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REVIEW

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Feeding ecology of Australian Christmas beetles (Coleoptera: Scarabaeidae: Rutelinae): Implications for conservation and habitat management

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Abstract

Christmas beetles (subfamily Rutelinae, genera *Anoplognathus*, *Calloodes* and *Repsimus*) are an ecologically important and culturally significant group of Australian scarabs, known for their striking appearance and seasonal mass emergences. Over the last decade, anecdotal reports suggest widespread population declines, raising concerns about their conservation status. Despite their prominence in Australian ecosystems, critical deficits remain in our understanding of their biology, particularly regarding their feeding ecology and larval habitat requirements. We reviewed available literature regarding adult and larval Christmas beetle feeding ecology, particularly feeding preferences, host plants and food finding behaviours. Our literature review found significant gaps in our knowledge of Christmas beetle feeding ecology: adult host plant association data were available for only 25 of the 44 described species of Christmas beetles. For larvae, our literature search identified feeding ecology information for only nine species. With the exception of a single study, all data regarding larval feeding came from observational studies rather than feeding trials. Notably, the only feeding trial we found failed to identify the larvae to species, significantly limiting the applicability of its findings. The limited information identified in this review highlights the urgent need for targeted research into the feeding ecology of Christmas beetles. The scarcity of data on larval feeding, in particular, limits our ability to determine how changes in land use, soil conditions, and plant communities impact their populations. Future studies incorporating feeding trials, long-term field observations, and experimental approaches will be critical for better understanding Christmas beetle ecology, especially for assessing their ecological roles, identifying key habitats, and developing effective conservation strategies where needed. Given the increasing concerns over Christmas beetle declines, prioritising research on their habitat requirements and resource use will help to ensure the conservation of these iconic Australian insects.

KEYWORDS

Anoplognathus, *Calloodes*, food source, foraging, herbivory, *Repsimus*

INTRODUCTION

Understanding what insects eat, where they feed, and how these dietary preferences shape their life history is essential for effective management in both conservation and pest control contexts. This knowledge is particularly relevant for Australian Christmas beetles, a culturally significant and ecologically important group of scarab beetles native to Australia. Much beloved by the Australian public (Schroeder et al., in prep), the Christmas beetle has inspired plays (Legs on the Wall 2023), children's books (Bunting & Johnston 2023; Houghton 2023), and extensive media attention (Appendix 1).

Known for their large size, iridescent sheen, and dramatic mass emergence during the austral summer, Christmas beetles are an iconic feature of Australian summers. Their seasonal appearance, closely tied to the festive Christmas period, has earned them the common name 'Christmas beetles'. This common name is generally applied to the genus *Anoplognathus* Leach and has occasionally been extended to all species of Australian ruteline beetles (McKeown 1942), although in Tasmania it is used for the stag beetle (Lucanidae) *Lamprima aurata* Latreille (Grove 2023). Here, we use 'Christmas beetles' to refer to species within the genera *Anoplognathus*, *Calloodes* White, and *Repsimus* MacLeay. Recent phylogenetic analyses suggest that *Calloodes* and *Repsimus* may be embedded within *Anoplognathus* sensu lato or are sister taxa (Ospina-Rozo et al. 2024). At present, 38 species of *Anoplognathus*, including three subspecies, four species of *Calloodes*, and two species of *Repsimus*, including two subspecies, are described (ABRS 2025). There have been two recent studies of type material in European collections showing that some common species were misidentified by Carne (1957) resulting in confusion of names (Seidel, Matsumoto, & Reid 2023; Seidel & Reid 2021). For this review, we have appropriately adjusted names from earlier literature.

The adults of Christmas beetles may be important food for vertebrates as their mass emergence in early summer may provide vital nutrient pulses during the development of young, such as nestlings. Several native vertebrates such as sugar gliders (*Petaurus breviceps*) (Smith 1982), boobook owls (*Ninox boobook*) (Rose 1973), currawong (*Strepera graculina*) (Farrow 2016), and monitor lizards (*Varanus panoptes*) (Ward-Fear, Shine, & Brown 2020) are known to feed on Christmas beetles as a seasonal food source. Fox (*Vulpes vulpes*), an exotic species, is also recorded feeding on *Anoplognathus* adults (Farrow 2016).

The first revisions of the Christmas beetles (Carne 1957, 1958) were largely in response to their perceived pest status. An online revision of the New South Wales *Anoplognathus* was later developed as an educational tool (Reid & Smith 2002) and it is only in recent years that public interest in Christmas beetles has surged, driven by widespread concerns about their apparent population declines (e.g. Radford 2025; Smith 2011). This growing awareness has spurred initiatives such as a smartphone app for identification of the Australian *Anoplognathus* (Burleigh & Reid 2017), and the popular 'Christmas Beetle Count,' a citizen science project encouraging people to document sightings of Christmas beetles, which at the time of writing (June 2025) has involved over 9000 people contributing 22 000 observations for 39 species ('Christmas Beetle Count' 2025).

Despite their popularity, the ecology of Christmas beetles is surprisingly poorly known. Adult Christmas beetles are generally known to feed on *Eucalyptus* leaves, while the larvae reside and likely feed in the soil (Carne 1957). However, data on the specifics of their dietary breadth, including species-specific preferences for host plant species or soil conditions, are scattered across a fragmented body of literature. In this review, we bring together current knowledge on the feeding habits of Christmas beetles, emphasising key unanswered questions to help direct future research efforts.

