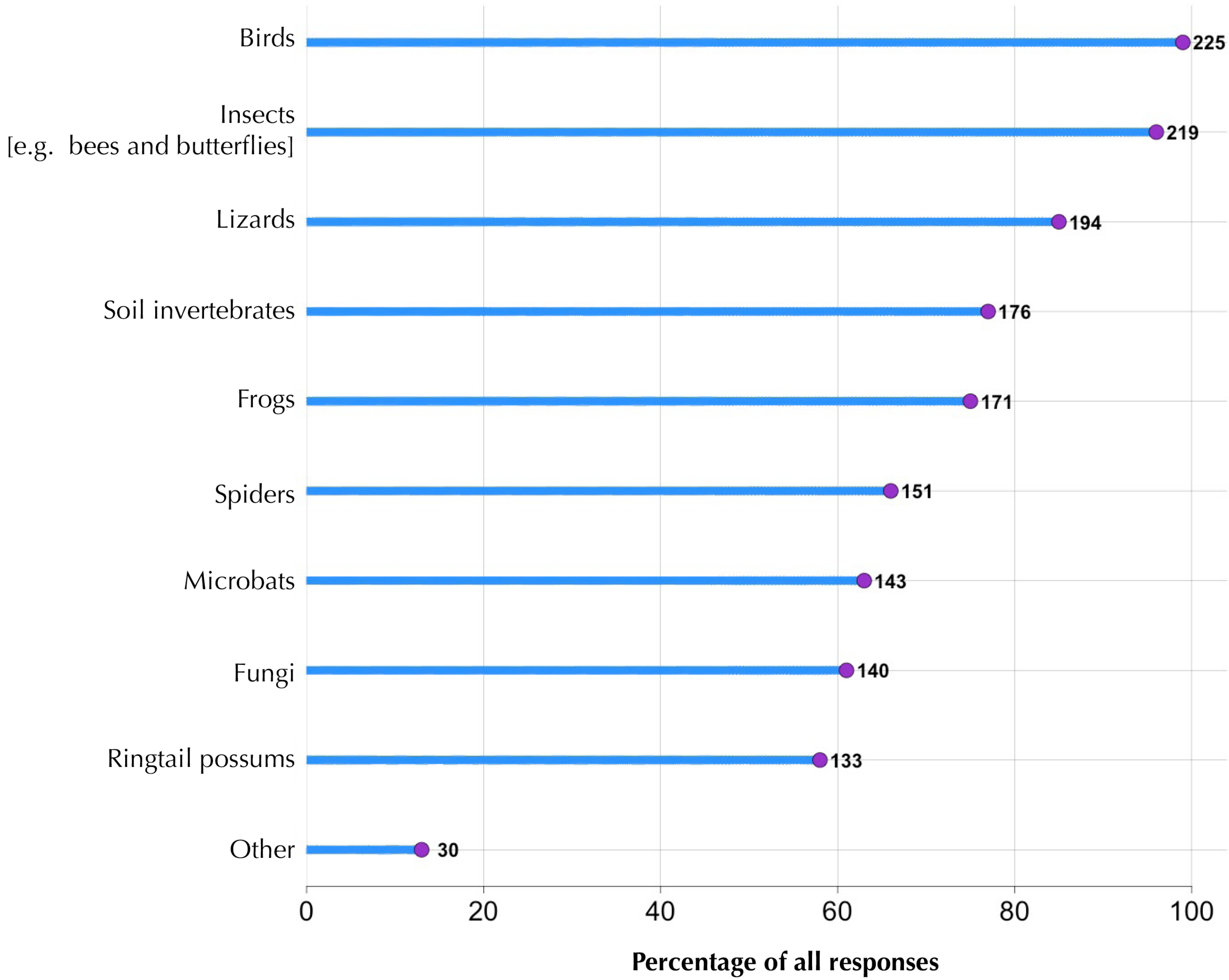

Figure 4.2. Animal groups respondents are motivated to attract and/or support.

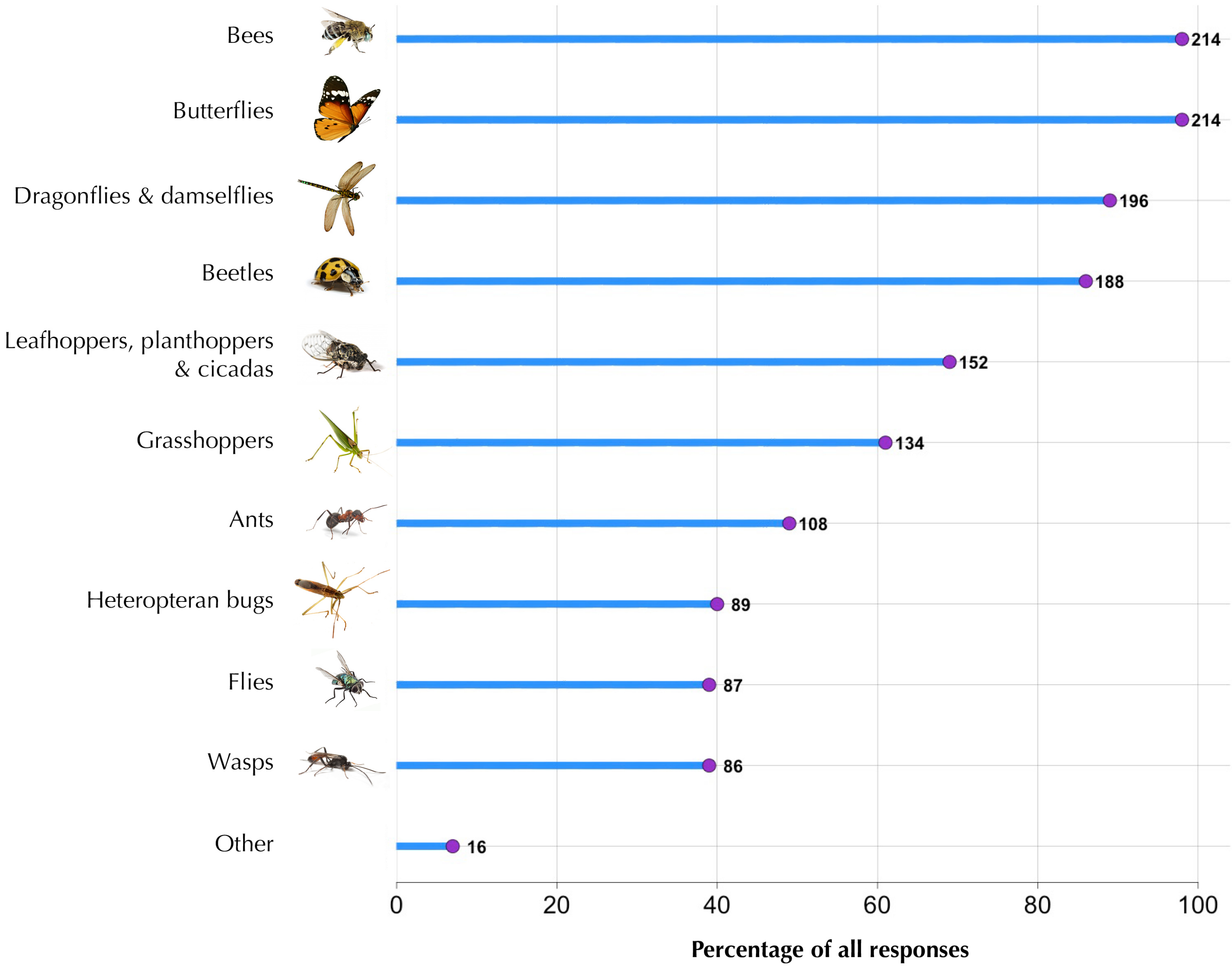

Figure 4.3. Insect groups participants are motivated to attract and/or support.

Figure 4.4. Sample of logos from Gardens for Wildlife Victoria program affiliates.

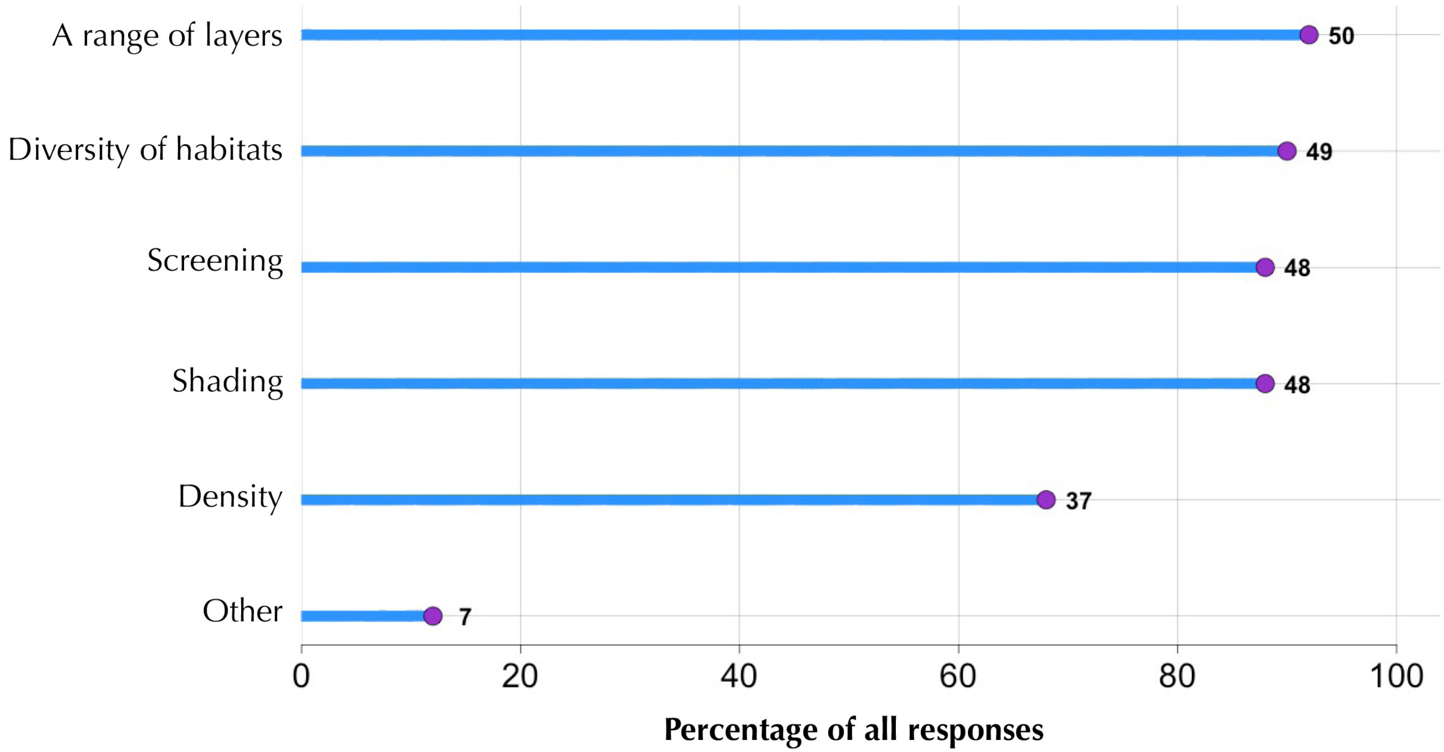

Figure 4.5. Plant functionalities that motivate wildlife gardeners.

human comfort – for example, screening and shading (Figure 4.5). There are few academic studies specifically about urban gardeners' plant choices, but in one such survey of gardeners in Ballarat and Melbourne (Kendal et al., 2012), when queried about plant functions, the greatest number of respondents chose beauty, screening, 'fill a space', and bird attracting. Interviews of participants in the Knox Gardens for Wildlife program showed that they most readily adopted wildlife gardening practices that met their gardening needs and preferences, and willingly planted indigenous species for screening, drought resistance, and to attract wildlife (Mumaw and Bekessy, 2017). Importantly, most wildlife gardening practices simultaneously support both native species stewardship and human amenity. Gardens for Wildlife Victoria celebrates the contribution participants in wildlife gardening programs can make to conserving indigenous biodiversity while supporting them to find wildlife gardening practices that can help them achieve their own goals for their gardens.

Most of the surveyed wildlife gardeners plant and maintain native plant species, remove environmental weeds, and put in water baths

Survey respondents participated in a number of wildlife gardening activities (Figure 4.6). The greatest number of respondents were involved with planting and maintaining native plant species (~89%), removing environmental weeds (~81%), and putting in and maintaining water baths (~76%). These activities are possible for many gardeners to perform. The first two activities not only help to preserve locally native plant species (Garland and Wells, 2020; Mata et al., 2020), but also provide habitat for and support associated faunal species, such as native birds, butterflies, and other insect pollinators (Burghardt et al., 2009; Ikin et al., 2015; Mata et al., 2021a; Salisbury et al., 2017). Water baths (water features smaller than frog ponds) also support and attract a variety of wildlife taxa (Loram et al., 2011; Miller et al., 2015). Lesser numbers, but over half of respondents, added rocks and logs for reptiles and invertebrates (~70%), planted and maintained small bird habitat (~64%), and/or kept and protected native trees (~57%). Smaller numbers established and maintained a frog pond (~39%) and/or put in and maintained nest boxes (~35%).

