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Ecological niche and microhabitat use of Australian geckos

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Abstract:	Modern biological research often uses global datasets to answer broad-scale questions using various modelling techniques. But detailed information on species–habitat interactions are often only available for a few species. Australian geckos, a species-rich group of small nocturnal predators, are particularly data-deficient. For most species, information is available only as scattered, anecdotal, or descriptive entries in the taxonomic literature or in field guides. We surveyed gecko communities from 10 sites, and 15 locations across central and northern Queensland, Australia, to quantify ecological niche and habitat use of these communities. Our surveys included deserts, woodlands, and rainforests, examining 34 gecko species. We assigned species to habitat niche categories: arboreal (9 species), saxicoline (4), or terrestrial (13), if at least 75% of our observations fell in one microhabitat; otherwise we classified geckos as generalists (8). For arboreal species, we described perch height and perch diameter and assigned them to ecomorph categories, originally developed for Anolis lizards. There was lower species richness in rainforests than in habitats with lower relative humidity; the highest species richness occurred in woodlands. Most arboreal and generalist species fit the trunk-ground ecomorph, except those in the genus Strophurus, whose members preferred shrubs, twigs of small trees, or, in two cases, spinifex grass hummocks, thus occupying a perch space similar to that of grass-bush anoles. Habitat use by Pseudothecadactylus australis, Saltuarius cornutus, and Gehyra dubia fit the trunk-crown ecomorph. We provide quantified basic ecological data and habitat use for a large group of previously poorly documented species.
Keywords:	Gecko; ecological niche; ecomorph; habitat use; ecology; perch space
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Ecological niche and microhabitat use of Australian geckos

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Abstract

Modern biological research often uses global datasets to answer broad-scale questions using various modelling techniques. But detailed information on species–habitat interactions are often only available for a few species. Australian geckos, a species-rich group of small nocturnal predators, are particularly data-deficient. For most species, information is available only as scattered, anecdotal, or descriptive entries in the taxonomic literature or in field guides. We surveyed gecko communities from 10 sites, and 15 locations across central and northern Queensland, Australia, to quantify ecological niche and habitat use of these communities. Our surveys included deserts, woodlands, and rainforests, examining 34 gecko species. We assigned species to habitat niche categories: arboreal (9 species), saxicoline (4), or terrestrial (13), if at least 75% of our observations fell in one microhabitat; otherwise we classified geckos as generalists (8). For arboreal species, we described perch height and perch diameter and assigned them to ecomorph categories, originally developed for *Anolis* lizards. There was lower species richness in rainforests than in habitats with lower relative humidity; the highest species richness occurred in woodlands. Most arboreal and generalist species fit the trunk-ground ecomorph, except those in the genus *Strophurus*, whose members preferred shrubs, twigs of small trees, or, in two cases, spinifex grass hummocks, thus occupying a perch space similar to that of grass-bush anoles. Habitat use by *Pseudothecadactylus australis*, *Saltuarius cornutus*, and *Gehyra dubia* fit the trunk-crown ecomorph. We provide quantified basic ecological data and habitat use for a large group of previously poorly documented species.

Keywords

Gecko, ecological niche, ecomorph, habitat use, ecology, perch space

Introduction

In recent decades, scientific effort has shifted from more detailed, descriptive observations about species (e.g. Fitch 1970; Wright & Vitt 1993), to answering broad questions with global implications (e.g. Harfoot et al. 2014). Robust studies in many fields of biology, ranging from evolution, biogeography, and conservation biology, to ecomorphology, frequently rely on large datasets of combined information (e.g. Melville et al. 2006; Garcia-Porta & Ord 2013; Davis & Betancur-R 2017; Vidan et al. 2019; Wölfer et al. 2019). But these large datasets may have limited scope or include only coarse-scale information (e.g. presence – absence data), because detailed baseline knowledge, especially regarding natural history and ecology, are unavailable for individual species (Meiri 2019; Vidan et al. 2019). More and more detailed, autecological studies for many species in many parts of the world, including abundant and common species, may enhance future global studies and the conclusions that can be drawn from these.