METHODS

We searched Web of Science, Google Scholar, Biodiversity Heritage Library (BHL) and TROVE (Newspapers & Gazettes) for the key words 'Anoplognathus' OR 'Calloodes' OR 'Repsimus'. Since Google Scholar searches for keywords anywhere in the document, it typically returns a large volume of publications, the majority of which are irrelevant. Consequently, we only examined the first 15 pages of Google Scholar references, as we found that relevance to the search terms decreased dramatically after 10 pages.

We searched for papers that discussed the feeding ecology of either larval or adult Christmas beetles, including feeding trials, observations of feeding, and sensory ecology related to host finding. We also searched each paper for any additional references. We excluded papers that did not reference feeding behaviours of either adults or larvae.

As Christmas beetle larvae feed underground, researchers have relied on various methods to study their feeding habits, ranging from simple correlations between larvae and specific host plants to well-controlled feeding trials. To assess the reliability of these findings, we categorised the studies based on the quality of their evidence, classifying them as anecdotal, observational, associational, feeding trials, or rearing. Data were classified as 'feeding trials' if they involved experimental procedures in which larvae were offered different food types to assess dietary preferences or suitability; 'associational' if the report was based on associations between a food type/habitat and insect abundance (eg. high numbers beneath sugar cane fields); 'observational' if the data were based on observations of the animal feeding on a particular food source; and 'rearing' if the study involved rearing larvae to adulthood for purposes other than explicit feeding trials (typically to identify beetle species or as part of another experiment). Data were classified as 'anecdotal' when the basis of the finding was unclear or not well-documented. This category was frequently used in agricultural reports, where insects were described as being 'pests' of a crop, without further detail about how the assessment of pest status was made.

RESULTS

Our initial search yielded a total of 1020 papers: 31 from Web of Science, 3 from the Biodiversity Heritage Library (BHL), 119 from TROVE, and 867 from Google Scholar.

After our screening process, 45 papers were deemed relevant and included in our final literature review. The majority of studies were excluded because they lacked any mention of feeding or feeding behaviours in Christmas beetles and focused instead on other aspects of their biology, such as taxonomy, evolution, or colouration.

Larval feeding

Christmas beetle larvae typically reside in soil where they feed on organic matter. This is generally assumed to include plant roots although *Anoplognathus montanus* Macleay has been observed feeding on the undersurface of rotting logs (Table 1). Preference for soil types also varies; for example, *Repsimus* larvae have been found in the sand of dried riverbeds (Dodd 1917), unlike other known larvae. In general, the exact feeding habits of most Christmas beetle larvae remain unclear, with some researchers suggesting that they feed primarily on plant roots, while others propose they consume mostly decaying organic matter.

Evidence for root feeding by *Anoplognathus* larvae primarily comes from associational studies, which have observed high densities of larvae in areas under agricultural production. A survey of sugar cane fields found high numbers of *A. porosus* (Dalman) and *A. boisduvalii* Boisduval (and to a lesser extent*, A. aureus* Waterhouse) in the soil beneath sugar cane fields in the Atherton Tablelands (far north Queensland). The sugar cane plants had symptoms of damage from root feeding (Sallam et al. 2011). The authors concluded that *A. porosus* and *A. boisduvalii* weaken cane plants over time by feeding on their roots. However, *Anoplognathus* larvae were found with other scarab larvae, including noted cane pest the greyback cane beetle (*Dermolepida albohirtum* [Waterhouse]) (Chandler & Jennings 2015). It is therefore unclear whether *Anoplognathus* were responsible for the observed plant damage in that study. A review of unpublished field trials of 'single species infestations' of *A. porosus* larvae in sugar cane plantations found evidence that beetle larvae fed on root hairs initially, before consuming entire root masses (Chandler & Jennings 2015).

TABLE 1 Food sources and soil associations for Christmas beetle larvae. Only studies that contain species-level identification are included.

Species	Food source	Type of data	Reference
Anoplognathus boisduvalii Boisduval	Decaying matter	Anecdotal	Illingworth & Dodd 1921
	Sugarcane field following ploughing	Collection	Dodd 1917 Cumpston 1941
	Germinated lawn seed	Rearing	Sallam et al. 2011
Anoplognathus montanus Macleay	Rotting wood	Associational/ observational	Carne 1957
	Natural pasture	Associational	
	Grass roots	Anecdotal	
	Leaf mould	Anecdotal	
	Surface roots of *Eucalyptus*	Anecdotal	
Anoplognathus parvulus Waterhouse	Sugarcane roots	Observation and rearing	Burns 1929
Anoplognathus porosus (Dalman)	Strawberry roots	Anecdotal	Murray 1980
	Potato roots	Anecdotal	Goodyer 1985
	Sugar cane roots	Associational	Chandler & Jennings 2015; Sallam et al. 2011
	Organic matter	Rearing	Carne, Greaves, & McInnes 1974
	Germinated lawn seed	Rearing	Sallam et al. 2011
	Perennial rye grass	Rearing	Hassan 1975
Anoplognathus punctulatus Olliff	Grass roots of native Australian Poaceae sp	Observation	Dodd 1917
	Roots of *Imperata* grass	Observation	
Anoplognathus viriditarsis Leach	Strawberry roots; humus	Anecdotal	Murray 1980; Froggatt 1915
Calloodes atkinsoni Waterhouse & *C. grayianus* White	Found in dry sandy river bed	Observation	Girault & Dodd 1915
Repsimus aeneus (Fabricius)	Found in alluvial sand loams and in pure sand	Observation	Dodd 1917
	Sugarcane field following ploughing, soil containing sugar-refuse manure	Observation	