The time spent on these activities was highly variable (Figure 4.7). The mean is highest for planting and maintaining native species and removing environmental weeds, with both accounting for approximately 30% of the time spent on wildlife gardening activities. Wildlife gardeners also regularly performed other gardening activities such as watering, mulching, caring for container plants, tending a vegetable garden, pruning trees and hedges, and mowing lawns (Figure 4.8). This shows how many respondents' gardens serve a number of functions and provide for a range of social and other activities (e.g. having lawns) characteristic of urban gardens (Clayton, 2007; Longhurst, 2006), in addition to wildlife gardening.

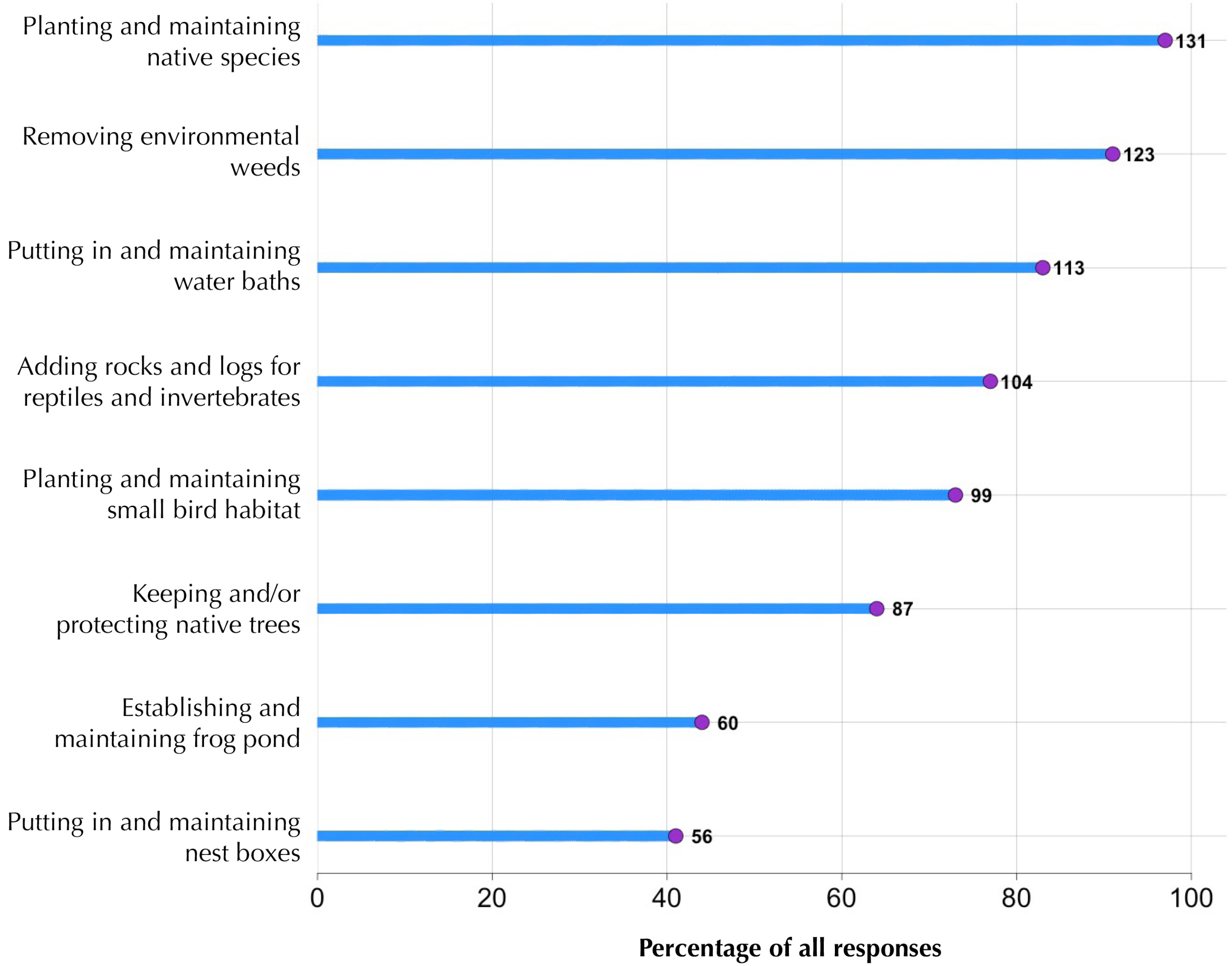

Figure 4.6. Percent of respondents participating in different wildlife gardening activities.

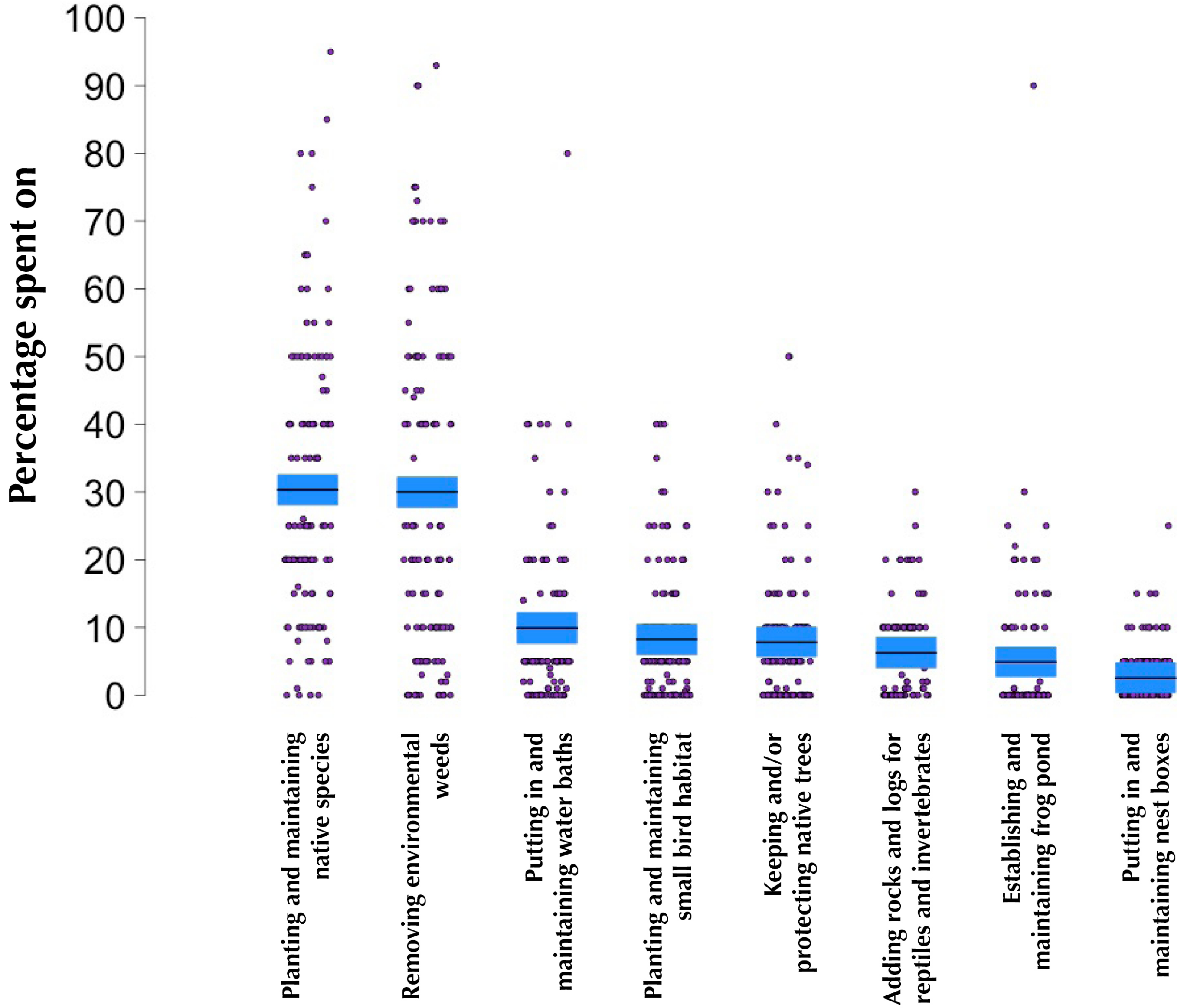

Figure 4.7. Estimated percent of time spent on different wildlife gardening activities. Dark horizontal lines represent mean responses. Blue boxes represent 95% credible intervals. Purple dots represent survey responses.

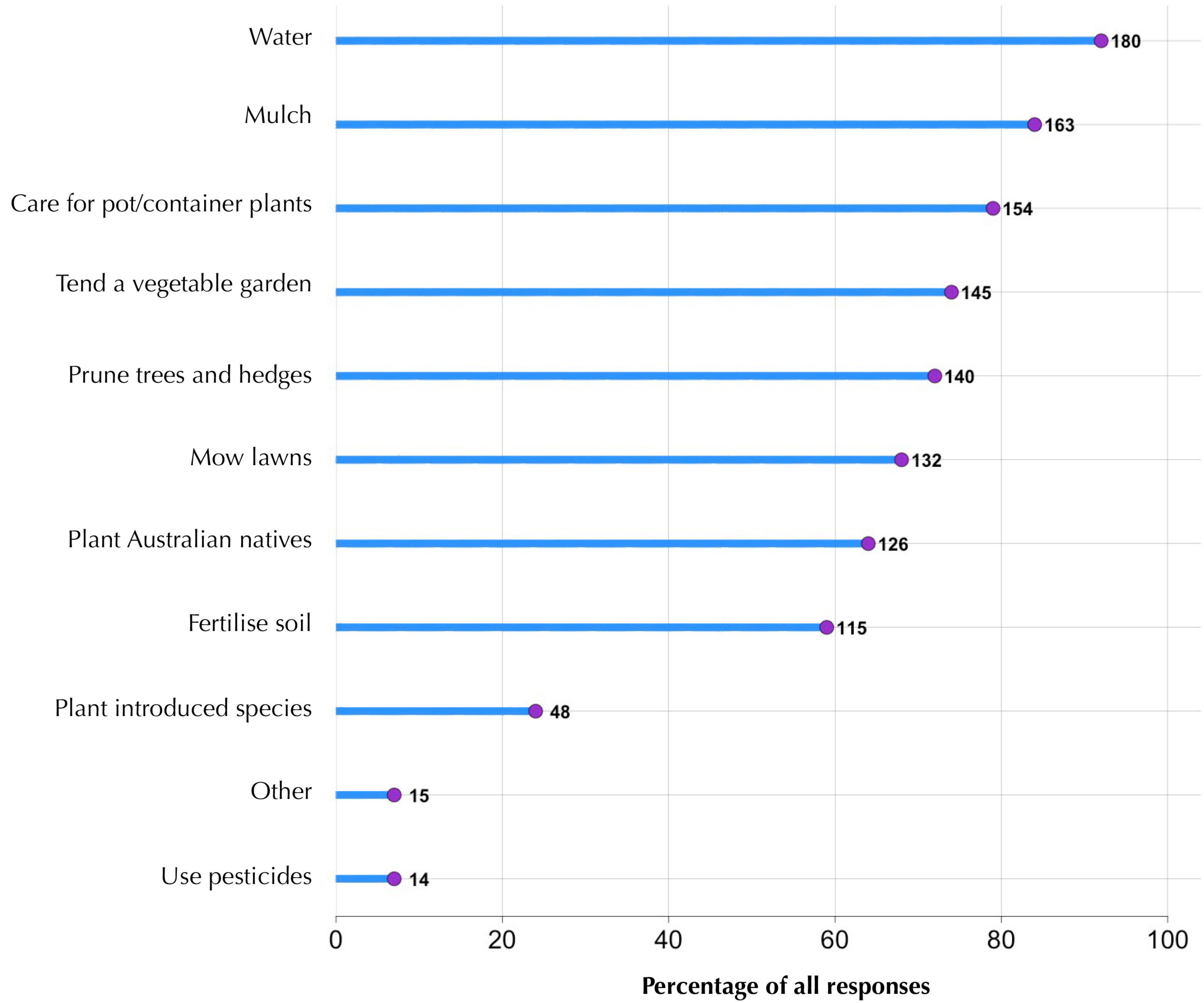

Figure 4.8. Percent of respondents doing other garden activities.

