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How can urban development support biodiversity retention on private lands?

Rapid review

NR2002

V1.0

Australian Government
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Acknowledgements

Disclaimer

Peer Review Statement

The CRCLCL recognises the value of knowledge exchange and the importance of objective peer review. It is committed to encouraging and supporting its research teams in this regard.

The author(s) confirm(s) that this document has been reviewed and approved by the project's steering committee and by its program leader. These reviewers evaluated its:

- originality
- methodology
- rigour
- compliance with ethical guidelines
- conclusions against results
- conformity with the principles of the Australian Code for the Responsible Conduct of Research (NHMRC 2007), and provided constructive feedback which was considered and addressed by the author(s).

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Background

With increasing urbanisation and reduced space for biodiversity within our cities, the private garden is an important refuge for fauna and flora. While individual private gardens are too small to support viable populations, collectively, gardens can help retain population species. There is a lack of understanding of how to incorporate effective policies to support the retention of biodiversity on private land.

Objective

The objective of this rapid review is to locate and summarise published peer-reviewed review papers, where possible, relating to the retention of biodiversity on private land in urban areas. The main question that this rapid review answers is "How can urban development support biodiversity retention on private lands?"

Data sources

Data sources included Scopus, Web of Science and ProQuest. A search on Google Scholar also pointed to additional relevant articles.

Study eligibility criteria

Peer-reviewed academic articles focusing on the retention of biodiversity on private lands were included in this review. Selected articles had to focus on private properties in an urban context and discuss instruments and strategies to conserve biodiversity. Included articles were published in English.

Study appraisal and synthesis methods

Studies that fulfilled the inclusion criteria were qualitatively summarised. The quality and risk of bias of these studies were assessed using an adapted version of the 16 questions from AMSTAR2 tool.

Results

Six articles published between 2006 and 2017 were included in this analysis. Whilst all articles discussed strategies to promote biodiversity in urban private properties, only one study had this topic as its central theme. Other identified themes consisted in the analysis of the interconnectedness of green areas at different city scales for an integrative approach to increasing urban biodiversity; the identification of residents' behaviours and attitudes toward biodiversity as a manner of informing

conservation programs; and the understanding of how household characteristics and urban forms affect biodiversity in residential properties.

Limitations

Only peer-reviewed studies written in English were included. Due to the limited number of systematic literature reviews in the topic of interest, non-systematic reviews and empirical research were also considered. An additional search using Google Scholar was conducted to capture anything that may have been missed.

Conclusions and implications

This rapid review identified that most common incentives for biodiversity conservation in urban private properties include:

- Indirect financial incentives
- Payment for ecosystem services
- Market-based certifications
- Community-based initiatives.

Whilst these voluntary incentives are considered effective to encourage biodiversity in private urban properties, they should be integrated with wider conservation efforts to maximise connectivity between habitats. Moreover, household characteristics and individual behaviours have been shown to correlate with the amount of biodiversity in private properties.

It is recommended that incentive strategies to enhance biodiversity on private lands also include the following measures:

- New developments should spatially arrange private gardens and green public spaces to maximise total habitat patch area.

- Biodiversity conservation at a city level should include private gardens and promote habitat heterogeneity.

- Householders and stakeholders operating at different scales should be given different tailored, but complementary, gardening advice.

- Residents should be given education and support to get involved in community and city-scale schemes.

- Marketing and communication strategies for households should be tailored and targeted at different groups, considering specific lifestyle behaviours, demographics, and motivations.

Amendments to the protocol

The scope of this rapid review was expanded to include empirical research articles in two of the databases, which did not return any reviews in the topic of interest.

Introduction

Rationale

Urbanization is driving land use change and reducing biodiversity coverage worldwide [1]. Increased density and the expansion of paved areas are reducing the space available for biodiversity. With predictions of 80% of the human population living in cities by 2030, active efforts need to take advantage of the remaining space, such as public and private gardens [2, 3].

The land area covered by private gardens varies in different countries and cities. For instance, they represent 16% of the total land in Stockholm (Sweden), 25% in UK cities, 36% in Dunedin (New Zealand) and 55% in Baton Rouge (Louisiana, USA) [2, 4, 5]. Private green space in gardens now plays an important role for protecting biodiversity that provides vital ecosystem services including reducing atmospheric and water pollution, albedo and radiation loads, and reducing the urban heat island effect. Biodiversity aspects such as habitat, food supply, breeding and migration sites are also found in the refuge of domestic gardens [6]. Studies have shown that some fauna are more likely to be present in urban areas than rural areas [7]. Thus it is important to encourage and support species in cities through a variety of green corridors, natural vegetation tracks and natural areas on the urban fringe [7]. Private backyards also play an important part in this effort through providing connections to other areas of biodiversity, encouraging the creation of wildlife gardens and domestic conservation actions [4, 8]. While individual private gardens are too small to support viable populations, collectively, gardens can help retain species populations [2].

Domestic gardens are reliant on individual households to plant and maintain them [2], leaving them vulnerable to inadequate management as well as disconnected from the surrounding greenspace. Research on private land conservation efforts has been underpinned by various assumptions regarding local residents' knowledge and behaviours and little work has been done on incorporating these considerations directly into the planning and development of conservation initiatives [8].

Local efforts to reduce or halt biodiversity loss often lack the resources, political will or knowledge to succeed, with most efforts being inadequate to sustain viable populations of species [8].

This rapid review proposes to examine the international literature on biodiversity on private land and summarises recommendations on how urban development can support and increase biodiversity.

Objectives

The main question that this rapid review answers is "How can urban development support biodiversity retention on private land?"

The objective of this rapid review is to locate and summarise published peer-reviewed review papers, where possible, relating to the retention of biodiversity on private land in urban areas.

A secondary objective of this review is to assess the time and resources needed to perform a scoping / rapid meta-review on a topic related to biodiversity in the built environment. Thus, information relevant to the review team's structure, review timeline and associated workloads are also included in this report.

Anigozanthos manglesii (photo by JBA)

Methods

Eligibility criteria

The following study characteristics were used as inclusion criteria for the review:

1. Studies published in peer-reviewed academic journals.
2. Studies published in English.
3. Full text available.
4. Review articles where available.
5. In databases where review articles were not found, relevant articles based on empirical research were used instead.
6. Studies about biodiversity in private properties, in an urban context. Articles discussing biodiversity conservation in private forests, grasslands, rural settings or agricultural landscapes were excluded from this review. Articles focusing on public urban areas such as street verges and parks were also excluded.
7. Studies addressing instruments to conserve biodiversity. Studies that described the variety of species found in domestic gardens or the benefits of biodiversity in urban areas but did not discuss how to promote it, were not included in the analysis.

Information sources

Data sources included Scopus, Web of Science and ProQuest. Google Scholar also pointed to additional relevant articles not captured through the three databases.