Plough sampling in eucalypt plantations and pastures revealed that *A. porosus* and *A. brunnipennis* (Gyllenhal) were most abundant in grazed pastures and in new eucalypt plantations established on former pastureland (Carne, Greaves, & McInnes 1974). In contrast, they were least abundant in older plantations dominated by woody perennials rather than grasses (Carne, Greaves, & McInnes 1974). Within older plantations, *Anoplognathus* larvae were more likely to be found in grassy clearings at plantation margins. This distribution pattern suggests a potential association with grasses; however, these associations do not necessarily indicate that the larvae are directly feeding on grass roots as association patterns could also be driven by soil composition, temperature, or other environmental differences.

Anoplognathus larvae may occasionally feed on the roots of exotic crop plants, causing losses. *Anoplognathus porosus* has been reported to cause 'occasional losses' to strawberry plants by feeding on roots (Murray 1980), as has *A. viriditarsis* Leach (Froggatt 1915). Murray (1980) noted that young *A. porosus* larvae initially consume organic matter in the soil but later feed on strawberry roots in late spring, causing wilting and 'complete root destruction' of the plants. However, the source of this information is unclear, as the report primarily summarised the life cycles and feeding behaviours of various strawberry pests and did not provide detailed descriptions of how the insects were studied. Goodyer (1985) also listed improved pastures and potatoes as host plants for *A. porosus* larvae, although the information was not based on original observations (Goodyer pers. com., March 2025).

Indirect studies of feeding ecology have examined the impact of livestock grazing on larval beetles. Grazing pressure led to increased *Anoplognathus* biomass at intermediate pressures, followed by steep declines as grazing pressure increased (Roberts & Morton 1985). Some degree of grazing may be beneficial to Christmas beetle larvae because it increases the root biomass, soil organic carbon, microbial biomass, and root exudates (Wilson et al. 2018).

Some Christmas beetle larvae have been reared to adulthood in captivity. For example, larvae of *A. porosus* and *A. boisduvalii* were reared to adulthood on a diet of 'germinated lawn seeds' (Sallam et al. 2011). Hassan (1975) successfully reared *A. porosus* on soil seeded with perennial rye grass (*Lolium perenne*). Since these were informal feeding trials, it is unclear whether larval growth and health were enhanced by the presence of plant roots or if the beetles simply consumed them as a supplement to a diet of organic matter found in the soil.

While most research on the feeding habits of Christmas beetle larvae focused on their potential to damage crops through root feeding, some authors suggested that several Christmas beetle species feed primarily on organic matter. Carne (1957) stated that *A. montanus* feeds on rotting wood and can be found under old rotten logs. The same species is also described as occurring under natural pasture where it may feed on 'soil organic matter, grass roots, leaf mould, or the finer surface roots of eucalypts' (Carne 1957). *Anoplognathus boisduvalii is* described as having a 'particular penchant for piles of trash, decaying rubbish in general, and even half-sandy vegetable-refuse heaps' (Illingworth & Dodd 1921). Interestingly, Carne, Greaves, & McInnes (1974) reported that *A. porosus* and *A. brunnipennis* feed primarily on organic matter in soil and rarely 'seek out' plant roots, but it is unclear how this conclusion was reached.

Our search only found a single controlled feeding trial (Davidson & Roberts 1968). These authors tested the growth and survivorship of unidentified *Anoplognathus* larvae in pots containing *Trifolium repens, L. perenne, Phalaris tuberosa*, or *Dactylis glomerata*. Factorial treatments included combinations of each plant species with 4% manure (or no manure) and 4 moisture levels. Larval growth and survivorship were higher on treatments amended with manure than on those containing plants alone, suggesting that larvae are primarily feeding on decaying organic matter rather than plant roots. Larvae did not gain weight and had low survivorship when kept in pots planted with *T. repens*; in fact, the larvae in the *Trifolium* treatment performed worse than the 'no plant' treatment containing only soil. Larval growth in pots growing *P. tuberosa* was also strongly depressed, with 4/9 larvae failing to pupate compared with a 100% pupation rate in most treatments, including the 'no plant' treatment. Larvae achieved the highest weight gain on a mixture of cow manure and soil planted with perennial ryegrass (*L. perenne*).

Plants grown in pots containing manure suffered negligible root damage, suggesting that larvae preferred to feed on decaying organic matter and turned to root feeding as a supplement rather than as a primary diet (Davidson & Roberts 1968). Alternatively, the authors suggest that the manure could have increased root growth such that root feeding larvae caused negligible damage. These results suggest that the *Anoplognathus* larvae were primarily feeding on organic matter within soil with plant root feeding as a supplement, as evidenced by the high survivorship in the 'no plant' treatments. Furthermore, they suggest that the presence of some plants (for example, *Trifolium*, an exotic genus common in Australian pastures) can depress larval growth. While these findings provide insight into the feeding ecology of *Anoplognathus* larvae, the fact that larvae were not identified to species diminishes the wider applicability of this study.

In summary, there is associational evidence suggesting that some *Anoplognathus* species may feed on plant roots. However, it remains unclear whether roots serve as the primary food source or are supplemental to a diet primarily based on decaying organic matter. Existing feeding trials indicate that roots may not constitute the main diet, but the absence of species-specific identification in these studies limits their reliability and applicability.