Many wildlife gardeners notice increased numbers and diversity of insects and birds since wildlife gardening

The great majority of respondents noticed increased numbers of insect pollinators (almost 90%) since wildlife gardening, followed by beneficial insects, spiders and/or other invertebrates (~75%) and birds (~75%) since wildlife gardening (Figure 4.9). Large but smaller proportions of respondents observed increased *diversity* of these same groups – insect pollinators (~75%), birds (~70%), beneficial insects, spiders and/or other invertebrates (~63%) (Figure 4.9). Birds and insects are also the groups that the greatest numbers of respondents were motivated to attract and/or support. While lizards ranked highly as motivators, they were not observed to increase in number and diversity by as many respondents. As well as actual presence of a species, observations will be affected by observer interest, frequency of looking, and skills of detection amongst other factors.

In a survey of household gardeners across five cities in the United Kingdom, 60% of respondents said they made some effort to attract wildlife and, on average, these respondents observed a significantly greater number of species in their gardens than those in which no effort was made (Loram et al., 2011). In this study, respondents were not queried on insects, but rather given choices of mammals (13 species), birds (nine species), amphibians (three species), and lizards (one species). More wildlife was observed in gardens in which water was provided to support wildlife than gardens in which it was not (Loram et al., 2011).

Previous research has shown that the species richness of a wide range of taxonomically and functionally diverse insect groups increase when indigenous plants are added to patches of urban greenspace (Mata et al. 2021b). Research involving sampling of indigenous insect and other species before and after wildlife gardening actions – by ecologist and gardeners themselves (such as that proposed for this study but prevented by COVID lockdowns) would help to ascertain the impact of wildlife gardening activities on animal communities, the engagement and reliability of gardeners as citizen scientists, and the opportunities to involve gardeners in monitoring changes.

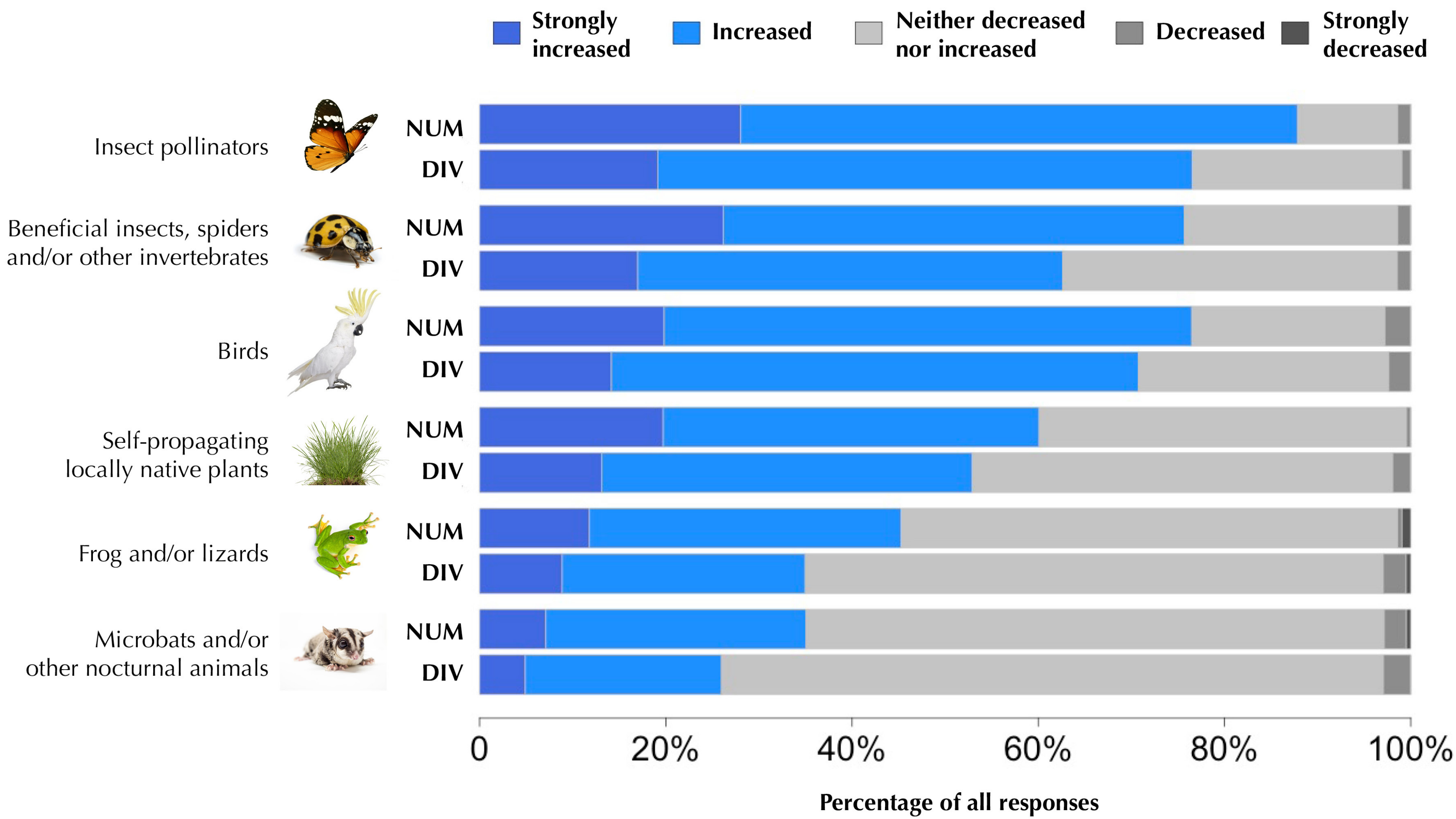

Figure 4.9. Percent of respondents observing changes in number and diversity of wildlife since wildlife gardening.

Observing greater numbers and diversity of wildlife that they are motivated to support helps to reward and sustain wildlife gardeners' efforts

Given how important attracting or supporting wildlife to their gardens is to wildlife gardeners (Figures 4.1-4.3), and how many report increased number of individuals and diversity of species after wildlife gardening (Figure 4.9), it is not surprising that those respondents report strong motivations to continue wildlife gardening and strong feelings of sense of purpose and self development (Figure 2.10), as well as self-esteem and place attachment (Figure 2.11). Previous research has shown that observing wildlife in their neighbourhood or garden can interest people in wildlife gardening (Mumaw and Bekessy, 2017) and that observing wildlife in their gardens after wildlife gardening was a key motivator, reward, and source of wellbeing (Mumaw, 2017).

A minority of wildlife gardeners notice a change in detrimental weeds and insects

In contrast with their observations of an increase in their favoured taxa, respondents noticed fewer changes in number and kinds of detrimental taxa since wildlife gardening, with the exception of detrimental insects, spiders, and other invertebrates (Figure 4.10). Almost 60% of respondents noticed a decrease in that category. Surprisingly, given that one of the foci of wildlife gardening activities is removing environmental weeds, just under a quarter of respondents reported noticing fewer environmental weeds since wildlife gardening. This may reflect the tenacity and abundance of these species.

Wildlife gardeners prefer a wide range of plant flower colours, leaf colours, and growth forms

Survey respondents indicated preferences for a wide range of flower colours, leaf colours, and plant growth forms (Figures 4.11-4.13). The preferred flower colour was blue/violet (over 70%), followed by white (~70%), yellow (~60%), and red/pink (~50%) (Figure 4.11). We found interesting differences between the reported flower colour preferences and the number of insect pollinator species by flower colour estimated in our statistical analyses (Figure 4.14). For example, our model indicates that red/pink and blue/violet flowers were the groups associated with the highest and lowest pollinator richness, respectively (Figure 4.14). Importantly however, we have shown that some plant species, independently of their flower colour, are associated

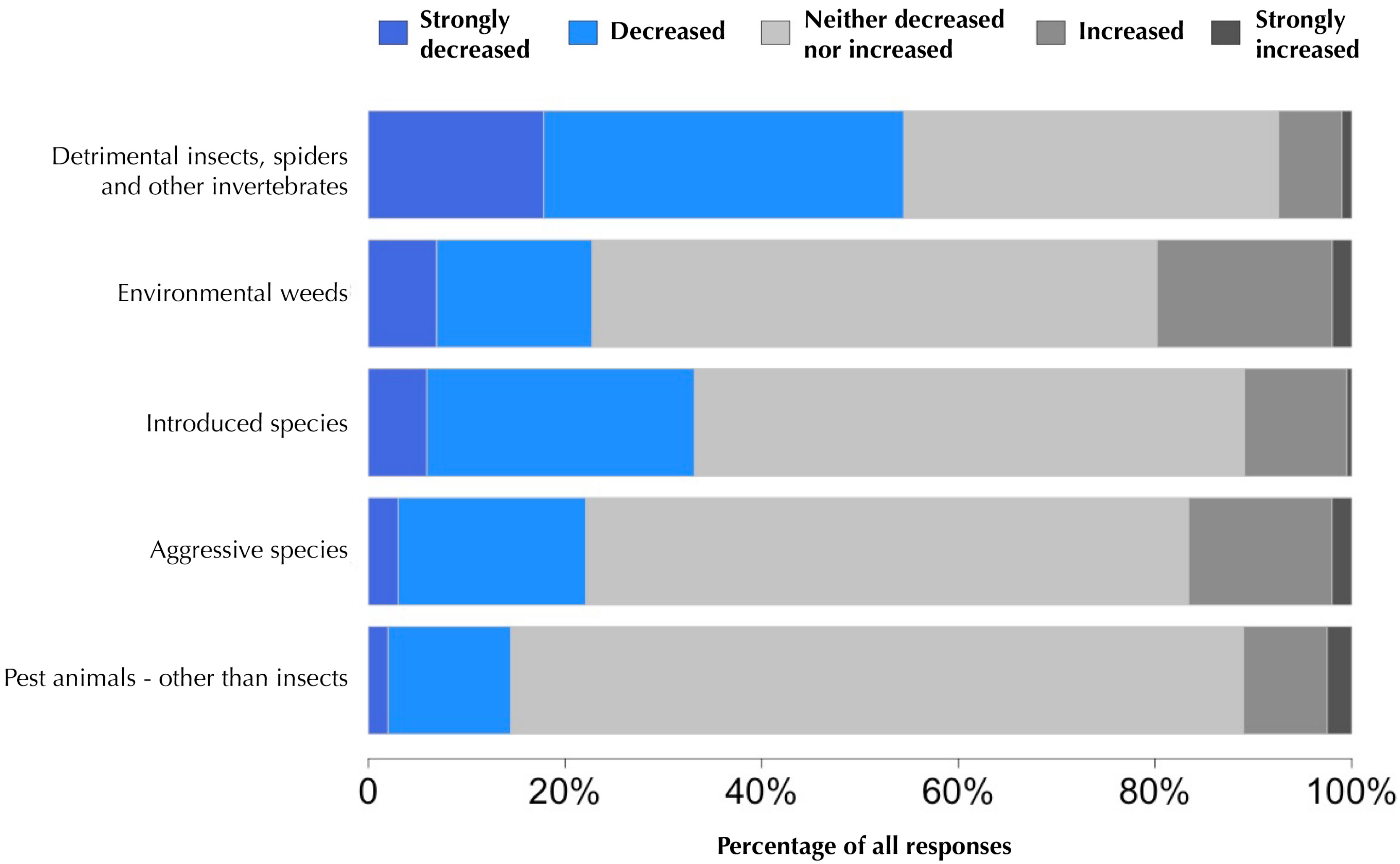

Figure 4.10. Percent of respondents observing changes in number and diversity of detrimental wildlife since wildlife gardening.