Literature search and study records

The searches were conducted on the 25th of April 2020 in three academic databases: Scopus, Web of Science and ProQuest and the results were combined to answer the research question. Each search was screened through article titles, abstracts and keywords.

The search string used in this rapid review combined synonyms of the following keywords: 'urban', 'biodiversity', 'private property', 'conservation' and 'incentives'. Attempts were made to find articles specifically mentioning 'Australia', but this keyword made the search too restrictive, not returning any results.

The specific string used for this search was the following:

((urban* OR cit* OR precinct OR development OR suburb*) AND (biodiversity OR vegetation OR flora OR green OR tree* OR plant* OR nature OR "land cover" OR garden) AND (household* OR individual* OR home* OR backyard OR garden OR yard* OR "private property" OR "private land" OR "private garden") AND (private) AND (preserv* OR conserv* OR retention OR retain OR protect* OR stewardship) AND (incentiv* OR polic* OR strateg* or program* OR manage* OR support* OR instrument*))

An additional search in Google Scholar, using the above search string was conducted on the 28th of April as a way of capturing additional academic articles of interest that may not have been found through the chosen databases. Given that the results in Google Scholar are sorted by relevance as well as number of citations, only the first 20 pages of results were screened. Articles were selected according to their scope and study eligibility criteria.

Finding literature reviews on the topic of biodiversity conservation in private urban land, specifically systematic literature reviews, proved difficult. A limited number of relevant literature reviews were found in Scopus and Web of Science. None were identified through ProQuest and no novel relevant reviews were found in Google Scholar. As such, the search was expanded in both ProQuest and Google Scholar, to include articles as well as reviews. Please refer to Table 1 to view the specific filters applied to each of the databases.

All records found through the three databases and Google Scholar were exported to the Endnote reference management software. Duplicates were excluded and titles, abstracts and keywords were screened by one reviewer. Articles that did not meet the eligibility criteria were excluded. The library was then exported to an Excel file for further eligibility assessment. All remaining articles and reviews were read in full by two researchers and classified individually according to their relevance and scope. Discrepancies in article classification were debated until a consensus was reached. Only articles deemed relevant or very relevant were included in this rapid review. The analysis of the included papers was conducted by the two researchers.

The search and screening processes are summarized in the PRISMA diagram in Figure 1.

Table 1 Specific search strings and filters applied in different databases

Database [results]	Search string	Filters
Scopus [55]	TITLE-ABS-KEY ((urban* OR cit* OR precinct OR development OR suburb*) AND (biodiversity OR vegetation OR flora OR green OR tree* OR plant* OR nature OR "land cover" OR garden) AND (household* OR individual* OR home* OR backyard OR garden OR yard* OR "private property" OR "private land" OR "private garden") AND (private) AND (preserv* OR conserv* OR retention OR retain OR protect* OR stewardship) AND (incentiv* OR polic* OR strateg* or program* OR manage* OR support* OR instrument*))	English, review, journals
Web of Science [22]	TS = ((urban* OR cit* OR precinct OR development OR suburb*) AND (biodiversity OR vegetation OR flora OR green OR tree* OR plant* OR nature OR "land cover" OR garden) AND (household* OR individual* OR home* OR backyard OR garden OR yard* OR "private property" OR "private land" OR "private garden") AND (private) AND (preserv* OR conserv* OR retention OR retain OR protect* OR stewardship) AND (incentiv* OR polic* OR strateg* or program* OR manage* OR support* OR instrument*))	English, review
ProQuest [189]	noft(((urban* OR cit* OR precinct OR development OR suburb*) AND (biodiversity OR vegetation OR flora OR green OR tree* OR plant* OR nature OR "land cover" OR garden) AND (household* OR individual* OR home* OR backyard OR garden OR yard* OR "private property" OR "private land" OR "private garden") AND (private) AND (preserv* OR conserv* OR retention OR retain OR protect* OR stewardship) AND (incentiv* OR polic* OR strateg* or program* OR manage* OR support* OR instrument*)))	English, scholarly journal, reviews and articles, full text NOT (endangered & extinct species AND tourism AND women AND birds AND children AND data processing AND gender AND water quality AND agricultural production AND agroforestry AND children & youth AND disasters AND employees AND hospitals AND information systems)
Google Scholar [28]	((urban* OR cit* OR precinct OR development OR suburb*) AND (biodiversity OR vegetation OR flora OR green OR tree* OR plant* OR nature OR "land cover" OR garden) AND (household* OR individual* OR home* OR backyard OR garden OR yard* OR "private property" OR "private land" OR "private garden") AND (private) AND (preserv* OR conserv* OR retention OR retain OR protect* OR stewardship) AND (incentiv* OR polic* OR strateg* or program* OR manage* OR support* OR instrument*))	20 first pages, English, scholarly journals, reviews and articles

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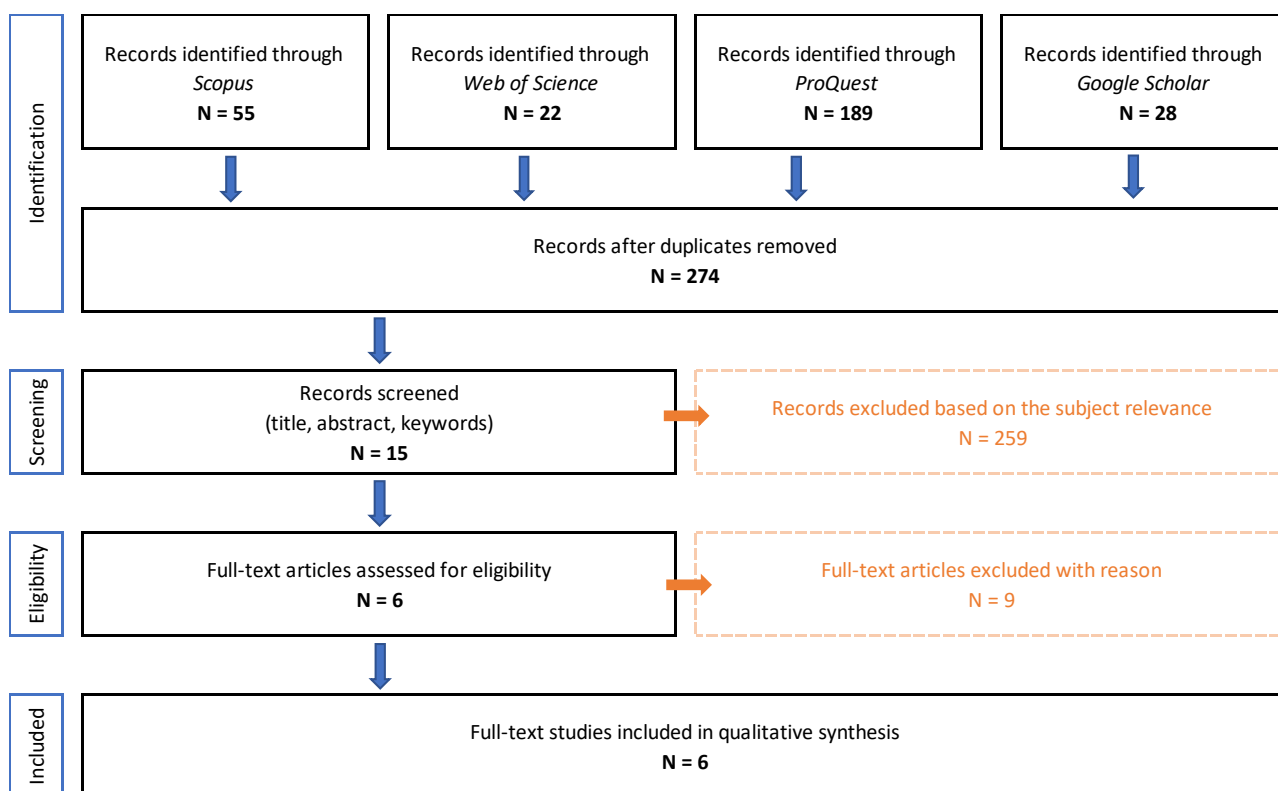
Figure 1 PRISMA diagram of the search and screening process