Adult feeding ecology

Most adult Christmas beetles feed primarily on the leaves of *Eucalyptus* trees (Table 2), sometimes causing severe

TABLE 2 Known host adult host plant associations for Australian Christmas beetle species.

Species	Host taxa	Reference
Anoplognathus aureus Waterhouse	*Breynia cernua* *Hibiscus tiliaceus* *Tristemma mauritianum*	Illingworth & Dodd 1921 cited in Carne 1957; Brooks 1948 (as '*Calloodes frenchi* Blackburn')
Anoplognathus boisduvalii Boisduval	*Eucalyptus tereticornis* *Euphorbia platyphylla* *Eucalyptus camaldulensis* *E. resinifera* *Corymbia tessellaris* (*rarely attacked*) *Eucalyptus leptophleba* (*rarely attacked*) *Corymbia* sp. (*attracted to tender post fire leaves*)	Girault & Dodd 1915; Illingworth & Dodd 1921; Jarvis 1929
Anoplognathus brunnipennis (Gyllenhal)	*Eucalyptus dalrympleana* *E. dives* *E. huberiana* *E. grandis* *E. botryoides* *E. globulus* *Eucalyptus fastigata* *E. obliqua* *Eucalyptus regnans* *E. dunni* *Eucalyptus melliodora* *E. conica* *Prunus domestica*[a] *Betula pendula*[a] *Quercus* sp.[a]	Froggatt 1920; Illingworth & Dodd 1921; Carne 1957; Edwards, Wanjura, & Brown 1993; Neumann 1993; Urquhart 1995; Thomson, Nicotra, & Steinbauer 2001; Johns, Stone, & Hughes 2004; Matsuki, Foley, & Floyd 2011
Anoplognathus concolor Burmeister	*Apocissus* sp. ('common on wild grape'; 'native vines & creepers')	Anonymous 1898; Chelba 1935
Anoplognathus daemeli Ohaus	*Commersonia* (Sterculiaceae)	De Baar & Hockey 1987
Anoplognathus explanatus Arrow	*E. botryoides* *E. globulus* *E. grandis* *E. fastigata* *E. obliqua* *E. regnans*	Girault & Dodd 1915; Neumann 1993
Anoplognathus flavipennis Boisduval	*Eugenia* sp.	Carne 1957
Anoplognathus montanus Macleay	*E. rubida* *Eucalyptus blakelyi* *Eucalyptus polyanthemos* *E. platyphylla* *E. melliodora* *Eucalyptus sideroxylon* *E. conica* *E. camaldulensis* *Schinus* sp.[a]	Girault & Dodd 1915; Carne 1957; Edwards, Wanjura, & Brown 1993; Steinbauer & Wanjura 2002
Anoplognathus multiseriatus Lea	Found on leaves *of Banksia serrata*; found in *Banksia aemula* heathland (unclear if feeding was observed)	Carne 1957, 1985; Carne & Monteith 1971; Cassis & Weir 2002
Anoplognathus olivieri (Schönherr & Gyllenhal)	*Eucalyptus* sp. *P. domestica*[a]	Walker 1906; Carne 1957; Cassis & Weir 2002
Anoplognathus pallidicollis Blanchard	*Eucalyptus albens* *E. melliodora* *E. blakelyi* *E. camaldulensis* *E. sideroxylon* *E. rubida* *E. pallida*	Carne 1957; Edwards, Wanjura, & Brown 1993; Wylie & Peters 1993; Steinbauer & Wanjura 2002

(Continues)

TABLE 2 (Continued)

Species	Host taxa	Reference
	E. tereticornis *Schinus* sp.[a]	
Anoplognathus parvulus Waterhouse	*Erythrina vespertilio* Bambusoideae ('bamboo') *Urena lobata*	Burns 1929; Brooks 1969
Anoplognathus porosus (Dalman)	*E. platyphylla* *E. grandis* *E. dunnii* *E. tereticornis* *E. melliodora* *E. sideroxylon* *Schinus* sp.[a]	Walker 1906; Girault & Dodd 1915; Edwards, Wanjura, & Brown 1993; Wylie & Peters 1993; Elliott, Ohmart, & Wylie 1998
Anoplognathus punctulatus Olliff	*Litsea leefeana* *Barringtonia calyptrata* (young leaves) *Myristica insipida* *Persea americana* (fruit)[a]	Illingworth & Dodd 1921; Cassis & Weir 2002
Anoplognathus rhinastus Blanchard	Found in plantation of *Eucalyptus pilularis* and *E. grandis*	Carne & Monteith 1971
Anoplognathus smaragdinus Ohaus	*H. tiliaceus* *Acacia mangium* *Tristemma mauritianum* *Breynia cernua*	Illingworth & Dodd 1921; Brooks 1948; Cassis & Weir 2002
Anoplognathus suturalis Boisduval	*Eucalyptus* sp *Eucalptus ovata*	Carne 1957; Elliott, Ohmart, & Wylie 1998
Anoplognathus velutinus Boisduval	*Eucalyptus* sp.	Walker 1906
Anoplognathus vietor Allsopp & Carne	*Eucalyptus* sp.	Allsopp & Carne 1986
Anoplognathus viridiaeneus (Donovan)	*Eucalyptus* sp. *Syncarpia glomulifera* (flowers)	Ohaus 1904 cited in Carne 1957; Walker 1906
Anoplognathus viriditarsis Leach	*Eucalyptus* spp. *Prunus armeniaca*[a]+	Anonymous 1904; Walker 1906; Froggatt 1915; Carne 1957
Calloodes atkinsoni Waterhouse	*Euphorbia corymbosa*	Illingworth & Dodd 1921
Calloodes grayianus White	*Corymbia* 'gummifera'[a] *Melaleuca* sp.	Girault & Dodd 1915
Repsimus aeneus (Fabricius)	*Corymbia 'gummifera'*[a] *Syzygium tierneyanum* *E. intermedia* *E. tereticornis* *Gaudium laevigatum* *Corymbia torelliana*	Girault & Dodd 1915; Illingworth & Dodd 1921; Hawkeswood & Turner 2002
Repsimus manicatus (Swartz)	*Leptospermum* sp. *Eucalyptus* sp	Walker 1906; Williams 1979