Lizards are some of the most widespread and abundant vertebrates in the world. In particular, geckos (Gekkota) are the second most speciose lizard group (after snakes), comprising nearly 1900 species or 27.5% of all lizards (if snakes are excluded), with the highest rate of new species descriptions in squamate reptiles (Roll et al. 2017; Meiri 2019; Uetz & Jirí Hošek 2019). Geckos have a worldwide distribution, mostly in tropical and subtropical regions. Australia is one of the global hotspots for gecko diversity, where they constitute a dominant part of the overall lizard biodiversity (Meiri 2019; Vidan et al. 2019).

Geckos are small- to medium-sized predators of invertebrates (Nordberg, Murray, et al. 2018) and small vertebrates (Nordberg 2019) and are themselves depredated by birds, mammals, larger reptiles, frogs, and even large invertebrates (Nordberg, Edwards, et al. 2018). Thus, they form an important part of tropical and subtropical food webs. Geckos have colonized diverse habitats, occupying terrestrial habitats and vertical rocks and trees, including overhanging microhabitats (Gamble et al. 2012; Collins et al. 2015; Russell et al. 2019).

Recent studies have described broad-scale evolutionary history, or revealed species complexes by examining biogeography, mapping species distributions, and conducting taxonomic analyses (e.g. Han et al. 2004; Gamble et al. 2008; Gamble et al. 2012; Skipwith et al. 2016; Brennan & Oliver 2017). But to understand the causes of diversification in particular bioregions, we require more detailed understanding of their ecology, for example which habitat niches, or which roles in the food-web are occupied (Meiri 2018). Many gecko groups are severely data deficient, especially in terms of natural history and ecological data, including habitat use. Detailed studies on gecko field ecology are often only available for small areas or single species (e.g. Henle 1990; Augros et al. 2018; Neilly et al. 2018; Nordberg, Murray, et al. 2018; Nordberg & Schwarzkopf 2019a; Nordberg & Schwarzkopf 2019b). For most species, information on basic ecological traits are only available as anecdotal information in field guides or the taxonomic literature, and may be based on limited personal observations by the authors from restricted geographic areas (Kulyomina et al. 2019; Vidan et al. 2019; Zhuang et al. 2019).

Our lack of detailed natural history knowledge is problematic for conservation and management purposes, because we may underestimate threats due to data deficiency (Roll et al. 2017; Meiri 2019). For example, we cannot accurately assess the problems caused by invasive weeds if we do not understand preferred habitat structures and characteristics (Valentine et al. 2008). Nor can we predict the influence of climate warming on lizard communities (Sinervo et al. 2010), if we do not know their thermal preferences and thresholds, or which microhabitats are needed to access temperatures vital for digestion, gamete development, or optimal performance. Further, geckos are often used as a model system for evolutionary (Garcia-Porta & Ord 2013; Nielsen et al. 2016; Hagey, Uyeda, et al. 2017) and ecomorphological studies (Zaaf & Van Damme 2001; Hagey, Harte, et al. 2017; Rothier et al. 2017; Kulyomina et al. 2019; Riedel et al. 2019; Zhuang et al. 2019). Yet, to fully understand the evolution of morphological structures, we need to understand gecko habitat use, and how they exploit various microhabitats, ideally within some kind of ecological classification system, which can be used to describe niches.

One group of lizards for which such a classification system is already established, and which has a substantial body of literature describing ecomorphology and natural history are the *Anolis* lizards (Roughgarden 1995; Losos 2011). *Anolis* lizards are a well-studied model for ecomorphological analyses and, like geckos, some have adhesive toepads (Losos 1992; Losos 1994; Irschick et al. 1996; Russell 2002; Losos 2010; Hagey, Uyeda, et al. 2017). Therefore, they provide an obvious starting point to use to classify gecko perch space use, and given the similarity in evolution and adaption to vertical habitats by geckos and *Anolis* lizards, niche classifications designed for anoles may be useful in this regard (c.f. Hagey, Harte, et al. 2017; Kulyomina et al. 2019).