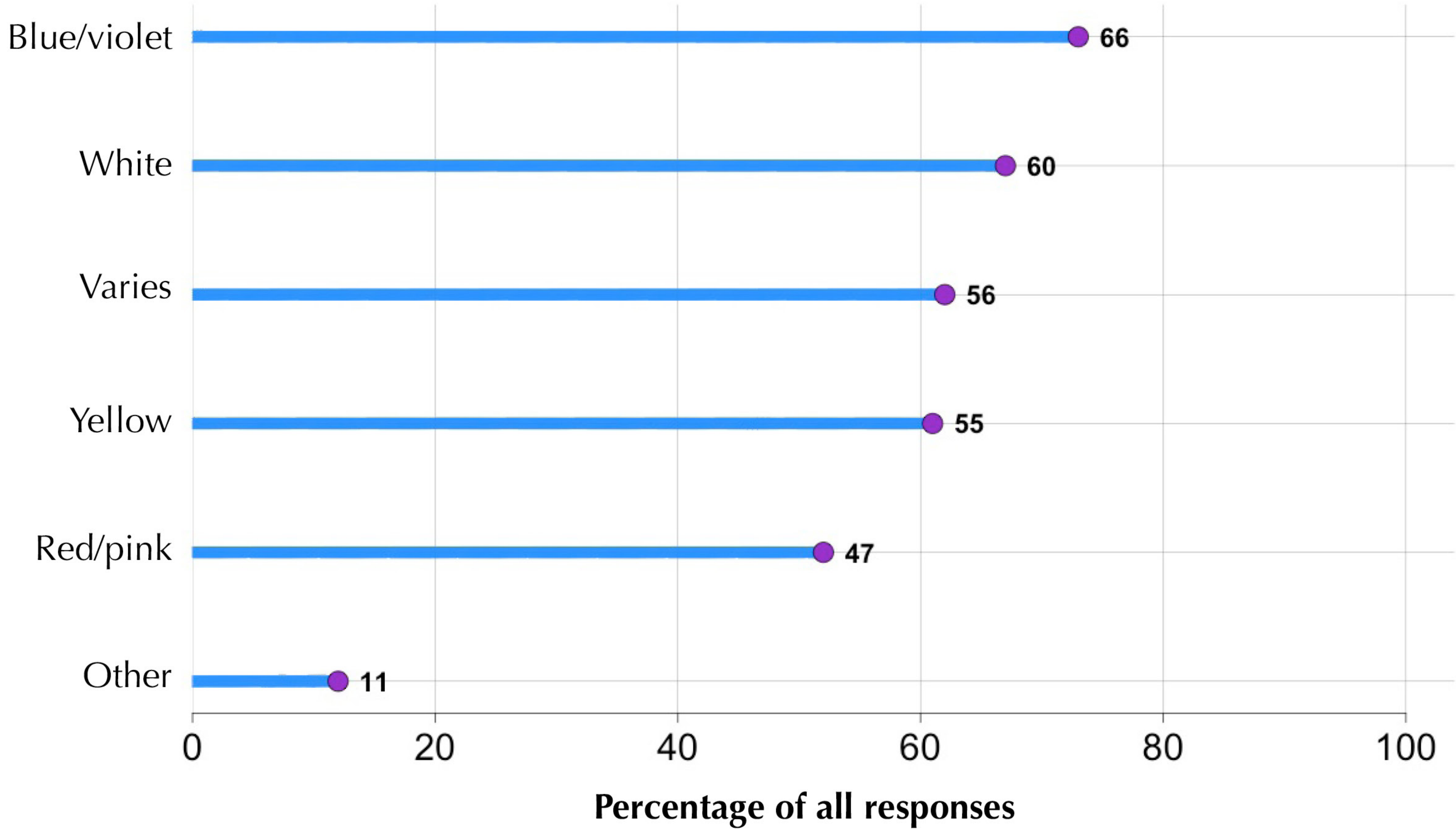

Figure 4.11. Flower colours preferred by respondents.

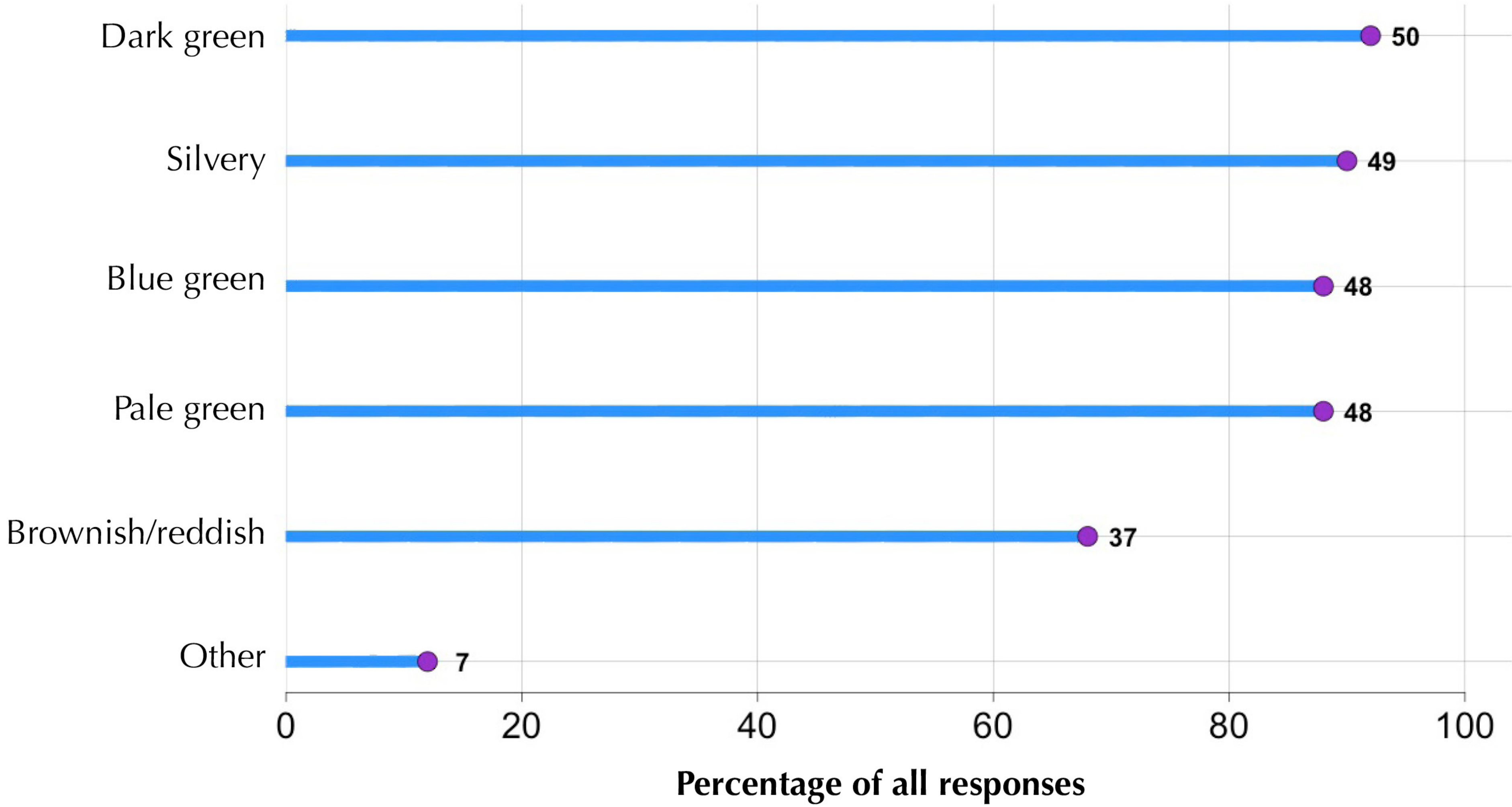

Figure 4.12. Leaf colours preferred by respondents.

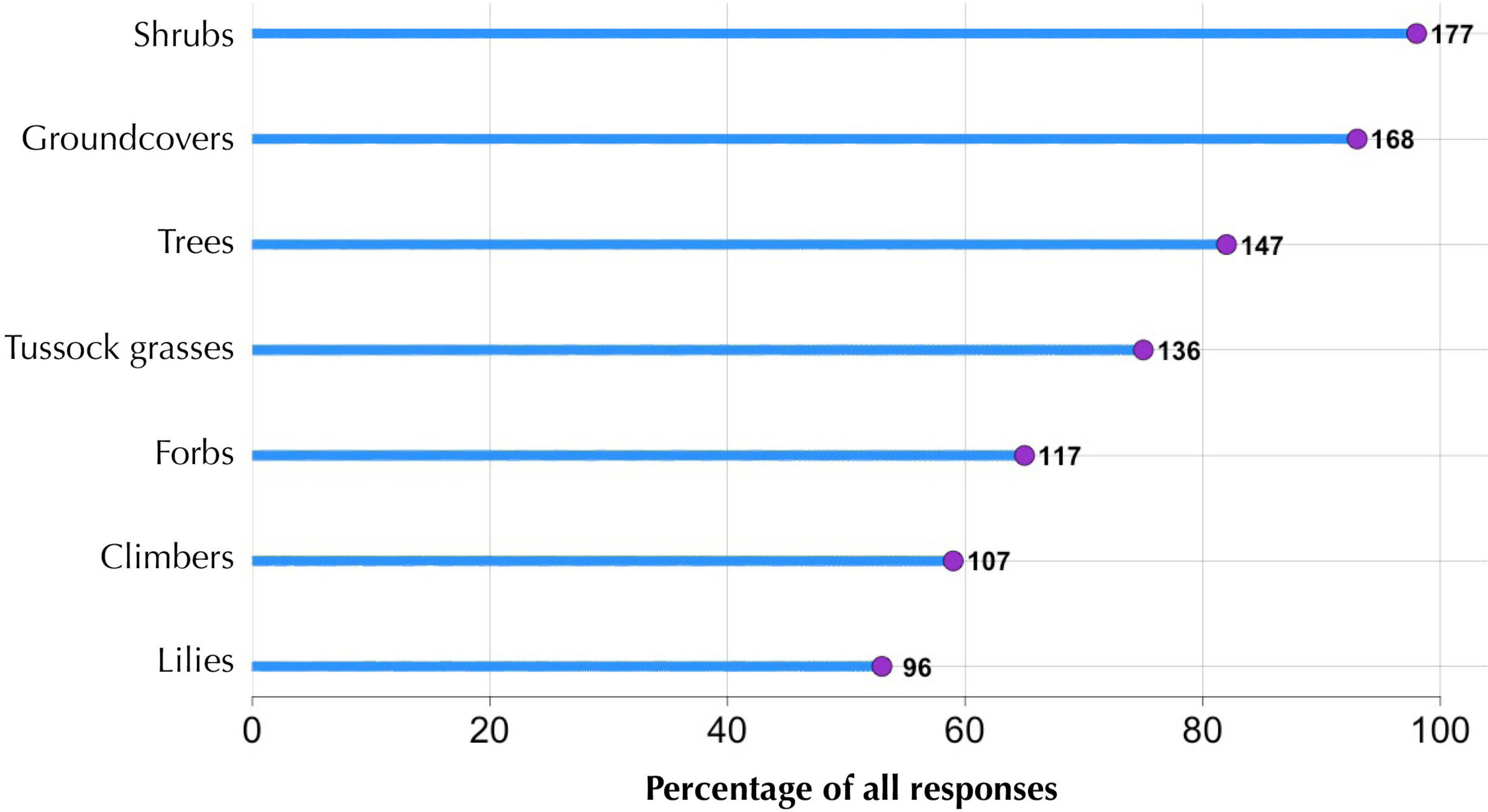

Figure 4.13. Plant growth forms preferred by respondent.

with substantially more pollinator species than others (Figure 3.5). These findings suggest that gardeners motivated to attract and support insect pollinators should focus on selecting plants based on species' known associations with insect pollinators rather than their flower colour.

Over 95% of respondents indicated shrubs as their preferred type of plant growth from, followed by groundcovers (~90%) and trees (~80%) (Figure 4.13). On the other hand, the least preferred growth forms were forbs (~65%), climbers (~60%), and lilies (~50%). We found that these preferences have considerable parallels with the estimated number of insect pollinator species associated with the growth forms surveyed in this study (Figure 4.15). For instance, our models indicate that shrubs and forbs were the groups associated with the highest pollinator richness (Figure 4.15). As indicated above for flower colours, our species-specific estimates show that some plant species, independently of their growth form, are associated with substantially more pollinator species than others (Figure 3.5), and, similarly suggest that wildlife gardeners motivated to attract and support pollinators may want to focus on selecting plants based on their species identity rather than their growth form.

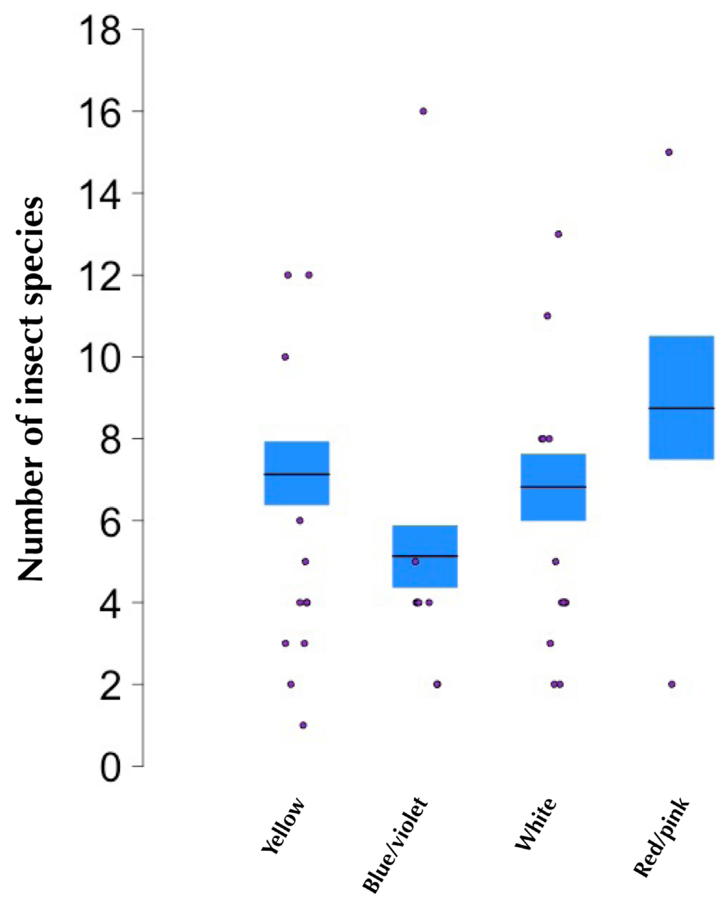

Figure 4.14. Estimated number of insect pollinator species by flower colour. Dark horizontal lines represent mean responses. Blue boxes represent 95% credible intervals. Purple dots represent survey responses.