Note: *Eucalyptus corymbosa* is listed as a host plant alongside a '?'. This plant, now *Corymbia gummifera*, does not occur in the known range of *C. grayianus*. It is included in the table for completeness.
[a]Exotic species.

defoliation (Carne 1957; Carne, Greaves, & McInnes 1974). Adult beetles use their long claws to anchor themselves on leaves and begin feeding at the leaf margin in a characteristic zig-zag pattern, eventually leaving the mid rib and the basal portion of the leaf margin as patches of unconsumed leaf area (Figure 1, Carne, Greaves, & McInnes 1974). Adult Christmas beetles are described as 'wasteful feeders' as large amounts of severed leaf matter may fall to the ground during the course of feeding (Carne, Greaves, & McInnes 1974).

As with the larvae, most studies on adult feeding behaviour were motivated by concerns from forestry/agricultural industries, notably *Eucalyptus* plantations (Carne, Greaves, & McInnes 1974; Floyd & Farrell 2007). *Eucalyptus* species varied in their resistance to herbivory by Christmas beetles (Carne, Greaves, & McInnes 1974;

(a) (b) (c)

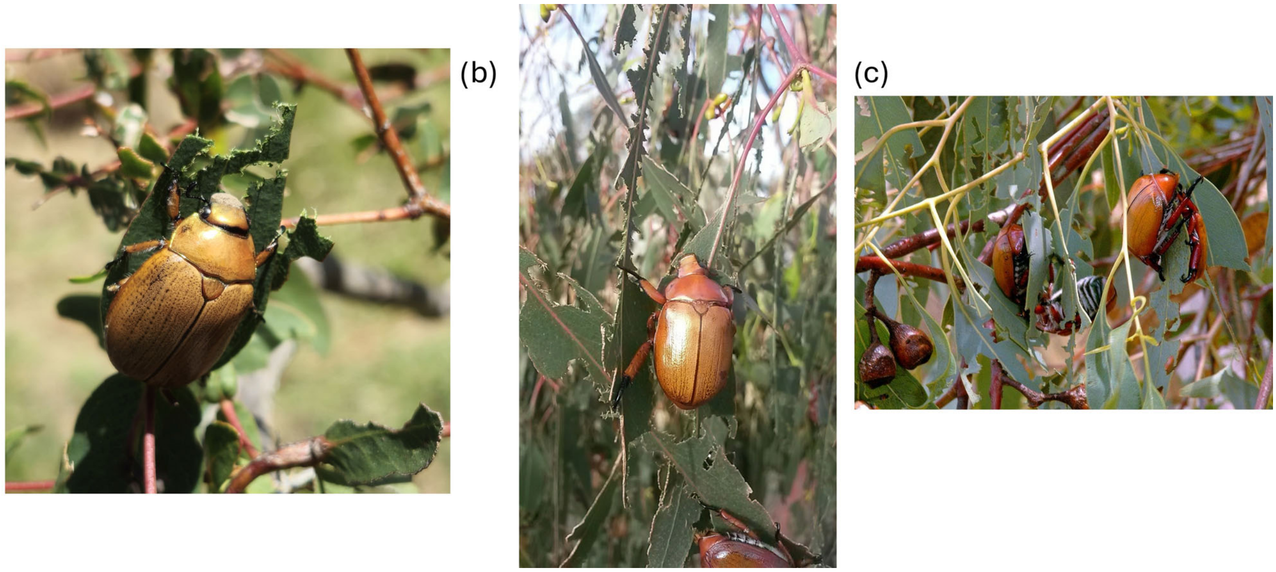

FIGURE 1 Examples of Christmas beetle feeding damage. (a) *Anoplognathus brunnipennis*, photo credit iNaturalist user claudiarose, CC0. (b) *Anoplognathus montanus*, photo credit iNaturalist user claudiarose, CC0. (c) Aggregation of *A. montanus*. Photo credit: iNaturalist user bayshark, CC0.

Floyd & Foley 2001; Johns, Stone, & Hughes 2004; Matsuki, Foley, & Floyd 2011; Shepherd, Chaparro, & Teasdale 2000). For example, *A. porosus* and *A. brunnipennis* preferentially feed on *Eucalyptus grandis*, often ignoring neighbouring eucalypt species (Carne, Greaves, & McInnes 1974).

Individual trees of the same species vary in their palatability to Christmas beetles. In a feeding experiment, individual *Eucalyptus melliodora* and *Eucalyptus sideroxylon* trees were classified as 'resistant', 'intermediate 'or 'susceptible' based on the history of damage from marsupial herbivores. When offered leaves from different tree resistance categories, Christmas beetles (*Anoplognathus brunnipennis, A. explanatus* Arrow, *A. montanus, Acalles pallidicollis* Blanchard, *A. suturalis* Boisduval, and *A. viriditarsis*) preferred leaves from trees classified as susceptible over leaves from trees classified as resistant or intermediate (Matsuki, Foley, & Floyd 2011). These data suggest that the factors that drive palatability for marsupial herbivores are similar to those that shape preferences in Christmas beetles.