The goal of our study was to quantify the microhabitat and niche space for a broad range of Australian gecko species, thereby providing baseline ecological information for use in future studies of gecko biology. Using the structural habitat categories perch height and perch diameter, we described the niche space of arboreal geckos (including padless Carphodactylidae), and compared their niche space use to those established for *Anolis* lizard ecomorphs (Losos 1992; Irschick et al. 1997; Langerhans et al. 2006; Poe & Anderson 2019), to provide a basis for classification of gecko ecomorphs. This study contributes valuable ecological data to the literature for many species that lack such information, which can be used and applied in future ecomorphological, evolutionary or conservation studies.

Methods

Field work

Geckos were surveyed at 10 sites during multiple field trips to 15 locations (distinct habitat types within the different sites) spanning a wide array of habitats across northern and central Queensland, Australia, between 2014 and 2018 (Fig. 1). Locations included 1 - 10 replicates of similar habitat, close together (< 50 kms apart). Habitats were classified as rainforest (which could be further distinguished into lowland and upland rainforest), savannah woodland, woodland, desert, and heath (Table 1). In the Cape York Peninsula bioregion (in and near Iron Range National Park), we sampled lowland rainforest, woodland and heath (Fig. 1A). Upland rainforests were sampled at three sites across the Australian Wet Tropics (AWT) bioregion (Mt. Elliot, Paluma Range and the Tablelands) and at one site in the Central Queensland Coast bioregion (Eungella National Park). Woodlands were sampled in the Greater Townsville Region (Brigalow Belt (BB)), at Hidden Valley (Einsleigh Uplands [bordering the AWT]) and at the Wambiana Cattle Station (Desert Uplands [bordering BB]; Fig. 1B). In the area close to Winton (Mitchell Grass Downs) we sampled both woodland and savannah woodlands (Fig. 1C). Locations around Windorah (Channel Country), included savannah woodlands and desert sites (Fig. 1D).

Locations were visited for an average of 5 days (range 1 - 12) to assess gecko species during nightly spotlight surveys. At each surveyed location, we either repeatedly surveyed 3-6 replicates of the same habitat (approximately 1 km^2 each, often along a road, on average 5 km apart) or walked transects (e.g., on rainforest tracks) of 5 km on average. An exception to this was Wambiana Station, at which 24 1-ha locations were surveyed intensely for a 3-year research project (Nordberg 2018).

We attempted to capture all observed geckos to collect morphometric data (mass, snout-vent-length, sex). Habitat and perch height and diameter were recorded for each gecko, regardless whether it was captured or not. We recorded perch location (e.g., tree trunk, grass, primary branch, on the ground; Fig. 2), perch height, perch diameter, body orientation (horizontal, vertical, inverted), and a general categorical classification for the type of microhabitat used (tree, shrub, sapling, vine, bamboo, rock, man-made structure) for each observation. Perch diameter was only recorded for arboreal habitats as it is irrelevant for wide or flat substrates such as building walls, boulders, or the ground.

Habitat niche classification and Perch location

We classified gecko species into one of four broad habitat niche categories: arboreal, terrestrial, saxicoline, or generalist. Species were classified as arboreal when geckos were captured above the ground on shrubs, bushes, trees, or grass; terrestrial if we captured them on the ground, sand, or leaf litter; or saxicoline if captured on rocks or boulders. Species that occurred on a variety of different substrata and did not have at least 75% of all captures in a single broad niche group were classified as generalists.

Additionally, we recorded gecko perch locations, which included subsets of arboreal habitats, for example on tree trunks, or primary, secondary, tertiary branches, or terrestrial habitats like logs, or on the ground (Fig. 2).

Comparison to Anolis ecomorphs

We plotted mean perch height (cm) and perch diameter (cm) for 16 gecko species in our communities, which frequent used vegetation, although they may have occasionally used rocks or the ground. Furthermore, we compared gecko perch ecomorphs to those of *Anolis* lizards by overlaying existing perch data for the *Anolis* ecomorph system (Losos 1992; Losos 1994; Irschick et al. 1997; Hagey, Harte, et al. 2017) on our gecko data. Based on current knowledge and data, we compare overlap of gecko and *Anolis* ecomorphs, to describe gecko habitats using terms established for perch-space niches.