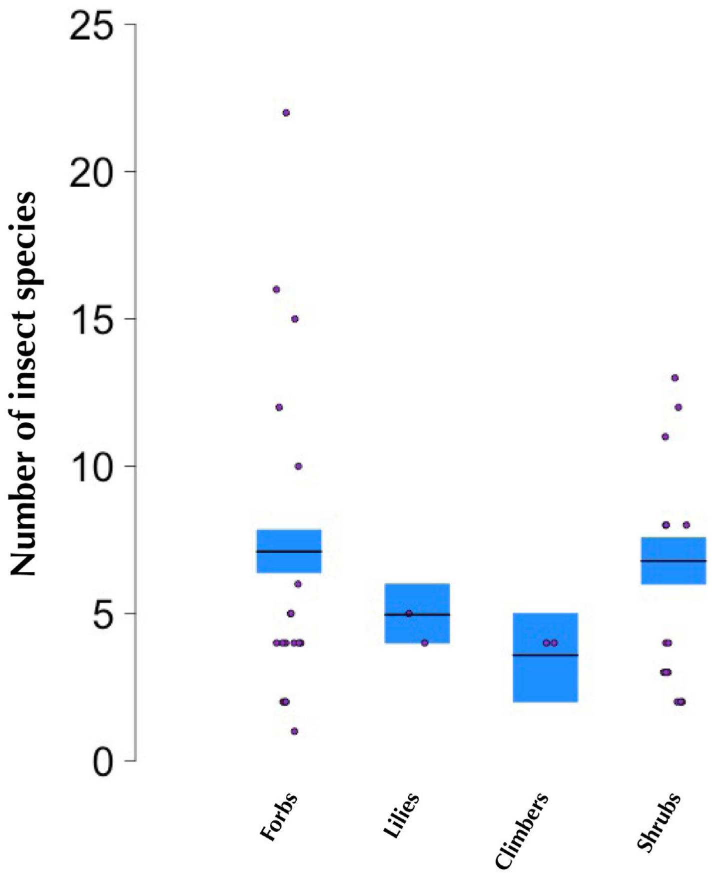

Figure 4.15. Estimated number of insect pollinator species by plant growth form. Dark horizontal lines represent mean responses. Blue boxes represent 95% credible intervals. Purple dots represent survey responses.

Plant palette recommendations

Taken together, our findings allow us to make informed plant species recommendations to gardeners motivated to attract and support insect pollinators in their wildlife gardens. Likewise, the new socio-ecological data from this study assists us to make plant species recommendations that match the aesthetic preferences of wildlife gardeners while concomitantly suggesting indigenous plant palettes that support a range of indigenous pollinators.

Ideal indigenous plant palette for insect pollinators

Based on the larger number of insect pollinator species they are associated with, we highly recommend the following indigenous plant palette to bring and support insect pollinators in wildlife gardens (also shown with photos of flowers in Figure 4.16):

Sticky everlasting *Xerochrysum viscosum*
Cut-leaf daisy *Brachyscome multifida*
Yarra burgan *Kunzea leptospermoides*
Austral stork's-bill Pelargonium australe
Common everlasting *Chrysocephalum apiculatum*
Hop goodenia *Goodenia ovata*

Twiggy daisy-bush *Olearia ramulosa*

Ideal indigenous plant species by flower colour

<u>Top blue/violet flowers</u>

Cut-leaf daisy *Brachyscome multifida*

Bluebells [genus Wahlenbergia]

Flax-lilies [genus Dianella]

<u>Top white flowers</u>

Yarra burgan *Kunzea leptospermoides*

Twiggy daisy-bush *Olearia ramulosa*

Cassinias [Genus Cassinia]

<u>Top red/pink flower</u>

Austral stork's-bill *Pelargonium australe*

Figure 4.16. Ideal plant palette for insect pollinators. Clockwise from top left: Sticky everlasting *Xerochrysum viscosum*, Cut-leaf daisy *Brachyscome multifida*, Yarra burgan *Kunzea leptospermoides*, Austral stork's-bill *Pelargonium australe,* Common everlasting *Chrysocephalum apiculatum*, Hop goodenia *Goodenia ovata,* and Twiggy daisy-bush *Olearia ramulosa*.

Top yellow flowers

Sticky everlasting *Xerochrysum viscosum*

Common everlasting *Chrysocephalum apiculatum*

Hop goodenia *Goodenia ovata*

Ideal indigenous plant species by growth form

Top shrubs

Yarra burgan *Kunzea leptospermoides*

Hop goodenia *Goodenia ovata*

Twiggy daisy-bush *Olearia ramulosa*

Top forbs

Sticky everlasting *Xerochrysum viscosum*

Cut-leaf daisy *Brachyscome multifida*

Austral stork's-bill *Pelargonium australe*

Top climber

Twining glycine *Glycine clandestina*

Top lilies

Flax-lilies [genus Dianella]

Bulbine lily *Bulbine bulbosa*

Plant palettes for specific insect pollinators

Based on the specialised interactions observed during the study we recommend the following indigenous plant palette to bring and support specific insect pollinators in wildlife gardens:

Blue-banded bees

Hop goodenia *Goodenia ovata* (Figure 4.17)

Flax-lilies [genus Dianella]

Green-and-gold nomia

Flax-lilies [genus Dianella] (Figure 4.18)

Masked bees

Silver banksia *Banksia marginata* (Figure 4.19)

Caper white

Austral stork's-bill *Pelargonium australe* (Figure 4.20)

Native flax *Linum marginale*

Meadow argus

Cut-leaf daisy *Brachyscome multifida*

Fairy fan-flower Scaevola aemula (Figure 4.21)

Figure 4.17. A blue-banded bee (genus Amegilla) on hop goodenia *Goodenia ovata*. Photo from Bushy Creek Reserve, Box Hill North, City of Whitehorse.

Figure 4.18. A green-and-gold nomia *Lipotriches australica* flying towards a flax-lily (genus Dianella). Photo from Bushy Creek Reserve, Box Hill North, City of Whitehorse.

Figure 4.19. A masked bee (genus Hylaeus) in amongst a flower of silver banksia *Banksia marginata*. Photo from Know Environmental Society Indigenous Nursery, Ferntree Gully, City of Knox.

Figure 4.20. A caper white *Belenois java* on Austral stork's-bill *Pelargonium australe*. Photo from Gill Reserve, Port Melbourne, City of Port Phillip.

Figure 4.21. A meadow argus *Junonia villida* on fairy fan-flower *Scaevola aemula*. Photo from Wally Tew Reserve, Ferntree Gully, City of Knox.

Respondents planted a variety of indigenous species, some more than others

Survey findings indicate that respondents planted a diverse range of indigenous shrub, forb, lily, climber, groundcover, and tussock grass species (Figures 4.22-4.26). We note that these do not represent all species available or known to wildlife gardeners but a representative sample of species commonly available at indigenous nurseries across the study area. Their inclusion in the social survey was also guided by our plant choices for the plant-pollinator interaction surveys.

The most commonly planted shrubs were correas, banksias, and wattles, each of which were planted by 70% or more of all respondents (Figure 4.22). Amongst forbs, lilies, climbers, groundcovers, and tussock grasses, only daisies, flax-lilies, clematises, running postman, and tussock grasses (genus Poa), respectively, were planted by the approximately the same percentage of respondents (Figure 4.23-4.26).

We note here some interesting correspondences but also a few mismatches between the species planted by respondents and the plants associated with the highest richness of insect pollinators. For example, there is a strong correspondence with the top planted forbs (daisies) with the forb associated with the second to largest richness of pollinators (cut-leaved daisy). Similarly, flax-lilies were simultaneously the top planted lily and the lily species associated with the largest number of pollinators. These and other related findings point to a good match between the forb and lily species that wildlife gardeners plant and those associated with insect pollinator richness. It seems that at least some respondents are making the appropriate plant selection decisions to support their motivation to attract and support insect pollinators in their wildlife gardens and indeed, this may be driven by their knowledge of these associations.

However, our survey responses also indicate some important mismatches. For example, some of the forbs associated with high pollinator richness (e.g. sticky everlastings and stork’s bills) were only planted by 60% and less than 40%, respectively, of respondents. Likewise, none of the shrubs planted by 70% or more of respondents correspond with shrubs associated with high pollinator richness (e.g. Yarra burgan and hop goodenia).

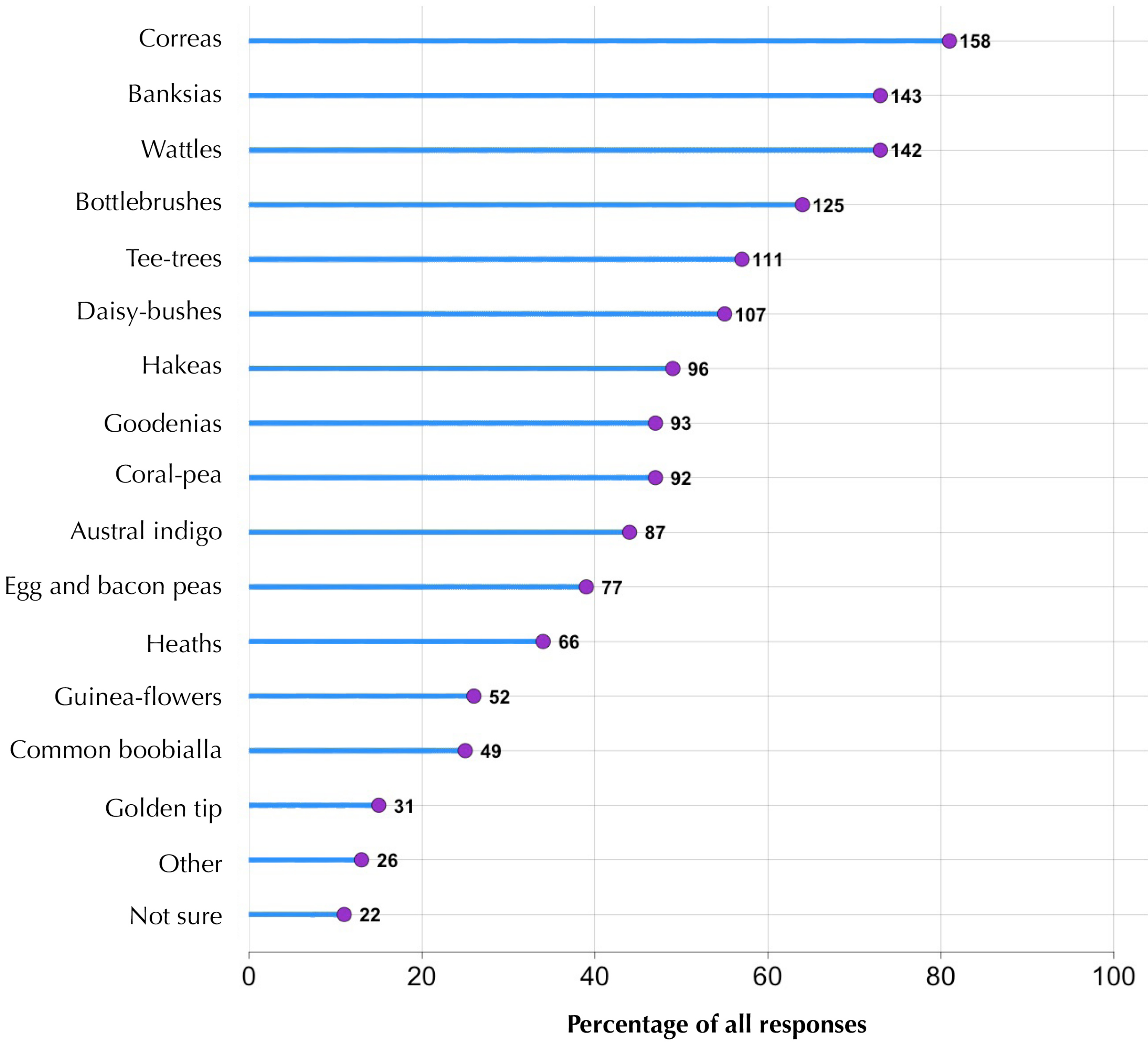

Figure 4.22. Indigenous shrubs species planted by survey respondents.