Preference for the leaves of particular host trees could be driven by the presence of toxic secondary metabolites. In the above study by Matsuki, Foley, & Floyd (2011), sideroxylonals and 1,8-cineole were negatively correlated with consumption by Christmas beetles such that when concentrations of sideroxylonals and 1,8-cineole were low, beetles tended to consume the entire leaf except the midrib and leaf margins, but when sideroxylonals and 1,8-cineole concentrations were high, beetles either did not feed or took a few small bites along the leaf margins. Additionally, secondary metabolites such as terpenoids can deter herbivorous insects due to their high toxicity. For example, Edwards, Wanjura, & Brown (1993) found that *A. montanus* adults avoided leaves with high levels of terpenoids. Moreover, the presence of terpenoids in the beetles' frass suggested that *A. montanus* lacked mechanisms to detoxify these toxic compounds.

Christmas beetles have been reported to avoid landing on resistant trees, suggesting the involvement of volatile cues (M. Matsuki, personal communication as reported in Floyd & Foley 2001). Electroantennogram studies found that *A. brunnipennis* antennae responded to 1,8-cineole, limonene, α-pinene, p-cymene, and α-phellandrene, supporting the hypothesis that Christmas beetles can assess leaf quality through olfactory cues (F. Schiestl & M. Matsuki, unpublished data as cited in Floyd & Foley 2001).

Other leaf characteristics may also play a role in tree selection. For example, *A. brunnipennis* adults avoided feeding on *E. grandis* leaves that had a high specific leaf weight (a measure of leaf toughness), suggesting that beetles prefer softer leaves (Johns, Stone, & Hughes 2004), although other research suggests feeding in *A. montanus* and *A. brunnipennis* is more strongly associated with an increase in sideroxylonals and 1,8-cineole concentration than with specific leaf weight (Matsuki, Foley, & Floyd 2011).

Several studies have recorded instances of non-eucalypt feeding by adult Christmas beetles including *A. olivieri* (Schönherr & Gyllenhal) on exotic plum trees (*Prunus*, Rosaceae) (Carne 1957), *A. punctulatus* Olliff feeding on *Barringtonia calyptrata* (Lecythidaceae) and *Litsea leefeana* (*Lauraceae*) and *A. smaragdinus* Ohaus on *Hibiscus tiliaceus* (Malvaceae), *Acacia mangium* (*Fabaceae*), *Tristemma mauritianum* (Melastomataceae, exotic) and *Breynia cernua* (Phyllanthaceae) (Carne 1957) (see Table 2 for other examples). Steinbauer & Wanjura (2002) documented *A. montanus* and *A. pallidicollis* feeding on exotic South American pepper corn tree leaves (*Schinus* sp., Anacardiaceae). Both species preferred to feed on peppercorn leaves even when there were neighbouring *Eucalyptus* available; thus, the feeding response did not appear to be due to lack of other options. The authors speculate the preferential attraction could be due to the absence of 1,8-cineole, a known repellent, in the leaves of peppercorn trees.

DISCUSSION

Regarding Christmas beetles (*Anoplognathus*), Carne (1957) stated: 'Very little is known as yet concerning the biology or ecology of members of this genus'. More than 65 years later, this statement remains largely true. In our literature review, we found information on adult host plants for only 25 of the 44 known species of Christmas beetles in the genera *Anoplognathus*, *Calloodes*, and *Repsimus*. Data on larvae were scarce—our literature search identified feeding ecology information for only nine species. With the exception of a single study, all data regarding larval feeding came from associational studies rather than feeding trials. Notably, the only published feeding trial did not identify the larvae to species, significantly limiting the applicability of its findings.

Most literature on Christmas beetle feeding ecology was from the 1970s and 1980s, with an average publication year of 1983 and a median publication year of 1993. Several records are furthermore from non-peer-reviewed literature such as newspaper and magazine articles that require verification of Christmas beetle and host plant species (e.g., records of *A. concolor* feeding on native grape/vine (Table 2; Anonymous 1898; Chelba 1935). Most studies focused on agricultural contexts, such as pastures or eucalypt plantations. As a result, our knowledge of Christmas beetle feeding ecology is biased toward agricultural systems. For example, most larval feeding records are for exotic crop species which cannot reflect the original feeding preferences of these animals. We know remarkably little about feeding habits in other contexts, such as urban environments or natural ecosystems, leaving significant limitations to our understanding of the ecology of Christmas beetles.

Our literature review confirmed that most adult Christmas beetles primarily feed on eucalypt leaves. However, the lack of exhaustive surveys means that the true dietary breadth of Christmas beetle species is poorly known. Several Christmas beetle species feed on a relatively high number and diversity of non-eucalypt hosts. *Anoplognathus punctulatus*, for example, is recorded as feeding on *Litsea leefeana*, *Barringtonia calyptrata*, *Myristica insipida*, and *Persea americana*, species belonging to four plant families (Illingworth & Dodd 1921).