Results

Sampling of habitat assemblages

We sampled 2063 geckos across 35 species belonging to the families Gekkonidae, Diplodactylidae, Carphodactylidae and Pygopodidae (Table 2). The widespread Australian native house gecko, *Gehyra dubia*, of which we sampled 1544 individuals, mostly at

Wambiana Cattle Station, dominated our data. For the remaining species, we sampled between 1 and 61 individuals. Our dataset represents a broad sampling distribution across species, geographic regions, and habitat types, with varying sample size pending on location and species abundance. We present data on all species but caution that the results from species with low sample sizes be interpreted with care. In particular, species with low sample sizes include: *Carphodactylus laevis* (n=4), *Strophurus elderi* (n=1), *Strophurus taeniatus* (n=2), *Cyrtodactylus hoskini* (n=3), *Lialis burtonis* (n=3), *Delma tincta* (n=1), and *Pygopus shraderi* (n=1). There are few ecological observations available for these species, so while our sample sizes are low, they still provide valuable data.

Species Composition and Community Structure

In terms of species composition and community structure in different habitats and bioregions, the rainforest habitats were generally less species-rich than habitats with lower average humidity, characterised by one or two species per location for rainforest compared to between 3 and 10 in other habitats (Table 1). Because of the high endemism of leaf tailed geckos (*Phyllurus* and *Saltuarius*), total species richness of all rainforest habitats (6) is only slightly lower than savannah woodland (9), but higher than heath (5) or desert (4) habitats. Woodland habitats had the highest total species richness (23, Table 2). The upland rainforest sites in the Australian Wet Tropics and adjacent regions typically hosted only a single species of leaf-tailed gecko (*Saltuarius* or *Phyllurus*), whereas the tablelands (upland rainforest) included the chameleon gecko (*Carphodactylus leavis)*. The dominant gecko species in lowland rainforest in the Iron Range were the giant tree gecko (*Pseudothecadactylus australis*), with occasional *Gehyra dubia*. Woodland and desert habitats, in comparison, were often characterised by 3 to 6 species, and the area around Winton (10 species) and the woodland and heath habitats in Cape York (adjacent to the rainforest of the Iron Range National park; 9 species) were the most species-rich areas we sampled (Table 1). Woodland habitats often contained (at least) one species of velvet gecko (genus *Oedura)*, a relatively large, and mostly climbing (arboreal, saxicoline, or generalist) species, at least one smaller, mostly climbing species in the genera *Gehyra*, *Amalosia*, or *Strophurus*, and at least one terrestrial species such as a *Lucasium*, or *Diplodactylus*. In more open habitats, species of mostly arboreal genera tended to be more generalist. Thus, in this study woodland habitats were characterised by *Oedura cincta* and *Strophurus ciliaris* or *S. krysalis*, which were found more often on the ground than their congeners from more eastern regions, which have higher tree density (Table 2, Fig. 3).

In terms of distribution across habitat types, species using rainforest tended to be restricted to that habitat, whereas species occupying drier habitats, like woodlands, savannah woodlands, heath, or deserts, often occupied more than one of these, but only occasionally used rainforest habitats (Table 2). The only exceptions were the giant tree gecko (*Pseudothecadactylus australis)*, which occurred in rainforests, but also in adjacent woodlands and heath, and the native house gecko (*Gehyra dubia)*, which occurred in rainforest at Iron Range. Notably, we found only two native house geckos in rainforest, and both on trees relatively close to a campground, where they could have been transported by human activity or vehicles.

Microhabitat

Throughout all sampled bioregions and habitat types, 9 species were arboreal, 4 saxicoline, 13 terrestrial and 8 generalists (Fig. 3, Table 2). Generalist species, by definition, used a combination of perch locations including natural substrates, like vegetation and rocks, and anthropogenic substrates, like wooden or concrete walls. Most species classified as terrestrial were nearly exclusively found on the ground, only *Nactus eboracensis* and *Diplodactylus tesselatus* were occasionally encountered on logs (20% and 7%, respectively). Similarly, three out of four saxicoline species were found exclusively on rocks, with only *Oedura monilis* also using vegetation (tree trunks in rocky habitats). Of the arboreal species, six were occasionally found on the ground, and the chameleon gecko (*Carphodactylus laevis*) occupied terrestrial microhabitats 25% of the time.