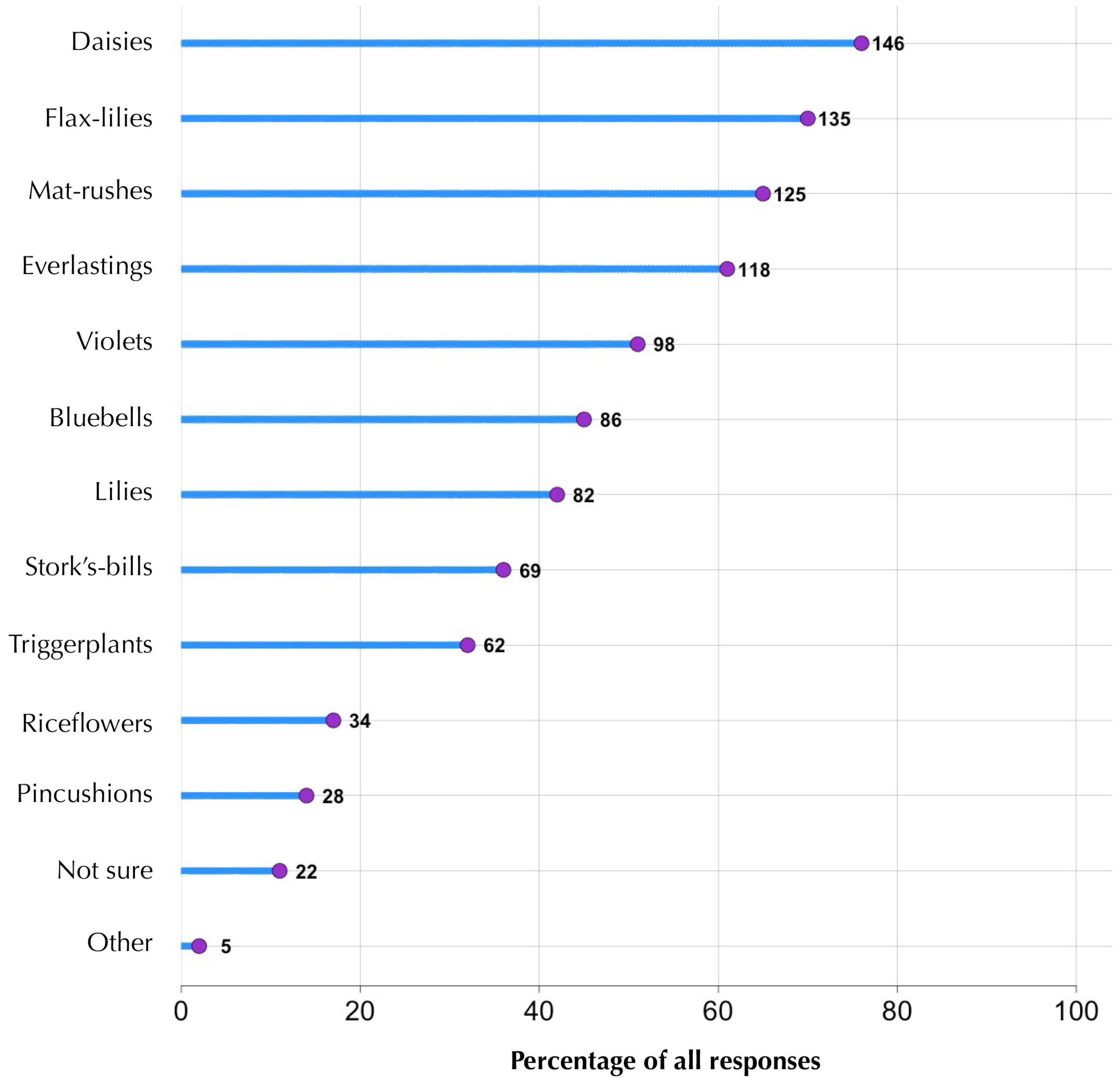

Figure 4.23. Indigenous forb and lily species planted by survey respondents.

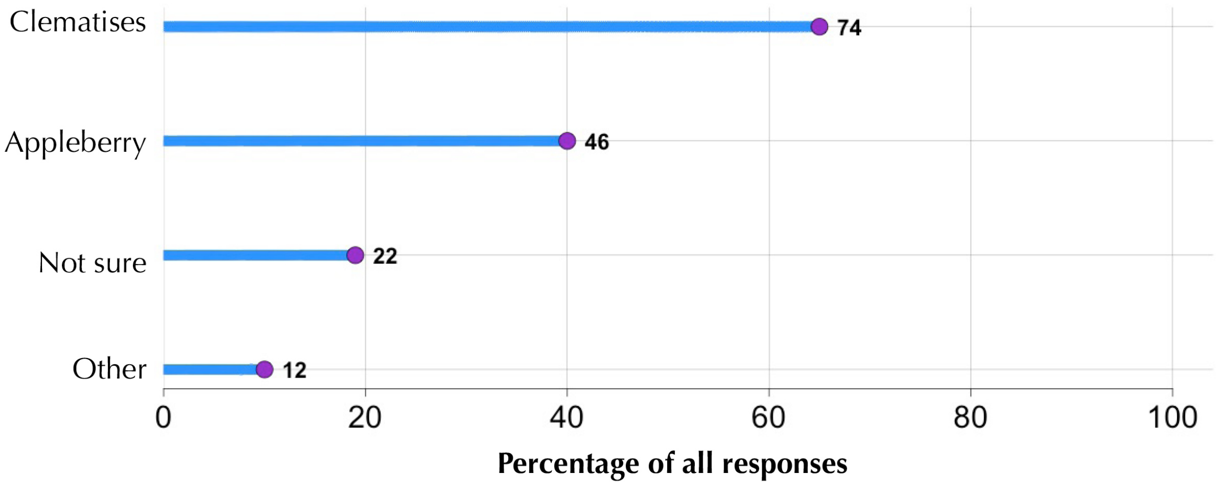

Figure 4.24. Indigenous climber species planted by survey respondents.

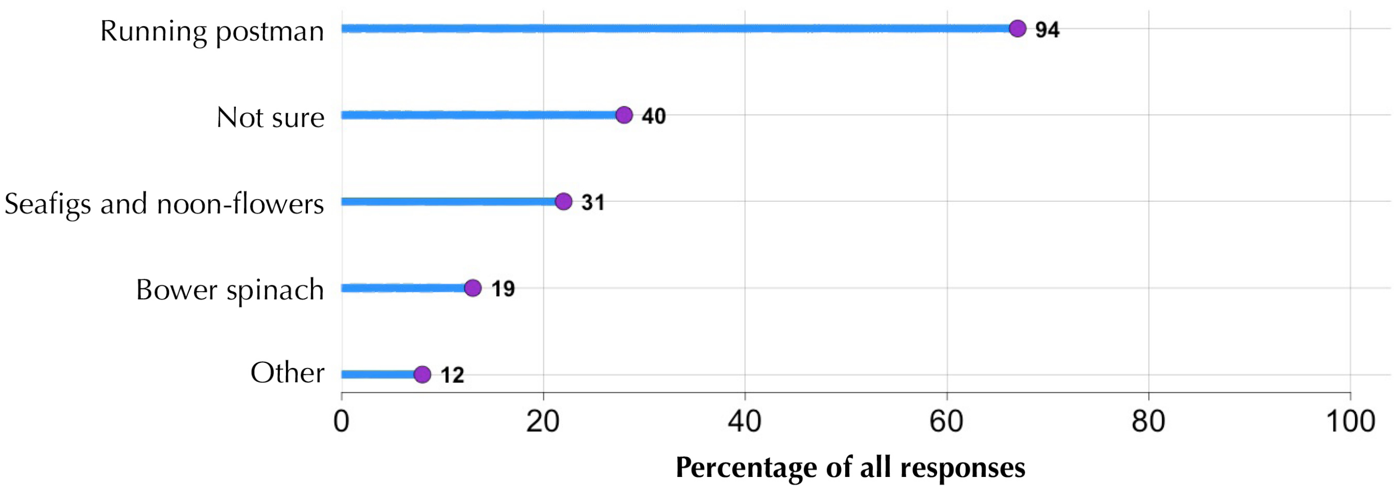

Figure 4.25. Indigenous climber species planted by survey respondents.

We hope findings from this study, particularly the proposed plant palettes, may assist both plant nurseries and wildlife gardeners motivated to promote garden pollinator biodiversity to better align their plant offerings and choices respectively with those species more likely to attract and support pollinators in gardens.

Wildlife gardeners primarily acquire indigenous plants from indigenous plant nurseries

Over 90% of respondents acquired the locally native plant species they used for wildlife gardening from indigenous plant nurseries (Figure 4.27), reinforcing how important these nurseries are in supporting wildlife gardening. Almost 40% of

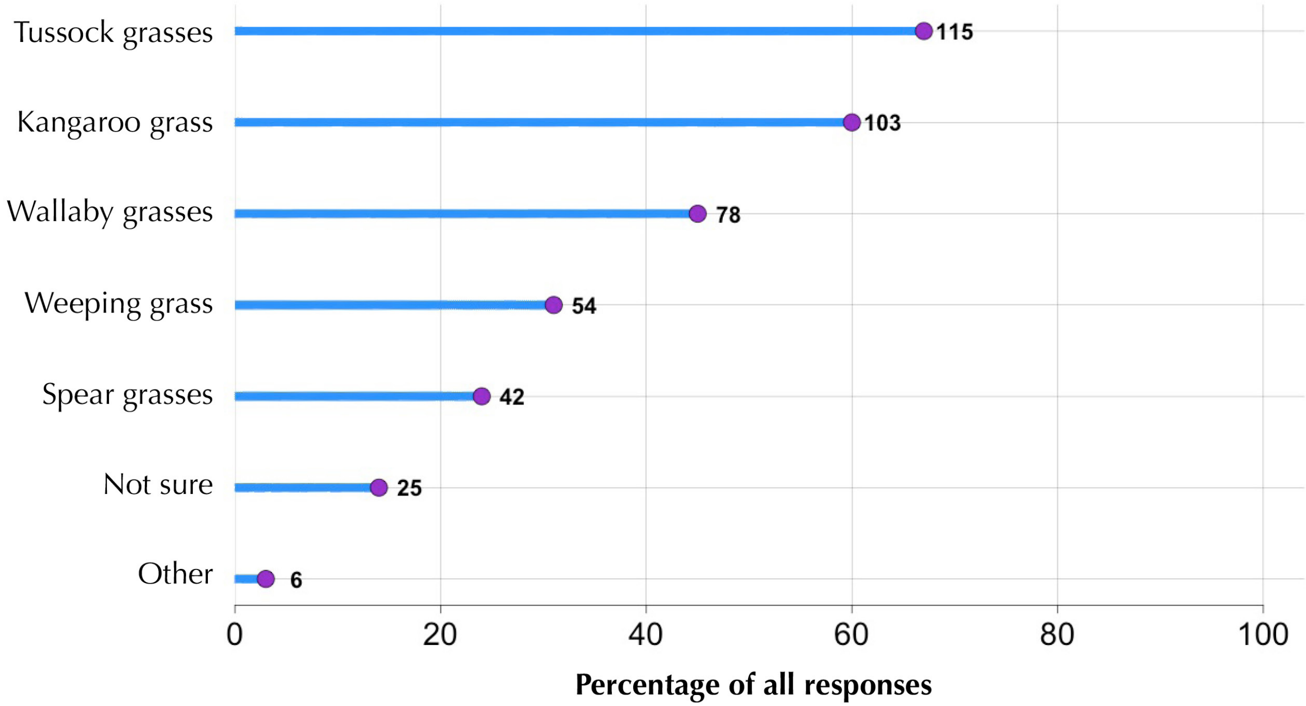

Figure 4.26. Indigenous tussock grass species planted by survey respondents.