Further research is needed to investigate how feeding on different host plants, including non-eucalypt species, affects beetle growth, development, fecundity, and lifespan. For instance, do diets consisting of exotic plants provide sufficient nutritional value to support reproduction and survival, or do they impose costs that might affect beetle fitness? This knowledge may help answer important conservation questions, such as whether Christmas beetles are likely to shift to novel or non-native plants under pressures such as habitat loss, urbanisation, or climate change.

There is a substantial body of research which explores how herbivores balance trade-offs between acquiring protein, carbohydrates and other nutrients and avoiding harmful secondary metabolites in their plant-based diets (e.g. Behmer 2009; Behmer, Simpson, & Raubenheimer 2002; Wilson et al. 2019). This framework has provided valuable insights into the mechanisms underlying herbivore feeding behaviour, host selection, and the physiological challenges posed by their diets. Investigating how Christmas beetles navigate trade-offs between the nutritional value and toxicity of their host plants could reveal the factors driving their host selection behaviours. For example, do Christmas beetles exhibit preferences for plants with optimal nutrient profiles, or are their choices constrained by the presence of deterrent compounds such as monoterpenes or phenolics?

Volatiles, which are chemical compounds emitted by plants, play a critical role in host location for many herbivorous insects, acting as attractants over varying distances. For Christmas beetles, the role of these cues in detecting and selecting suitable hosts, particularly among diverse *Eucalyptus* species, remains largely unexplored (but see Floyd & Foley 2001). Some authors have hypothesised that plant volatiles might serve as medium-range cues to guide insects toward potential host plants (e.g. Webster & Cardé 2017), but this idea remains speculative and untested in Christmas beetles. In addition to identifying the role of volatiles, it would be useful to understand how beetles integrate chemical signals with other sensory inputs, such as visual or tactile cues, to locate and select host plants.

Our literature review found a surprising lack of information about the feeding biology of Christmas beetle larvae. As with adults, studies on larval feeding were largely driven by agricultural concerns; consequently, the vast majority of feeding information came from pastures, crops or eucalypt plantations. There is evidence that at least some Christmas beetle larvae have a relatively wide range of feeding substrates. For example, the larvae of *Anoplognathus porosus*, one of the most commonly observed Christmas beetles ('Christmas Beetle Count' 2025), have been described as feeding on organic matter as well as the roots of crops such as potatoes, strawberries, sugarcane, and pastures (Table 1). However, the extent to which these different food sources influence larval fitness and subsequent adult fecundity remains unclear.

Determining the feeding ecology of larval Christmas beetles presents numerous challenges. A major obstacle is that morphological identification to species is not yet feasible for most larval Christmas beetles. Consequently, wild-caught larvae often need to be reared to adulthood for identification, a process that is complicated by the lack of detailed knowledge about their diets. Molecular techniques, such as DNA barcoding, could be used to identify larvae to species. Comprehensive mitochondrial Cytochrome Oxidase I DNA barcodes exist for most Christmas beetle species (Mitchell 2015; Ospina-Rozo et al. 2024); therefore, sequences derived from field collected larvae should be easily identifiable. While effective, this approach is destructive and limits opportunities for subsequent behavioural or ecological studies on the same individuals. Feeding trials will therefore likely require the collection of eggs from identified adults.

Soil environmental DNA (eDNA) techniques may offer an efficient method to identify Christmas beetle larvae in the field (Kirse et al. 2021). This approach would circumvent the need for labour-intensive techniques like plough transects or soil pits and would be particularly useful in protected or urban environments where traditional sampling is prohibited or impractical. Additionally, soil eDNA could provide information about larval distributions, diversity, and habitat preferences. Sequencing of gut contents of larvae or adults could provide identification of the host plants (Cooper et al. 2016; Fluch et al. 2024; Jurado-Rivera et al. 2009; Wallinger et al. 2013).

To address growing concerns about the health of Christmas beetle populations, we urgently need to broaden our understanding of Christmas beetle diets and feeding requirements across a range of environments. This includes not only agricultural systems but also native bushland and urban settings, where their interactions with diverse plant communities remain poorly understood. Research in these contexts could illuminate how habitat fragmentation, urbanisation, and climate change are affecting Christmas beetle populations. A more comprehensive understanding of Christmas beetle feeding ecology will be critical for informing conservation strategies that maintain healthy populations of these culturally and ecologically significant insects in Australia's changing environment.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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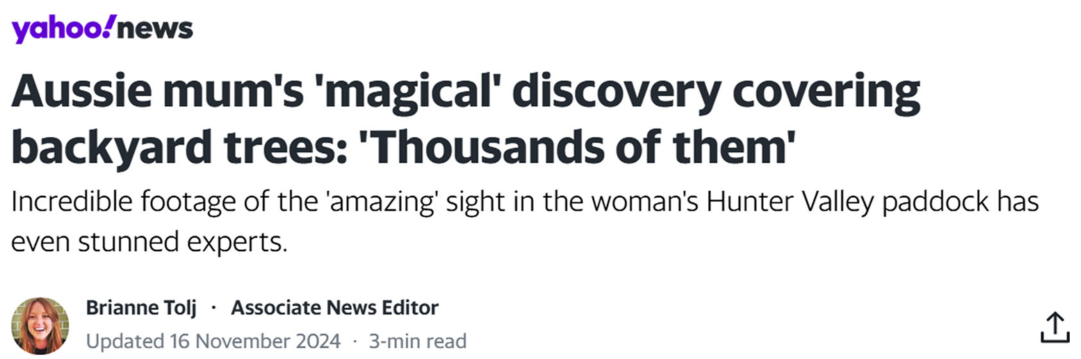
APPENDIX: Examples of media coverage about Christmas beetles (non-exhaustive list). Links to each article can be accessed by clicking the blue text above the screenshot.