Data items

For each included study, the following characteristics were extracted: first author and year of publication, study title, study theme, location conditions, review type, number of articles reviewed, study funding and conflict of interests. Table 2 presents the main extracted variables (as used in Table 3 in the Results section). Data extraction was performed by two reviewers who checked each other's work. For each study, quality assessment scores, risk of bias and overall comments were provided (for details, see the "Risk of bias of individual studies" section below).

Table 2 List of the main study variables extracted

Study variable	Description
First author_year	Key (ID) of the article is created by concatenating the last name of the first author and the year published
Reference	Full publication reference information, including title of the article
Study theme	Main topic addressed in the article
Location conditions	Country in which researchers are located and case studies are located
Review type	Type of certification scheme considered in the study
Number of articles reviewed	Number of certified buildings for which data is reported in the study
Study funding	Funding sources declared in the article
Conflict of interests	Conflicts of interests declared in the article

Outcomes and prioritisation

The main outcome of this rapid review was to identify strategies to encourage the retention of biodiversity on private lands located in urban settings. Data about conservation strategies in public areas or rural private lands were not extracted or analysed.

Risk of bias in individual studies

Information on the included studies' funding sources and conflict of interest statements were recorded. Where available, information was also collected to assess the extent to which the articles addressed the study quality criteria. Methodological details and any concerns related to data collection or analysis were noted. A quality assessment of the studies included in this review was performed using the AMSTAR2 checklist [9]. Table 9 presents the 16 questions used for this assessment process, with codes and explanations. The assessment was performed by two reviewers who checked the other's work.

Data Synthesis

No quantitative assessment was performed due to the heterogeneity and small number of included studies. A qualitative summary is provided in the form of tables and a narrative description of the patterns in the literature that was reviewed.

Meta-bias(es)

Not applicable, due to the qualitative summary nature of this review.

Results

The final study list included six articles that fulfilled the inclusion criteria (see Table 3).

Overview of the included studies

The articles included in this rapid review were published between 2006 and 2017 and reported findings based on studies from Australia, Brazil, Japan and the USA.

Despite the rapid review's original intent of reviewing only systematic literature reviews or meta-analysis, only one article met this criterion. The lack of research focusing on urban private lands has been acknowledged in the literature and was identified as an area requiring further investigation [4, 10]. The remaining five articles consisted of one in-depth narrative review and four empirical studies. Empirical studies were included given the small number of relevant articles in the topic of interest.

All articles discussed biodiversity in private properties located in well-established city suburbs, except for Black *et* al. [8] whose case study was located in an urban fringe undergoing densification, adjacent to a rural setting.

Whilst all articles discussed strategies to promote biodiversity in private areas, only one study had this topic as its central theme [4]. Other identified themes consisted of the analysis of the interconnectedness of green areas at different city scales for an integrative approach to increasing urban biodiversity [2]; the identification of residents' behaviour and attitudes toward biodiversity as a means of informing conservation programs [8]; and the understanding of how household characteristics and urban forms affect biodiversity in residential properties [3, 5, 11].

Home gardening (https://www.pexels.com/photo/green-plants-on-brown-clay-pots-3673763/)

Qualitative summary

A description of the articles' respective findings and recommendations with regard to biodiversity conservation on private lands can be found in Table 4. These are further summarized in this section, which starts with an account of the typical incentives used worldwide to encourage conservation in private properties. This section then discusses how city-wide biodiversity plans and individual household characteristics should be taken into consideration when devising strategies directed at private properties.

- Incentives to encourage biodiversity conservation

Incentives for biodiversity in urban private properties can be from a top-down or bottom-up approach [2]. Top-down approaches are usually aligned with citywide conservation efforts and often originate from government initiatives. These include:

- **Indirect incentives** to owners who commit to restore or create green spaces on their properties [4]. These are through tax reductions, government grants, subsidies, fee credits or development rights. In addition to financial incentives, participants may receive technical and implementation assistance and

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be subject to periodic monitoring and reporting obligations.

- **Payment for Ecosystem Services (PES)**, which aim to protect ecosystem services by compensating landowners who adopt favourable practices [4]. Payments are made in cash or in-kind (*e.g.* through loan waivers, access to finances/microcredits or provision of services) to the owner of the ecosystem asset in exchange for its preservation. Agencies may assist with the design, implementation, enforcement, and fundraising for a PES scheme. Households involved in this scheme may be subject to periodic surveys and reporting for compliance verification.

Woman planting
(https://unsplash.com/photos/QMj47_NSmfs)

Top-down approaches have been criticized for failing to understand owners' motivations as well as values and attitudes [2]. In recent years there has been a move toward bottom-up approaches, which are individual or community-led initiatives. These include:

- **Market-based certifications**, which stimulate biodiversity conservation during site development in exchange for a formal recognition [4]. These are appealing as they provide a competitive advantage to owners and developers. Certification is conducted by a third-party organization after demonstrated compliance with set standards and may involve periodic monitoring and reporting.

- **Community-based initiatives** include the engagement of private owners who are interested in conservation [2, 4]. These owners are usually recruited through an organizing entity such as a

community organization or an NGO, to manage their land towards supporting biodiversity and wildlife. These landowners may receive technical support and participate in long-term monitoring. No formal incentives are given. However, participants experience a sense of contribution towards the community and benefit from landowner relationships and social cohesion.