Perch location and orientation

For most species, especially leaf-tailed geckos (*Saltuarius* and *Phyllurus*), and species in the genera *Oedura*, and *Gehyra*, tree trunks were the most frequently used perch, followed by primary and secondary branches. In contrast, species in the genus *Strophurus* use predominantly small-diameter, low, complex, vegetation structures, such as shrubs, grass, or tertiary branches of trees and bushes. *Carphodactylus leavis* was exclusively found on small saplings (on which they perch head down), when not using the ground. *Amalosia rhombifer* occupied both tree trunks and shrubs quite frequently (Fig. 3). Perch orientation for most saxicoline species was predominantly vertical, but horizontal areas were also frequently used by all species. Only *Cyrtodactylus hoskini* and *Phyllurus amnicola* were found on overhanging surfaces (Fig. 4).

Ecomorphs

Most gecko species fell within one or two of the perch-space niches originally described for *Anolis* ecomorphs, according to their habitat use (Fig. 5). *Strophurus* species, which were associated with shrubs, bushes, and small trees, typically clustered within the perch-space of the 'grass – bush' ecomorph, except *S. elderi, which* occupied a smaller perch diameter and lower perch height, below the mean perch-space occupied by *Anolis* ecomorphs. Similarly, trunk-using species, such as *Oedura tryoni*, *Oedura castelnaui*, clustered in or near the space occupied by 'trunk' and 'trunk – ground' ecomorphs. *Saltuarius cornutus*, *Pseudothecadactylus australis* and *Gehyra dubia* fit within the 'trunk – crown' perch-space, with the former also overlapping with the 'crown – giant' perch-space, which is appropriate as they are often found in the canopy of rainforest trees. *Amalosia rhombifer*, a generalist species, was situated in between 'ground – bush' and 'trunk – ground' perch-space, appropriate for its diverse habitat use. The perch heights of generalist species *O. cincta* and *G. versicolor* were below the mean range established for any anoles. In addition, the generalist *Heteronotia binoei* and the terrestrial *Nactus eboracensis* fell beneath the perch space occupied by *Anolis* ecomorphs, using large perch diameters at very low perch heights.

Discussion

General habitat niche and habitat use

Based on quantitative data, we classified the habitat niche categories, macro- and microhabitat use of 35 gecko species from four families across a wide range of available habitat types in central and north Queensland, Australia. Additionally, we classified perch-space niches for these gecko species using the perch-space niches established for *Anolis* ecomorphs, and found the *Anolis* ecomorphs broadly useful (Losos 2010; Losos 2011; Hagey, Harte, et al. 2017), although our geckos seemed to use the ground more. Although the results for some species should be interpreted with care due to low sample sizes, this study provides an overview of species composition in tropical gecko communities, and a detailed account of habitat use for a variety of Australian gecko species. To our knowledge, this study represents the first detailed account of microhabitat use and especially perch-site behaviour for some species (Table 2). Quantified assessments of habitat use are available for some Australian species, e.g. for native house geckos (*Gehyra dubia)*, eastern spiny tailed geckos (*Strophurus williamsi)* and northern velvet geckos (*Oedura castelnaui)* (e.g. Nordberg & Schwarzkopf 2019b), and for some desert gecko communities in varying degrees of detail (Pianka 1969; Pianka & Pianka 1976; Pianka et al. 2017). Perch location data was previously only reported by Hagey, Harte, et al. (2017) from between three and nine observations for 13 species, 12 of which overlap with this study (Table 2).