Yahoo news


yahoo!news

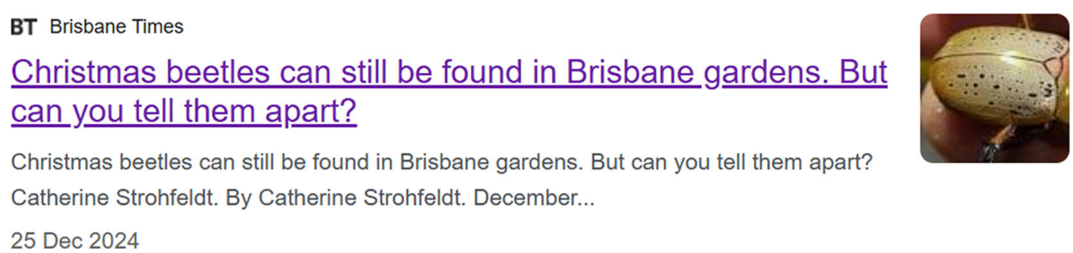
Aussie mum's 'magical' discovery covering backyard trees: 'Thousands of them'

Incredible footage of the 'amazing' sight in the woman's Hunter Valley paddock has even stunned experts.

Brianne Tolj · Associate News Editor

Updated 16 November 2024 · 3-min read

Brisbane times (paywalled)


BT Brisbane Times

Christmas beetles can still be found in Brisbane gardens. But can you tell them apart?

Christmas beetles can still be found in Brisbane gardens. But can you tell them apart? Catherine Strohfeldt. By Catherine Strohfeldt. December...

25 Dec 2024

9Now (video, requires account to view)

9Now

Watch 9News Latest Stories - Season 2024 - Where have the Christmas beetles gone?

Where have the Christmas beetles gone? 9News Latest Stories Season 2024 · Where have the Christmas beetles gone? · Tesla terror at Sydney...

29 Nov 2024

The Conversation

The Conversation

People worry Christmas beetles are disappearing. We're gathering citizen data to see the full picture

In recent years, public perception seems to suggest these lovely insects may no longer be arriving in high numbers.

11 Dec 2023

Gardening Australia (video)

Australian Broadcasting Corporation

Christmas Beetle Mania - Gardening Australia

Clarence learns about one of our most iconic Aussie insects, the Christmas beetle, their dwindling numbers, and what gardeners and citizen scientists can do to...

15 Dec 2023

The Guardian

The Guardian

'A huge worry': Christmas beetle decline spurs calls for citizen sightings

Spurred by a lack of long-term data, Latty and her colleagues are calling on volunteers to contribute to their monitoring of Christmas beetle populations.

18 Dec 2022

Sydney Morning Herald (may be paywalled)

The Sydney Morning Herald

Where have all the Christmas beetles gone?

It's a question Tanya Latty, associate professor at the University of Sydney, often gets. And she's hoping a citizen science project might help...

23 Dec 2023

Australian Geographic

Home ▷ Topics ▷ Wildlife ▷ Where have all the Christmas beetles gone?

Where have all the Christmas beetles gone?

By Jennifer Ennion • 21 November 2016

ABC (Audio)

Australian Broadcasting Corporation

Christmas beetles decline by 90%

"There's only a couple of species in South Australia", she said. "A big, round caramel-coloured beetle". More information at inaturalist...

3 Dec 2023

ABC

Australian Broadcasting Corporation

Christmas beetles seem fewer in number. Citizen science aims to help explain why

The possible decline could be due to several factors including the increased use of broad-spectrum insecticides and pesticides in gardens.

3 Nov 2021

Region Illawara

Region Illawarra

Are Christmas Beetles back or are tiny imposters taking over the Illawarra?

Christmas Beetle populations are believed to be in decline, but researchers need help from the community to collect data.

11 Dec 2023

ABC

Australian Broadcasting Corporation

Could this be the year we solve the mystery of the disappearing Christmas beetle?

News reports in 1922 describe tree branches bending under the weight of beetle hordes at Christmas, and drowning in Sydney Harbour, but the...

7 Dec 2022

9news

9News.com.au

Explained: Where have all the Christmas beetles gone?

Scientists suspect that the insects' population numbers have been on a decline in recent years, but there's not enough official data to prove it.

22 Nov 2022

Cosmos

Cosmos

Are Christmas beetles in decline? Help find out with citizen science

In southern and eastern Australia, summer is heralded by the arrival of swarms of colourful Christmas beetles. The iridescent insects are...

22 Nov 2022

News.com.au

News.com.au

'Disappearing': Fight to save iconic Aussie insect

Many Aussies insist Christmas beetles are vanishing in huge numbers, but there's something you can do to save the iconic insect.

13 Dec 2023

BBC

BBC

Christmas beetles: Scientists ask Australians for help finding missing festive bugs

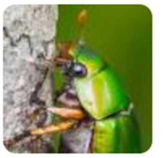
The project asks Australians to upload pictures of any Christmas beetles they see this festive season to an app, to work out how many there are.

22 Dec 2022

The Guardian

The Guardian

The humming of Christmas beetles was once a sign of the season. Where have they gone? | Jeff Sparrow



Although there's no hard data on Christmas Beetle numbers, Entomologists say beetle populations have almost certainly declined.

22 Dec 2019