Voluntary strategies for biodiversity conservation in private properties, as opposed to regulatory frameworks, provide a way of including private gardens into wider conservation strategies and coordinate collaboration at different city scales.

- Integration of biodiversity conservation at different scales

Biodiversity is enhanced with connectivity, in the sense that many species need a wider habitat to thrive. It is important therefore, that private garden conservation is not only encouraged, but its management is coordinated with the surrounding landscape, including the neighbourhood and the wider city. For maximisation of city-wide biodiversity, the following is recommended in relation to private gardens [2]:

- New developments should spatially arrange private gardens and green public spaces to maximise total habitat patch area and minimise isolation.

- Biodiversity conservation at a city level should include private gardens and promote habitat heterogeneity and complexity for higher diversity of species.

- Householders and stakeholders operating at different scales should be given different tailored, but complementary, gardening advice.

- Residents should be given education and support to get involved in community and city-scale schemes.

Ringneck Parrot in a nesting box (photo by Mandy Bamford)

- Household characteristics and behaviours as influencing factors

Research has correlated household behaviours and characteristics with the amount of biodiversity found in private properties.

Findings show that biodiversity on private lands increases with wealth [11], home value, household size, marriage rate, lower density, high school graduation rate, proximity to public green spaces and home ownership [5]. Likewise, investment in garden maintenance is positively influenced by income, home value, the median age of residents, household size, home ownership and low density [5].

Property age was also found to correlate with the amount of vegetation cover [11]. Vegetation abundance in gardens reach a peak between 40 and 50 years, then gradually decrease [3, 5].

One study found that lifestyle behaviour was the main predictor of vegetation cover on private lands [3]. This refers to the social identity of the household and how residents associate social status with their lifestyle. Lifestyle behaviour is associated with land management decisions, which is influenced by social norms. Neighbouring houses usually have gardens that are similar to each other and wealthier areas have more luxurious gardens [2, 3].

A relationship between connection to nature and biodiversity conservation behaviours in the home was considered in Black *et* al. [8]. However, these tended to be restricted to low-cost actions within the home boundaries and were not necessarily in line with wider conservation schemes, suggesting a need for education programs and community engagement campaigns.

Although the findings relating to household characteristics and behaviours may be culture and/or context specific and not necessarily applicable to Australia, they show that strategies of one-size fits all may not be suitable when devising conservation programs. Marketing and communication strategies to promote conservation on private lands should be tailored and targeted at different groups, taking into account specific lifestyle behaviours, demographics and motivations. Insights into household characteristics can also inform how to select the most adequate incentive strategies as well as how financial resources could be distributed to encourage biodiversity in specific residential areas.

Street verge planting with native species (photo by Patrick Schutler)

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Table 3 List and main characteristics of the included articles.

First Author _year	Title	Study scope	Theme	Location conditions	Article type	Number of articles analysed or data source	Study funding	Conflict of interests
Black_2017	Using residents' attitudes, knowledge and behaviours to improve biodiversity conservation in an Australian rural–urban landscape	To understand residents' behaviours and attitudes toward biodiversity to inform future conservation programs.	Behaviours and attitudes	Researchers based in Australia and the USA Australian case study	Empirical research	300 resident surveys	No funding acknowledged	None declared
Cerra_2017	Emerging strategies for voluntary urban ecological stewardship on private property	To review initiatives and programs to encourage voluntary stewardship in urban private properties.	Incentives	Researchers based in the USA Case studies are from: Brazil, Japan and USA	Systematic literature review in scientific database and review of grey literature, plus interviews	10 articles	No funding acknowledged	None declared
Goddard_2010	Scaling up from gardens: biodiversity conservation in urban environments	To review the role of biodiversity in private gardens and suggest mechanisms to encourage 'wildlife friendly' management of gardens and green areas at different city scales.	Incentives Integration of urban green spaces	Researchers based in the UK Article locations not specified	Narrative review	Not stated	University of Leeds Earth and Biosphere Institute	None declared
Grove_2006	Characterization of Households and its Implications for the Vegetation of Urban Ecosystems	To understand the influence of population density, lifestyle behaviour, social stratification and housing age on vegetation cover	Externalities affecting biodiversity on private lands	Researchers based in the USA American case study	Empirical research	Data from city databases, satellite images, maps, census and GIS	US Forest Service's Northeastern Research Station and Northeastern Area State and Private Forestry Program, and the National Science Foundation	None declared
Lowry_2012	Determinants of urban tree canopy in residential neighbourhoods: Household characteristics, urban form, and the geophysical landscape	The research investigates how a range of factors relate to residential tree canopy density in South Lake City.	Externalities affecting biodiversity on private lands	Researchers based in the USA and Fiji American case study	Empirical research	Data from census and GIS	Intermountain Digital Image Archive Center	None declared
Troy_2007	Predicting Opportunities for Greening and Patterns of Vegetation on Private Urban Lands	To understand the influence of population density, social stratification and lifestyle clusters on vegetation cover on private lands.	Externalities affecting biodiversity on private lands	Researchers based in the USA American case study	Empirical research	Data from city databases, census and GIS	US Forest Service's Northeastern Research Station and Northeastern Area State and Private Forestry Program, and the National Science Foundation	None declared

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Table 4 Summary of article findings and authors' recommendations for the included studies

First Author _year	Summary of findings	Summary of recommendations/conclusions
Black_2017	The research found a relationship between connection to nature and conservation behaviours. Households had a strong likelihood to participate in low-cost pro-environmental behaviours within their home boundaries. However, households did not engage in community-based conservation activities beyond their homes, suggesting they have an external locus of control. Residents had low levels of biodiversity knowledge and their education levels did not correlate to pro-environmental behaviours, unlike other studies. Understanding residents' behaviours and attitudes assists in tailoring strategies that increase the likelihood of resident engagement.	It is suggested that residents' biodiversity knowledge could be improved through environmental education programs supported by local councils. This could include the distribution of guidelines on how to attract and support biodiversity on residential properties. It is suggested at a policy level, that private lands are integrated into a city-wide biodiversity conservation strategy, coordinating approaches between multiple scales. Community engagement campaigns should build upon current conservation actions to increase the impact of private land conservation on the surrounding landscapes.
Cerra_2017	Incentives for voluntary stewardship in private urban properties are of four types, listed below. - **Indirect incentives** programs are usually aligned with citywide conservation efforts. They incentivize owners to restore/create green spaces on properties through tax reduction, fee credit or development rights. Landowners and/or developers enter into a conservation agreement with the municipality to demonstrate commitment. Participants may receive technical assistance. These programs may involve periodic monitoring and reporting. - **Market-based certifications** stimulate biodiversity conservation during development in exchange for a formal certification. Certification is conducted by a third-party organization after demonstrated compliance with standards and may involve periodic monitoring and reporting. - **Community-based initiatives** appeal to landowners who are interested in conservation. An organizing entity recruits private landowners to take part and provide technical assistance. There are no formal incentives, except for a sense of contribution and social cohesion. Long-term monitoring may be conducted. - **Payments for Ecosystem Services (PES)** aim to protect ecosystem services by compensating landowners who adopt favourable practices (*via* conservation or restoration of an ecosystem). Payments are made in cash or in-kind (through loan waivers, access to finances/microcredits or provision of services). Payment schemes can be public or private. Agencies may assist with the design, implementation, enforcement, and fundraising for a PES scheme. Periodic surveys and reporting may be required to verify compliance.	Voluntary urban ecological stewardship strategies offer solutions that are often inaccessible to regulatory frameworks. It provides a way of including private green spaces in conservation strategies and coordinates collaboration between landowners.