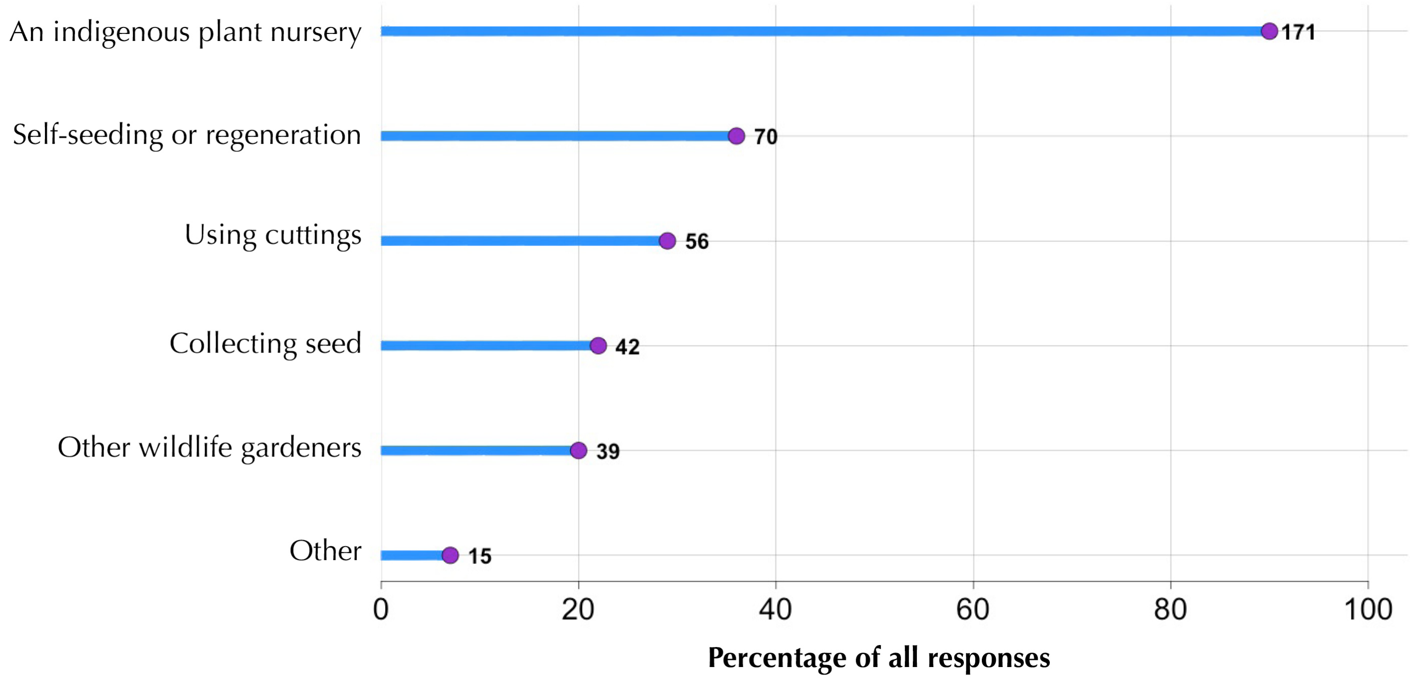

Figure 4.27. Source of locally native species used for wildlife gardening.

respondents acquired indigenous plants from self-seeding or regeneration, 30% used cuttings, 20% collected seed, and 20% acquired these plants from other wildlife gardeners. As a comparison, market research of garden owners in the United Kingdom (in 1999 when DIY retailers were overtaking garden centres in sales, pushing low maintenance gardening and availability of plants and shrubs in containers) shows remarkable alignment in the proportion of gardeners (termed 'Horticultural Hobbyists') that propagated plants from seeds and cuttings – 23% (Bhatti and Church, 2001). In a recent Australian market research survey of a representative sample of Australian adults (The Navigators Community, 2021), eight plant nursery customer segments were identified based on respondents' plant purchase and ownership variables. Of the two segments that did the most

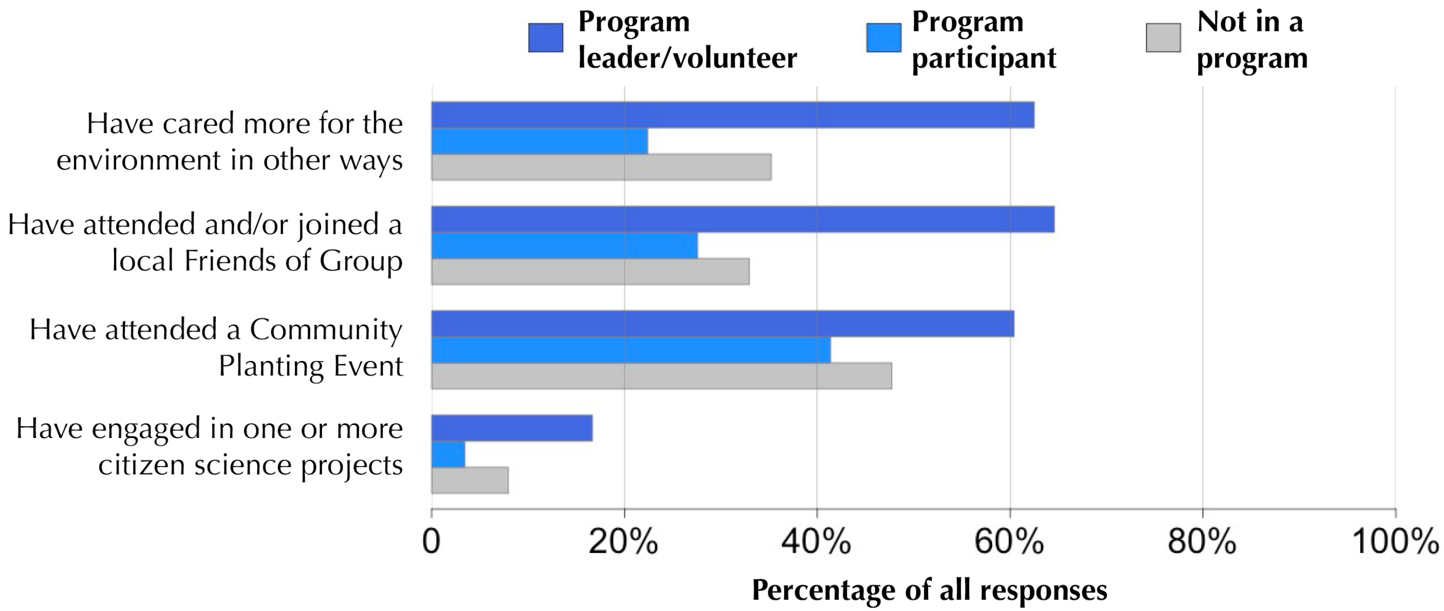

Figure 4.28. Percent of wildlife gardeners caring for the environment in other ways.

outdoor gardening and plant purchasing (together comprising 23% of the sample), about 50% – or 11% of the total sample, propagated plants using cuttings and 60% – or 13% of the total sample planted seeds. This is a smaller proportion than our sample of wildlife gardeners.

Wildlife gardeners care for the environment in other ways

Over 60% of wildlife gardening program leaders and volunteers have cared for the environment in other ways, including in 'Friends of groups' and community planting events (Figure 4.28). Interestingly, wildlife gardeners not in a program engage in these activities more than those in a program, but to a lesser extent than the leaders/volunteers. Community planting events were the most participated in activity (60% program leaders/ volunteers, 50% not in a program, 40% program participants). Citizen science was the least participated in activity by all three groups.

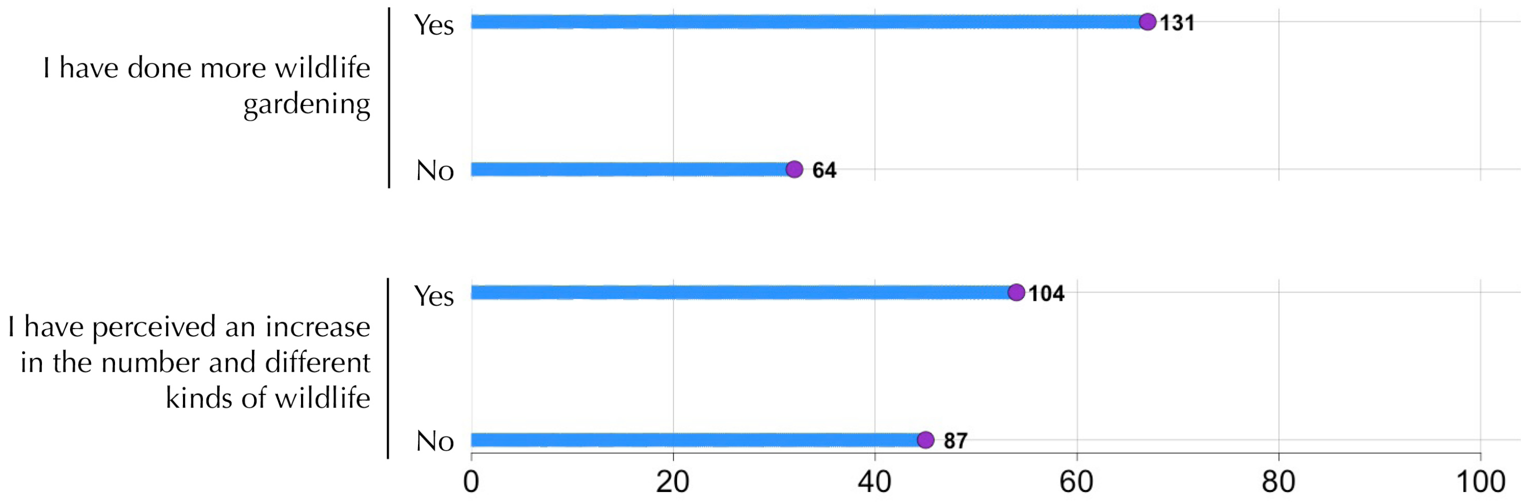

Figure 4.29. Effect of COVID lockdowns on respondents' wildlife gardening and wildlife observations.

Impact of COVID lockdowns on wildlife gardening activity and perception of neighbourhood wildlife

Approximately 70% of respondents had done more wildlife gardening since the COVID lockdowns (Figure 4.29). Just over half (55%) had perceived an increase in the number and different kinds of wildlife in their neighbourhoods. Understanding the effects of the COVID lockdowns on wildlife gardening, and on gardening and greenspace use more broadly, is undoubtedly a promising area of future research.

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Appendix I - Supplementary material

Table S1.1. List of plant species.

Table S1.2. List of insect pollinator species/taxa.

Table S1.3. Estimated insect species richness across the study.

Table S1.4. Estimated number of pollinator species occurring at each plant species.

Table S1.1. List of plant species.

Common name	Scientific name	Family	Order	Clade	Growth form	Flower colour	Bili Nursery	Frankston Indigenous Nursery	Greenlink Box Hill	Knox Environ. Society Indigenous Nursery
Austral stork's-bill	*Pelargonium australe*	Geraniaceae	Geraniales	Superrosids	Forbs	Red/Pink	x		x	
Blue pincushion	*Brunonia australis*	Goodeniaceae	Asterales	Superasterids	Forbs	Blue/Violet				x
Bluebells	*Wahlenbergia sp.*	Campanulaceae	Asterales	Superasterids	Forbs	Blue/Violet	x		x	x
Bulbine lily	*Bulbine bulbosa*	Asphodelaceae	Asparagales	Lilioid	Lilies	Yellow	x		x	x
Button everlasting	*Coronidium scorpioides*	Asteraceae	Asterales	Superasterids	Forbs	Yellow	x			x
Cassinias	*Cassinia sp.*	Asteraceae	Asterales	Superasterids	Shrubs	White				x
Clustered everlasting	*Chrysocephalum semipapposum*	Asteraceae	Asterales	Superasterids	Forbs	Yellow			x	x
Common correa	*Correa reflexa*	Rutaceae	Sapindales	Superrosids	Shrubs	Red/Pink	x		x	
Common everlasting	*Chrysocephalum apiculatum*	Asteraceae	Asterales	Superasterids	Forbs	Yellow	x	x	x	
Common heath	*Epacris impressa*	Ericaceae	Ericales	Superasterids	Shrubs	White			x	x
Crane's-bills	*Geranium sp.*	Geraniaceae	Geraniales	Superrosids	Forbs	White			x	
Cut-leaf daisy	*Brachyscome multifida*	Asteraceae	Asterales	Superasterids	Forbs	Blue/Violet	x		x	x
Fairy fan-flower	*Scaevola aemula*	Goodeniaceae	Asterales	Superasterids	Forbs	Blue/Violet				x
Flax-lilies	*Dianella sp.*	Asphodelaceae	Asparagales	Lilioid	Lilies	Blue/Violet	x		x	x
Hoary sunray	*Leucochrysum albicans*	Asteraceae	Asterales	Superasterids	Forbs	White			x	
Hop goodenia	*Goodenia ovata*	Goodeniaceae	Asterales	Superasterids	Shrubs	Yellow	x	x	x	x

Table S1.1 Continued. List of plant species.