The quantified habitat niche categories of our study are typically similar to the above-mentioned studies, and with commonly ascribed habitat niche categories from the published taxonomic descriptions and other literature (Cogger 2015; Wilson 2015; Nielsen et al. 2016; Hagey, Harte, et al. 2017), including the species for which we only have low sample sizes. The three species belonging to the Pygopodidae (*Delma tinca* [n=1], *Lialis burtonis* [n=3] and *Pygopus shraderi* [n = 1]) are unquestionably terrestrial, normally preferring leaf-litter or ground layer vegetation (Cogger 2015, Macdonald et al. 2013, Wall and Shine 2013). Although we have limited records for the spiny tailed geckos *Strophurus taeniatus* (n=2) and *Strophurus elderi* (n=1), both were found in spinifex grass hummocks, consistent with previous descriptions of their habitat use as grass-dwelling (graminicolous) (Cogger 2015; Nielsen et al. 2016; Laver et al. 2017).

In agreement with Hagey, Harte, et al. (2017), we found that *Gehyra robusta* is a generalist species, using both the ground (n=4) and rocks (n=3). We found, however, that ocellated velvet geckos (*Oedura monilis)* were rock-dwelling (saxicolous), rather than generalist (Hagey, Harte, et al. 2017) or arboreal (Henle 1991; Mesquita et al. 2016; Nielsen et al. 2016; Meiri 2018), because we found individuals mostly on rocks (9 on rocks and 2 on trees). These habitat niche classifications could vary among populations and ecoregions, so possibly this species uses a wider variety of microhabitats than we detected. Our results for *Cyrtodactylus hoskini* were consistent with the sparse descriptive information on their natural history (Shea et al. 2011; Cogger 2015). We describe *Carphodactylus laevis* as arboreal, as we often found *C. laevis* foraging close to the ground on slender branches and twigs, consistent with Wilson (2015). Other studies describe it more generally as as scansorial, i.e., adapted for climbing (Nielsen et al. 2016). *Heteronotia binoei* is typically described as terrestrial (Cogger 2015; Wilson 2015), although Mesquita et al. (2016) classified them as arboreal. Henle (1990) reported *H. binoei* as mostly terrestrial but using bushes and trees up to 0.8 m as retreats, which was corroborated by our study. It must be noted, however, that *H. binoei* is a cryptic species complex(Fujita et al. 2010; Moritz et al. 2016), and different lineages use available microhabitats to different degrees, including rocks (Zozaya et al. 2019; S. Zozaya unpublished data).

Comparison with Anole ecomorphs

Our results show that the perch-space use of Australian geckos overlaps, at least partially, with *Anolis* ecomorphs. Consistent with (Hagey, Harte, et al. 2017), we describe arboreal *Oedura* as using habitat similar to ‘trunk’ and ‘trunk – ground’ anoles. Species of the genus *Strophurus* use habitat structure similar to that of 'grass – bush' anoles (consistent with Hagey, Harte, et al. (2017)), such as low-growing shrubs or small-diameter tertiary branches of trees at relatively low heights (Fig. 3, 5). Although most *Strophurus* species fall within the broad perch-space of the 'grass – bush' anoles, there is a clear separation between the spinifex-associated *Strophurus elderi* (which was not included in Hagey, Harte, et al. (2017)), and *S. williamsi*, *S. krysalis*, and *S. ciliaris*. *Strophurus elderi* had perch heights lower even than means for 'ground – bush' anoles, whereas the latter three species used shrubs and twigs of small trees, and fall within the 'ground – bush' niche space (Fig. 3, 5). The differences in habitat use we note among *Strophurus* spp. were consistent with morphological and taxonomic distinction between the so-called 'graminicolus' and 'scanso-arboreal' groups (Greer 1989; Storr et al. 1990), and assessments of microhabitat use in these species (Nielsen et al. 2016; Laver et al. 2017). Although we did not record perch height and diameter for *S. taeniatus*, we found them in spinifex, suggesting they might occupy a perch space similar to *S. elderi*. Thus, although our suggestions are preliminary because we have only a small sample of *S. elderi*, we suggest that there are two distinct 'grass – bush' ecotypes in Australian geckos: a spinifex-hummock grass-associated 'grass' ecotype and a 'bush-twig' ecotype, using higher and thicker perches of shrubs and small trees (Nielsen et al. 2016). Perch height for *Amalosia rhombifer* fell within the overlapping area between the 'grass' and the 'trunk – ground' perch-space area, consistent with its generalist habitat use (Fig. 3). As the generalist species *Gehyra versicolor* and *Oedura cincta* both fell outside of the perch spaces plotted for *Anolis*, but were close to *A. rhombifer*, we propose a new 'generalist' or 'ground – bush – twig' ecotype for Australian geckos, overlapping with the 'bush – twig' and the 'trunk – ground' perch-space area.