Goddard_2010	There is a need to coordinate garden management with the surrounding landscape as biodiversity is enhanced with connectivity. New developments should spatially arrange private gardens and green spaces to maximise total habitat patch area and minimise isolation.	Plans for biodiversity conservation at a city level should include private gardens and promote habitat heterogeneity. Householders, community groups, NGOs and housing developers operating within each habitat zone could be given tailored wildlife-gardening advice.
	There is a need to increase the complexity of gardens to enhance biodiversity. However, social norms make it so that neighbouring areas have gardens similar to each other. Some areas lack resources for garden management.	The gardens and green spaces of new housing developments offer opportunities for the creation of tailored habitat gardens comprised of native planting. Given appropriate education and support, residents are likely to take pride in getting involved in community and city-scale schemes.
	Collaboration between stakeholders is required to ensure coordinated management at multiple scales.	
	Incentives for wildlife friendly gardening for householders are of two kinds, listed below.	
	- **Top-down**, which includes financial incentives such as tax reductions, government grants, subsidies; or planning regulations (e.g. declining applications for development on existing gardens). However, these mechanisms fail to change underlying values and attitudes and fail to understand the motivation of gardeners.	
	- **Bottom-up**, which consist in community-led initiatives. Community organisations can be targeted for participatory techniques that engage groups of gardeners in managing their land to support wildlife. Examples of garden conservation programs include: The 'Healthy Yard Pledge', where participants commit to garden management principles; the 'Homes for Wildlife' scheme, which encourages people to take tailored management actions in their gardens; incentives for dwellers to certify their gardens as wildlife habitats; involvement of homeowners in monitoring biodiversity in their own gardens.	
Grove_2006	Social stratification predicts the possibility for vegetation (wealthier households tend to live in larger blocks) but not whether vegetation is realized.	The understanding of lifestyle behaviours can shape marketing strategies for land management approaches.
	Lifestyle behaviour is the best predictor of vegetation cover on private lands, followed by median housing age. Lifestyle behaviour is associated with land management decisions, which is influenced by prestige and social norms.	Communication strategies and management activities should be targeted at different lifestyle groups' preferences and motivations, building on desire for social status and group identity.
	Vegetation cover in houses increases until the house reaches 40 to 50 years of age, then declines.	

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Lowry_2012	Time strengthens the effect of income on neighbourhood canopy abundance because wealthy homeowners have the financial resources to invest in growing vegetation.	Knowing more about how urban tree canopy is related to different social groups provides practitioners with information about how to distribute scarce financial resources to encourage biodiversity.
	In new neighbourhoods with predominantly mid-stage families, tree canopy is low.	
	In houses that are 15 years old or more, tree canopy decreases as household size decreases. As the median population age increases, so does tree canopy.	
	There is no relationship between family life-stage and tree cover in older neighbourhoods, which are less likely to be planned developments.	
	In new neighbourhoods, there is a positive relationship between both street connectivity and density, and residential tree canopy. Neighbourhoods that are dense and well-connected start off with greater tree canopy than less dense and less well-connected streets, but after about 50 years street design no longer makes a difference.	
Troy_2007	Biodiversity on private lands was found to be positively influenced by: - Median home value - Household size (trees only, either through planting and maintaining or self-selecting to neighbourhoods with more trees) - Marriage rates (trees only) - Single family detached homes - High school graduation rate - African American populations - Proximity to public green spaces - Home ownership (grass only) Biodiversity on private lands was found to be negatively influenced by population density. New houses have little vegetation cover, reaching a peak at around 46 years old, then declining again, reaching zero vegetation cover at 89 years old. Yard expenditures vary positively with income, home value, median age of resident, average household size, percent owner occupancy and percent single-family detached homes. African Americans are less likely to spend money on planting and yard maintenance but tend to live in neighbourhoods with higher than average private vegetation.	There is a potential for developing marketing and communication strategies to address different lifestyle groups' preferences and motivations for various environmental behaviours.

Overview of the excluded studies

Table 8 in the appendix lists the studies excluded from this review after full-text screening, alongside the reasons for exclusion. Five of the studies were excluded as they discussed conservation strategies in rural settings. Although this was not explicitly stated in the abstract or research methods, the incentive mechanisms for biodiversity conservation discussed in the articles were clearly targeted at larger land parcels, and often productive ones used for agriculture. Another three studies were excluded as they were either out of scope or their findings were too context specific, not being applicable to Australia. Finally, the article by Haaland (2015) was excluded as it focused on public green spaces, while acknowledging that private gardens form an important contribution to cities' biodiversity.

Quality, risk of bias and confidence in cumulative evidence

Table 5 summarises the quality and risk of bias assessment of included systematic reviews and meta-analyses, with more details provided in Table 10 in the appendix. Overall, the included reviews were of low quality, the majority not being reviews but based primarily on empirical evidence. The majority of articles did not provide sufficient detail on their search strings, keywords or databases searched. Article selection criteria were also missing. Only one study, which was also the only systematic literature review (Cerra_2017), stated the keywords, databases used and selection criteria employed. Risk of bias within the articles reviewed was also high, and two articles did not declare funding for their research. This suggests that there is scope for improving how the methodologies and outcomes of systematic and narrative literature reviews are reported.

Table 5 Quality Scores (QS) and Risk of Bias (RoB) summaries for the included studies.

QS values: A – minimal flaws, B – some flaws, C – major flaws in many aspects of the review (most likely due to poor reporting or the review not being a full systematic review of evidence). Risk of Bias (RoB) values: low, medium, high – refer to the risk of bias of the conclusions of the review.