Common name	Scientific name	Family	Order	Clade	Growth form	Flower colour	Bili Nursery	Frankston Indigenous Nursery	Greenlink Box Hill	Knox Environ. Society Indigenous Nursery
Ivy-leaved violet	*Viola hederacea*	Violaceae	Malpighiales	Superrosids	Forbs	White	x	x	x	
Kurwan	*Bursaria spinosa*	Pittosporaceae	Apiales	Superasterids	Shrubs	White			x	
Murnongs	*Microseris sp.*	Asteraceae	Asterales	Superasterids	Forbs	Yellow	x			x
Native flax	*Linum marginale*	Linaceae	Malpighiales	Superrosids	Forbs	Blue/Violet	x			
Purple loosestrife	*Lythrum salicaria*	Lythraceae	Myrtales	Superrosids	Forbs	Blue/Violet			x	
Rock correa	*Correa glabra*	Rutaceae	Sapindales	Superrosids	Shrubs	Yellow			x	
Showy podolepis	*Podolepis jaceoides*	Asteraceae	Asterales	Superasterids	Forbs	Yellow	x			
Silky daisy-bush	*Olearia myrsinoides*	Asteraceae	Asterales	Superasterids	Shrubs	White			x	
Silver banksia	*Banksia marginata*	Proteaceae	Proteales	Basal eudicots	Shrubs	Yellow				x
Small leaved-clematis	*Clematis microphylla*	Ranunculaceae	Ranunculales	Basal eudicots	Climbers	White			x	x
Spur goodenia	*Goodenia paradoxa*	Goodeniaceae	Asterales	Superasterids	Forbs	Yellow	x			
Sticky everlasting	*Xerochrysum viscosum*	Asteraceae	Asterales	Superasterids	Forbs	Yellow	x		x	x
Swamp daisy	*Brachyscome paludicola*	Asteraceae	Asterales	Superasterids	Forbs	White	x			
Teatrees	*Leptospermum sp.*	Myrtaceae	Myrtales	Superrosids	Shrubs	White			x	x
Twiggy daisy-bush	*Olearia ramulosa*	Asteraceae	Asterales	Superasterids	Shrubs	White	x		x	x
Twining glycine	*Glycine clandestina*	Fabaceae	Fabales	Superrosids	Climbers	Blue/Violet			x	
Varnish wattle	*Acacia verniciflua*	Fabaceae	Fabales	Superrosids	Shrubs	Yellow			x	

Table S1.1 Continued. List of plant species.

Common name	Scientific name	Family	Order	Clade	Growth form	Flower colour	Bili Nursery	Frankston Indigenous Nursery	Greenlink Box Hill	Knox Environ. Society Indigenous Nursery
White correa	*Correa alba*	Rutaceae	Sapindales	Superrosids	Shrubs	White	x	x		x
Yarra burgan	*Kunzea leptospermoides*	Myrtaceae	Myrtales	Superrosids	Shrubs	White			x	
Yellow hakea	*Hakea nodosa*	Proteaceae	Proteales	Basal eudicots	Shrubs	Yellow			x	

Table S1.2. List of insect pollinator species/taxa by group.

Common name	Scientific name of species/taxa	Order	Origin
Ants			
Ants	Formicidae	Hymenoptera	Indigenous
Aphids			
Aphids	Aphidoidea	Hemiptera	Introduced
Bees			
African carderbee	*Pseudoanthidium repetitum*	Hymenoptera	Introduced
Blue-banded bees	Amegilla	Hymenoptera	Indigenous
European honeybee	*Apis mellifera*	Hymenoptera	Introduced
Green-and-gold nomia	*Lipotriches australica*	Hymenoptera	Indigenous
Leafcutter bees	Megachile	Hymenoptera	Indigenous
Masked bees	Hylaeus	Hymenoptera	Indigenous
Wolly sweat bees	Lasioglossum	Hymenoptera	Indigenous
Beetles			
Checkered beetles	Cleridae	Coleoptera	Indigenous
Ladybugs	Coccinellidae	Coleoptera	Indigenous
Net-winged beetles	Lycidae	Coleoptera	Indigenous
Pintail beetles	Moredellidae	Coleoptera	Indigenous

Table S1.2 Continued. List of insect pollinator species/taxa by group.

Common name	Scientific name of species/taxa	Order	Origin
Butterflies			
Cabbage white	*Pieris rapae*	Lepidoptera	Introduced
Caper white	*Belenois java*	Lepidoptera	Indigenous
Grass blue	*Zizina labradus*	Lepidoptera	Indigenous
Meadow argus	*Junonia villida*	Lepidoptera	Indigenous
Painted lady	*Vanessa cardui*	Lepidoptera	Indigenous
Skippers	Hesperiidae	Lepidoptera	Indigenous
Flies			
Banded beeflies	Bombyliidae	Diptera	Indigenous
Craneflies	Tipulidae	Diptera	Indigenous
Dronefly	*Eristalis tenax*	Diptera	Indigenous
Fruit flies	Tephritidae	Diptera	Indigenous
Garden maggot	*Bibio imitator*	Diptera	Indigenous
Greenbottle flies	Lucilia	Diptera	Indigenous
Hoverflies	Syrphidae	Diptera	Indigenous
Grasshoppers			
Grasshoppers	Orthoptera	Orthoptera	Indigenous

Table S1.2 Continued. List of insect pollinator species/taxa by group.

Common name	Scientific name of species/taxa	Order	Origin
Heteropteran bugs			
Crop mirid	*Sidnia kinbergi*	Hemiptera	Indigenous
Earth-coloured bugs	Rhyparochromidae	Hemiptera	Indigenous
Long-legged stilt bug	*Chinoneides tasmaniensis*	Hemiptera	Indigenous
Orange assassin bug	*Gminatus australis*	Hemiptera	Indigenous
Pacific damselbug	*Nabis kinbergii*	Hemiptera	Indigenous
Rutherglen bugs	Nysius	Hemiptera	Indigenous
Tip wilters	Amorbus	Hemiptera	Indigenous
Lacewings			
Lacewings	Neuroptera	Neuroptera	Indigenous
Moths			
Moths	Lepidoptera	Lepidoptera	Indigenous
Wasps			
Carrot wasps	Gasteruptiidae	Hymenoptera	Indigenous
European wasps	Vespula	Hymenoptera	Introduced
Sand wasp	*Podalonia tydei*	Hymenoptera	Indigenous

Table S1.3. Posterior estimates for insect pollinator species richness as estimated under the multi-species community model. SD: Standard deviation; CI: Credible interval.

	Mean	SD	2.50% CI	97.50% CI
Introduced species	1.72	0.14	1.47	2.03
Indigenous species	6.17	0.33	5.58	6.92
All species	7.89	0.39	7.19	8.72

Table S1.4. Posterior estimates insect pollinator species richness by plant species as estimated under the multi-species community model. SD: Standard deviation; CI: Credible interval.

Common name	Scientific name	Introduced species				Indigenous species				All species			
		Mean	SD	2.50% CI	97.50% CI	Mean	SD	2.50% CI	97.50% CI	Mean	SD	2.50% CI	97.50% CI
Austral stork's-bill	*Pelargonium australe*	4.45	0.50	4.00	5.00	14.10	1.50	11.00	17.00	18.55	1.59	16.00	22.00
Blue pincushion	*Brunonia australis*	2.00	0.00	2.00	2.00	3.43	0.86	2.00	5.00	5.43	0.86	4.00	7.00
Bluebells	*Wahlenbergia sp.*	1.40	0.49	1.00	2.00	5.29	0.87	4.00	7.00	6.69	1.00	5.00	9.00
Bulbine lily	*Bulbine bulbosa*	2.00	0.00	2.00	2.00	4.70	1.19	3.00	7.00	6.70	1.19	5.00	9.00
Button everlasting	*Coronidium scorpioides*	1.00	0.00	1.00	1.00	4.71	0.85	3.00	6.00	5.71	0.85	4.00	7.00
Cassinias	*Cassinia sp.*	1.00	0.00	1.00	1.00	9.63	1.43	7.00	12.00	10.63	1.43	8.00	13.00
Clustered everlasting	*Chrysocephalum semipapposum*	1.00	0.00	1.00	1.00	11.55	1.23	9.00	14.00	12.55	1.23	10.00	15.00
Common correa	*Correa reflexa*	0.00	0.00	0.00	0.00	2.36	0.48	2.00	3.00	2.36	0.48	2.00	3.00
Common everlasting	*Chrysocephalum apiculatum*	2.88	0.72	2.00	4.00	12.24	1.20	10.00	15.00	15.12	1.43	13.00	18.00
Common heath	*Epacris impressa*	1.00	0.00	1.00	1.00	4.10	0.85	3.00	6.00	5.10	0.85	4.00	7.00
Crane's-bills	*Geranium sp.*	1.00	0.00	1.00	1.00	4.64	0.88	3.00	6.00	5.64	0.88	4.00	7.00
Cut-leaf daisy	*Brachyscome multifida*	3.45	0.50	3.00	4.00	15.77	1.77	13.00	19.00	19.22	1.84	16.00	23.00
Fairy fan-flower	*Scaevola aemula*	2.00	0.00	2.00	2.00	3.01	0.74	2.00	4.00	5.01	0.74	4.00	6.00
Flax-lilies	*Dianella sp.*	0.00	0.00	0.00	0.00	2.33	0.47	2.00	3.00	2.33	0.47	2.00	3.00
Hoary sunray	*Leucochrysum albicans*	2.39	0.49	2.00	3.00	11.55	1.16	10.00	14.00	13.94	1.27	12.00	17.00
Hop goodenia	*Goodenia ovata*	2.39	0.49	2.00	3.00	11.55	1.16	10.00	14.00	13.94	1.27	12.00	17.00
Ivy-leaved violet	*Viola hederacea*	3.00	0.00	3.00	3.00	2.59	0.85	1.00	4.00	5.59	0.85	4.00	7.00
Kurwan	*Bursaria spinosa*	0.00	0.00	0.00	0.00	4.02	0.70	3.00	5.00	4.02	0.70	3.00	5.00
Murnongs	*Microseris sp.*	1.42	0.49	1	2	6.84	0.99	5	9	8.27	1.10	6	10

Table S1.4 Continued. Posterior estimates of species richness of pollinator insects by plant species as estimated under the multi-species community model.

Common name	Scientific name	Introduced species				Indigenous species				All species			
		Mean	SD	2.50% CI	97.50% CI	Mean	SD	2.50% CI	97.50% CI	Mean	SD	2.50% CI	97.50% CI
Native flax	*Linum marginale*	1.00	0.00	1.00	1.00	1.36	0.48	1.00	2.00	2.36	0.48	2.00	3.00
Purple loosestrife	*Lythrum salicaria*	1.00	0.00	1.00	1.00	1.76	0.43	1.00	2.00	2.76	0.43	2.00	3.00
Rock correa	*Correa glabra*	1.00	0.00	1.00	1.00	4.14	0.85	3.00	6.00	5.14	0.85	4.00	7.00
Showy podolepis	*Podolepis jaceoides*	1.01	0.73	0.00	2.00	4.58	0.49	4.00	5.00	5.58	0.89	4.00	7.00
Silky daisy-bush	*Olearia myrsinoides*	0.00	0.00	0.00	0.00	2.45	0.50	2.00	3.00	2.45	0.50	2.00	3.00
Silver banksia	*Banksia marginata*	1.42	0.49	1.00	2.00	2.33	0.47	2.00	3.00	3.75	0.68	3.00	5.00
Small leaved-clematis	*Clematis microphylla*	2.00	0.00	2.00	2.00	3.33	0.85	2.00	5.00	5.33	0.85	4.00	7.00
Spur goodenia	*Goodenia paradoxa*	0.00	0.00	0.00	0.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00
Sticky everlasting	*Xerochrysum viscosum*	3.00	0.00	3.00	3.00	22.27	1.93	19.00	26.00	25.27	1.93	22.00	29.00
Swamp daisy	*Brachyscome paludicola*	0.81	0.39	0.00	1.00	6.65	1.10	5.00	8.00	7.45	1.18	5.00	9.00
Teatrees	*Leptospermum sp.*	2.95	1.00	2.00	4.00	7.89	1.25	6.00	10.00	10.85	1.60	8.00	14.00
Twiggy daisy-bush	*Olearia ramulosa*	3.27	0.93	2.00	5.00	10.85	1.09	9.00	13.00	14.12	1.47	11.00	17.00
Twining glycine	*Glycine clandestina*	2.43	0.49	2.00	3.00	2.74	0.69	2.00	4.00	5.17	0.85	4.00	7.00
Varnish wattle	*Acacia verniciflua*	1.59	0.49	1.00	2.00	1.00	0.00	1.00	1.00	2.59	0.49	2.00	3.00
White correa	*Correa alba*	2.41	0.49	2.00	3.00	7.70	1.09	6.00	10.00	10.11	1.20	8.00	13.00
Yarra burgan	*Kunzea leptospermoides*	2.42	0.49	2.00	3.00	14.31	1.38	12.00	17.00	16.73	1.49	14.00	20.00
Yellow hakea	*Hakea nodosa*	1.00	0.00	1.00	1.00	3.18	0.70	2.00	4.00	4.18	0.70	3.00	5.00