First Author _year	Title	QS	RoB	Comments
Black_2017	Using residents' attitudes, knowledge and behaviours to improve biodiversity conservation in an Australian rural–urban landscape	C	High	Primarily empirical research, not a review, study does not state search strings or how articles were selected. Funding not acknowledged, no reported conflict of interest.
Cerra_2017	Emerging strategies for voluntary urban ecological stewardship on private property	B	High	States keywords, databases and selection criteria. Funding not acknowledged
Goddard_2010	Scaling up from gardens: biodiversity conservation in urban environments	C	High	Study does not state search strings, keywords or how articles were selected. Funding acknowledged
Grove_2006	Characterization of Households and its Implications for the Vegetation of Urban Ecosystems	C	High	Primarily empirical research, does not state search strings, keywords or how articles were selected. Funding acknowledged
Lowry_2012	Determinants of urban tree canopy in residential neighborhoods: Household characteristics, urban form, and the geophysical landscape	C	High	Primarily empirical research, does not state search strings, keywords or how articles were selected. Funding acknowledged
Troy_2007	Predicting Opportunities for Greening and Patterns of Vegetation on Private Urban Lands	C	High	Primarily empirical research, does not state search strings, keywords or how articles were selected. Funding acknowledged

Review Limitations

The literature search was not fully comprehensive and some relevant papers may have been missed. Only peer-reviewed studies published in English were included. Although this rapid review originally intended to focus on a review of systematic literature reviews or meta-analysis, the literature on the topic of interest – biodiversity conservation in private urban lands - was found to be very limited. An attempt to capture important studies that may have been missed was carried out through an additional search using Google Scholar. However, no additional reviews or literature reviews were found. This limitation resulted in the researchers expanding the scope to include relevant empirical studies in the databases that did not return any reviews (ProQuest and Google Scholar). These supplementary articles yielded additional insights but pose a risk of bias.

Summary and conclusions

The purpose of this rapid review was to locate and summarise published peer-reviewed academic articles that contributed to answering the question 'How can urban development support biodiversity retention on private land?'

A search string covering the topic in question was devised and applied to three scholarly databases as well as Google Scholar, identifying 274 original articles. After a screening process and evaluation of articles against a list of criteria, six papers consisting of two reviews and four empirical studies were selected for inclusion in this rapid review. The limited number of available reviews, which may have also suffered from methodological problems and potential biases, as well as the inclusion of empirical articles, may limit the extent to which robust conclusions can be drawn.

The articles included in this rapid review were published between 2006 and 2017 and reported findings based on studies from Australia, Brazil, Japan and the USA. All articles discussed strategies to promote biodiversity in private areas, but only one study had this topic as its central theme. Other identified themes were: the analysis of the interconnectedness of green areas at different city scales for an integrative approach to increasing urban biodiversity; the identification of residents' behaviours and attitudes toward biodiversity as a manner of informing conservation programs; and the understanding of how household characteristics affect biodiversity in residential properties.

This rapid review identified that incentives for biodiversity in urban private properties can be from a top-down (*i.e.* driven by government) or a bottom-up (*i.e.* driven by individuals) nature. Most common incentives include:

- Indirect financial incentives through tax reductions, government grants, subsidies, fee credit or development rights.
- Payment for Ecosystem Services, consisting of payment made in cash or in-kind, to the owner of an ecosystem asset in exchange for its preservation.

- Market-based certifications, formally recognizing that a development meets certain biodiversity standards.
- Community-based initiatives, including the engagement of private owners to manage and monitor their land to support biodiversity.

Whilst these voluntary incentives are considered effective to encourage biodiversity in private urban properties, it is recommended that they are integrated with wider conservation efforts to maximise connectivity between habitats. Moreover, household characteristics and individual behaviours have been shown to correlate with the amount of biodiversity in private properties. Factors such as lifestyle behaviour, income, household size, marriage status, density, residents age, education level, home ownership and house age, all influence the likelihood of residents to invest in garden maintenance and value biodiversity.

With these considerations on board, it is recommended that strategies to enhance biodiversity on private lands include the following measures:

- New developments should spatially arrange private gardens and green public spaces to maximise total habitat patch area.
- Biodiversity conservation at a city level should include private gardens and promote habitat heterogeneity.
- Householders and stakeholders operating at different scales should be given different tailored, but complementary, gardening advice.
- Residents should be given education and support to get involved in community and city-scale schemes.
- Marketing and communication strategies for households should be tailored and targeted at different groups, considering specific lifestyle behaviours, demographics, and motivations.

In summary, in order to support and maximise biodiversity on private lands, urban developments need to coordinate efforts at a wider city-scale, promoting habitat connection and garden heterogeneity; provide households with adequate education and support; and develop incentive strategies that align with specific household characteristics and lifestyle. As a next step, it is recommended that these solutions are developed and tested in collaboration with new residential communities.

Gen Y Demonstration House: garden integrating property and streetscape spaces (photo by Rob Frith)

Resources, workload and timeline
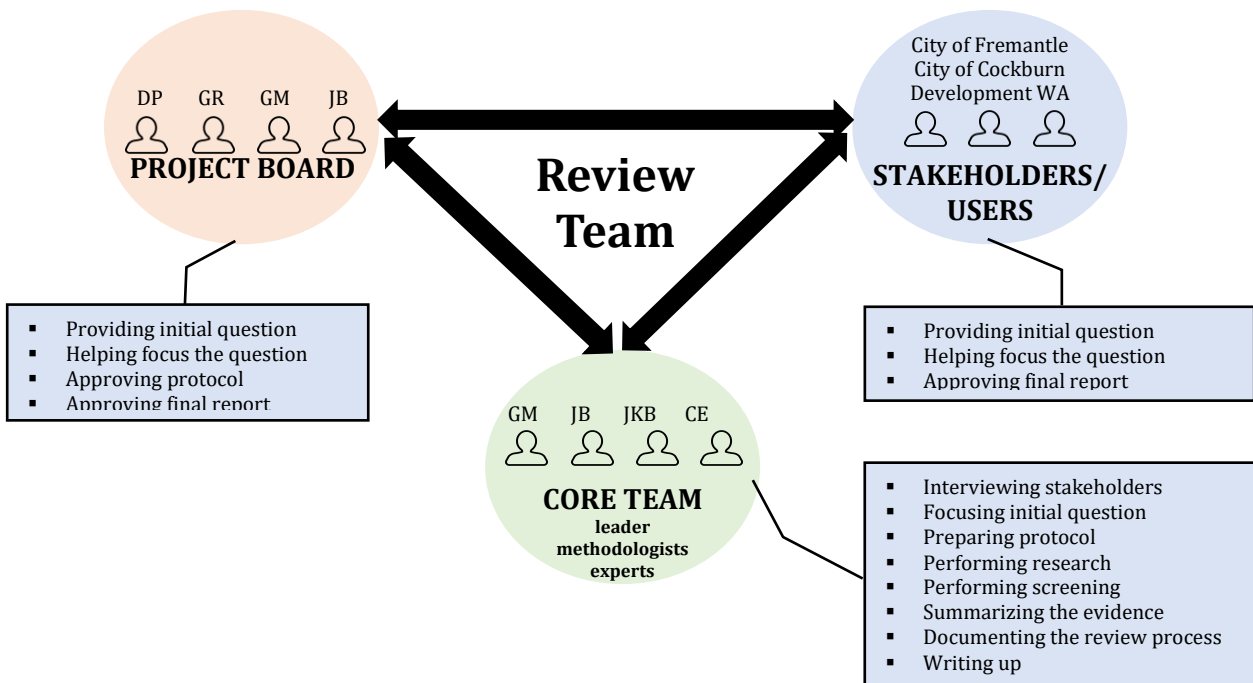
Figure 2 Review team members

Table 6 Review timeline.

Note: this rapid review project ran in conjunction with another, the first 3 activities were undertaken at the same time, with the final 4 undertaken separately, hence the gap in activities between January and April 2020.

Activity	November 2019 (19/11/19)	December 2019	January 2020	April 2020	May 2020	June 2020
Team formation	■					
Question refinement	■	■	■			
Protocol preparation			■			
Search and screening				■		
Data extraction					■	
Synthesis/report					■	■
Approvals/Revisions						■

Table 7 Workloads (in hours) of the team members for each main review stage.

Review Stage	GM	JB	JKB	CE	Total	Comments
Team formation	2	1			3	Shared with buildings RR
Question refinement	2	2	10	4	18	Shared with buildings RR
Protocol preparation	1	1	8		10	
Search and screening			10	20	30	
Data extraction			10	20	30	
Synthesis / Report	3	3	10	40	56	
Total	8	7	73	59	147	hours

Supplementary Information

Table 8 Table of the excluded studies at the full-text eligibility stage

First Author_year	Full reference	Reason for exclusion
Cooke_2012	Cooke, B., Langford, W. T., Gordon, A. & Bekessy, S. Social context and the role of collaborative policy making for private land conservation. Journal of Environmental Planning and Management 55, 469-485, doi:10.1080/09640568.2011.608549 (2012).	The review focuses on private land in rural settings
Giannini_2014	Giannini, H. C. & Heinen, J. T. Miami-Dade County's Environmentally Endangered Lands covenant program: Creating protected areas on private lands via financial incentives. Natural Areas Journal 34, 338-345, doi:10.3375/043.034.0308 (2014).	The review focuses on private land in rural settings
Haaland_2015	Haaland, C. & van den Bosch, C. K. Challenges and strategies for urban green-space planning in cities undergoing densification: A review. Urban For. Urban Green. 14, 760-771, doi:10.1016/j.ufug.2015.07.009 (2015).	Focus is on public spaces.
Hungerford_2017	Hungerford, H. & Moussa, Y. Seeing the (urban) forest through the trees: governance and household trees in Niamey, Niger. African Geographical Review 36, 286-304, doi:10.1080/19376812.2016.1226909 (2017).	Article reports the diversity of trees found in private gardens and use that occupants have for them. This is out of the scope for this research.
Mayer_2012	Mayer, A. L. et al. Building green infrastructure via citizen participation: A six-year study in the Shepherd Creek (Ohio). Environmental Practice 14, 57-67, doi:10.1017/S1466046611000494 (2012).	The case study discusses the adoption of green infrastructure in gardens to increase water infiltration. The article discussion and conclusions are outside the scope of this review.
Parkhurst_2003	Parkhurst, G. M. & Shogren, J. F. Evaluating incentive mechanisms for conserving habitat. Nat. Resour. J. 43, 1093-1149 (2003).	The review focuses on private land in rural settings
Rawat_2017	Rawat, Y. S. Sustainable biodiversity stewardship and inclusive development in South Africa: a novel package for a sustainable future. Current Opinion in Environmental Sustainability 24, 89-95, doi:10.1016/j.cosust.2017.03.003 (2017).	The review focuses on private land in rural settings
Schottker_2019	Schöttker, O. & Maria João, S. Easement or public land? An economic analysis of different ownership modes for nature conservation measures in California. Conservation Letters 12 (2019).	Focus is on private lands in rural settings
Shackleton_2014	Shackleton, C. M. et al. Low-cost housing developments in South Africa miss the opportunities for household level urban greening. Land Use Policy 36, 500-509, doi:https://doi.org/10.1016/j.landusepol.2013.10.002 (2014).	The article is very context specific, relating tree cover to local history and culture. Findings are not applicable to the Australian context.

Table 9 Quality assessment tool.

A modified AMSTAR [12, 13] and AMSTAR-2 [9] checklists, used to asses quality and risk of bias of individual systematic reviews / meta-analyses included in this meta-review.

Question (recommendations)	Decision rules and comments
Q1. Are the research questions and inclusion criteria for the review clearly delineated?	1 = "Yes" = Who (Population/Subject), What (Intervention, Comparator group, Outcome), Where and When described.
	0.5 = "Can't answer / not sure / partially" = Cannot decide between "yes" and "no", basing on the information provided in the paper.
	0 = "No" = research question and inclusion criteria not outlined in detail.
Q2. Did the report of the review contain an explicit statement that the review methods were established prior to the conduct of the review and did the report justify any significant deviations from the protocol?	1 = "Yes" = The authors state that they had a written protocol or guide that included ALL the following: review question(s), a search strategy, inclusion/exclusion criteria, risk of bias assessment.
	0.5 = "Can't answer / not sure / partially" = The authors state that they had a written protocol or guide that included ALL the following: review question(s), a search strategy, inclusion/exclusion criteria, a risk of bias assessment.
	0 = "No" = no mention of *a priori* design of the systematic review, as listed above.
Q3. Did the review authors explain their selection of the study designs for inclusion in the review?	1 = "Yes" = explicit justification of the study designs/types included in the review.
	0.5 = "Can't answer / not sure / partially" = more than one online source but no supplementary sources or one online source and one supplementary source. Cannot decide between "yes" and "no", basing on the information provided in the paper.
	0 = "No" = only one online source or no supplementary search used
Q4. Did the review authors use a comprehensive literature search strategy?	1 = "Yes" = searched at least 2 databases (relevant to research question), provided key word and/or search strategy, justified publication restrictions (e.g. language), AND searched the reference lists / bibliographies of included studies, searched trial/study registries, included/consulted content experts in the field, where relevant, searched for grey literature, conducted search within 24 months of completion of the review.
	0.5 = "Can't answer / not sure / partially" = searched at least 2 databases (relevant to research question), provided key word and/or general search strategy, justified publication restrictions (e.g., language).
	0 = "No" = no information on search strategy, or not fulfilling criteria for "Yes" and "Partially".
Q5. Did the review authors perform study selection in duplicate?	1 = "Yes" = either ONE of the following: at least two reviewers independently agreed on selection of eligible studies and achieved consensus on which studies to include OR two reviewers selected a sample of eligible studies and achieved good agreement (at least 80%), with the remainder selected by one reviewer.
	0.5 = "Can't answer / not sure / partially" = Cannot decide between "yes" and "no", basing on the information provided in the paper.
	0 = "No" = only one reviewer involved in the study selection or no description how many reviewers participated in study selection.
Q6. Did the review authors perform data extraction in duplicate?	1 = "Yes" = either ONE of the following: at least two reviewers achieved consensus on which data to extract from included studies OR two reviewers extracted data from a sample of eligible studies and achieved good agreement (at least 8 %), with the remainder extracted by one reviewer.
	0.5 = "Can't answer / not sure / partially" = Cannot decide between "yes" and "no", basing on the information provided in the paper.

	0 = "No" = only one reviewer involved in the study selection or no description how many reviewers participated in data extraction.
Q7. Did the review authors provide a list of excluded studies and justify the exclusions?	1 = "Yes" = provided a list of all potentially relevant studies that were read in full-text form but excluded from the review AND justified the exclusion from the review of each potentially relevant study.
	0.5 = "Can't answer / not sure / partially" = only provided a list of all potentially relevant studies that were read in full-text form but excluded from the review, but not justified the exclusion from the review of each potentially relevant study that were read in full-text.
	0 = "No" = No list of studies excluded at a full-text stage.
Q8. Did the review authors describe the included studies in adequate detail?	1 = "Yes" = ALL the following: Who (Population), What (Intervention, Comparator group, Outcome), Where and When described in detail..
	0.5 = "Can't answer / not sure / partially" = Who (Population), What (Intervention, Comparator group, Outcome), Where and When briefly described, or only some of these described in detail. Cannot decide between "yes" and "no", basing on the information provided in the paper.
	0 = "No" = no, or partial description of the included studies
Q9. Did the review authors use a satisfactory technique for assessing the risk of bias (RoB) in individual studies that were included in the review?	1 = "Yes" = specifically mentions RoB assessment of individual included studies.
	0.5 = "Can't answer / not sure / partially" = Cannot decide between "yes" and "no", basing on the information provided in the paper. RoB mentioned or not sufficiently assessed (e.g. if multiple sources of bias potentially present, but not all assessed).
	0 = "No" = no mention of RoB assessment of individual included studies.
	[RoB sources: from confounding, from selection bias, from exposure bias, from selective reporting of outcomes, selection of the reported result from among multiple measurements or analyses of a specified outcome].
Q10. Did the review authors report on the sources of funding for the studies included in the review?	1 = "Yes" = Must have reported on the sources of funding for individual studies included in the review. Note: Stating that the reviewers looked for this information but it was not reported by study authors, also qualifies.
	0.5 = "Can't answer / not sure / partially" = sources of funding mentioned for individual studies included in the review, or reported only for some of the included studies. Cannot decide between "yes" and "no", basing on the information provided in the paper.
	0 = "No" = no report of the sources of funding for individual studies included in the review.
Q11. If meta-analysis was performed did the review authors use appropriate methods for statistical combination of results?	1 = "Yes" = The authors justified combining the data in a meta-analysis AND they used an appropriate technique to combine study results and adjusted for heterogeneity if present *AND* investigated the causes of any heterogeneity or adjusted for heterogeneity or confounding if present.
	0.5 = "Can't answer / not sure / partially" = Requirements for "Yes" only partially fulfilled. Cannot decide between "yes" and "no", basing on the information provided in the paper.
	0 = "No" = no justification of meta-analysis or inappropriate statistical methods were used for quantitatively combining and analysing the data, heterogeneity not assessed.
	N/A = "Not Applicable" = No meta-analysis conducted.
Q12. If meta-analysis was performed, did the review authors assess the potential impact of RoB in individual studies on the	1 = "Yes" = included only low risk of bias studies OR the authors performed analyses to investigate possible impact of RoB on summary estimates of effect.

results of the meta-analysis or other evidence synthesis?	0.5 = "Can't answer / not sure / partially" = Cannot decide between "yes" and "no", basing on the information provided in the paper.
	0 = "No" = no assessment of the potential impact of RoB.
	N/A = "Not Applicable" = No meta-analysis conducted.
Q13. Did the review authors account for RoB in individual studies when interpreting/ discussing the results of the review?	1 = "Yes" = included only low risk of bias studies OR the review provided a discussion of the likely impact of RoB on the results.
	0.5 = "Can't answer / not sure / partially" = Cannot decide between "yes" and "no", basing on the information provided in the paper.
	0 = "No" = no discussion of the potential impact of RoB in individual studies.
Q14. Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review?	1 = "Yes" = There was no significant heterogeneity in the results OR if heterogeneity was present the authors performed an investigation of sources of any heterogeneity in the results and discussed the impact of this on the results of the review.
	0.5 = "Can't answer / not sure / partially" = Cannot decide between "yes" and "no", basing on the information provided in the paper.
	0 = "No" = No explanation or discussion of heterogeneity present in the results.
Q15. If they performed quantitative synthesis did the review authors carry out an adequate investigation of publication bias (small study bias) and discuss its likely impact on the results of the review?	1 = "Yes" = The authors performed graphical or statistical tests for publication bias and discussed the likelihood and magnitude of impact of publication bias.
	0.5 = "Can't answer / not sure / partially" = more than one online source but no supplementary sources or one online source and one supplementary source. Cannot decide between "yes" and "no", basing on the information provided in the paper.
	0 = "No" = The authors did not perform any tests for publication bias and did not discuss potential impact of publication bias.
	N/A = "Not Applicable" = No meta-analysis conducted.
Q16. Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?	1 = "Yes" = The authors reported no competing interests OR the authors described their funding sources and how they managed potential conflicts of interest.
	0.5 = "Can't answer / not sure / partially" = Cannot decide between "yes" and "no", basing on the information provided in the paper.
	0 = "No" = The authors did not provide statement on competing interests and funding sources, and how they managed potential conflicts of interest.

Table 10 Responses to quality assessment questions from Table 9 coded for each of the included studies.

The responses to each question were coded numerically and color-coded as following: green = 1 = "Yes"; yellow = 0.5 = "Can't answer / not sure / partially", red = 0 = "No", grey = N/A = "Not Applicable".

First Author _year	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16
Black_2017	1	0	0	0	0	0	0	1	0	0	NA	NA	0	1	NA	0.5
Cerra_2017	1	0.5	1	1	0	0	0	1	0	0	NA	NA	0	1	NA	0
Goddard_2010	0.5	0	0	0	0	0	0	1	0	0	NA	NA	0	1	NA	1
Grove_2006	0.5	0	0	0	0	0	0	1	0	0	NA	NA	0	1	NA	1
Lowry_2012	0.5	0	0	0	0	0	0	1	0	0	NA	NA	0	1	NA	1
Troy_2007	0.5	0	0	0	0	0	0	1	0	0	NA	NA	0	1	NA	1

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