Hagey, Harte, et al. (2017) suggested that *Pseudothecadactylus australis* was in the overlapping area between 'trunk – crown' and 'crown – giant' ecotype. Our more extensive sampling revealed that it does use thick trunks of rainforest trees, but also thin branches of the same trees, vines, bamboo, and occurs outside rainforest in heath and woodland habitats, where it uses lower-growing trees with thin branches as well (Fig. 3, 5). Thus, we agree they are 'trunk – crown' ecotypes, but not in the 'crown – giant' group. Our extensive sampling of *Gehyra dubia* reveals that it uses higher perches on average than previously recorded (Hagey, Harte, et al. 2017). This suggests that extensive sampling of habitat use can be useful, even for common species (in Australia). The primarily padless Carphodactylidae were not included in Hagey, Harte, et al. (2017), and detailed ecological data, including perch height and diameter, are reported here for the first time. While *Saltuarius cornutus* occupies a perch space similar to 'trunk – crown'/'crown – giant' ecotypes, *Phyllurus nepthys* fits within the 'trunk – ground' ecotype similar to *Oedura* or *Gehyra* species outside rainforest habitats. Notably, we found *Phyllurus nepthys* using its full range of microhabitats (trees, rocks, ground) only in the highest elevation areas of its habitat (Dalrymple Heights, nearly 1000 m), whereas they used boulders or man-made structures (concrete bridges) in or near rainforest streams in the lower elevations of their range (Finch Hatton Gorge, 300 - 400 m; Broken River, 600 - 700 m). Leaf-tailed geckos are dependent on habitats with high humidity, and these ancient rainforest lineages use rocky landscapes (lithorefugia) as habitats (Couper & Hoskin 2008). *Carphodactylus leavis*, which exclusively used small saplings to perch head-down, low to the ground, potentially falls in our proposed 'grass' ecotype. Both, *Heteronotia binoei* and *Nactus eboracensis* occupied perch spaces far outside those plotted for anoles. And although *H. binoei* is a generalist, while *N. eboracensis* is terrestrial, both species used the ground in more than 50% of captures (Fig. 3). Therefore, these two species might be described as part of a 'ground-log' or 'ground-log-trunk' ecotype. We would need additional perch data from more Australian gecko species to validate the consistency of these proposed ecotypes.

Importance of natural history studies

Australia supports some of the world's most diverse gecko communities, yet most species are data deficient, even in terms of basic ecological or natural history data (Meiri 2018). To better manage communities and understand the impacts of environmental changes on communities, we need to understand how species use their environment. Overall, our results are in accord with previous detailed studies, where they are available (Pianka 1969; Pianka & Pianka 1976; Henle 1990; Nordberg, Edwards, et al. 2018; Nordberg, Murray, et al. 2018; Nordberg & Schwarzkopf 2019b), emphasizing that even anecdotal observations can provide useful insights into animal ecology. Our study adds considerable new or updated information about the microhabitat use, perch-space, and ecological niche space of Australian geckos, and provides an ecomorph classification of geckos similar to that established for anoles. We encourage field biologists in all research areas to collect data on the ecology of the species they collect, and to publish them, or make them publicly available in other venues, such as public databases.

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Authors contribution

JR, EJN and LS conceived the project idea and designed the project. JR and EJN collected and analysed the data and led the writing of the manuscript. JR, EJN and LS contributed critically to drafts and gave final approval for publication.

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Ethics and permits

Field work at Wambiana cattle station was conducted under the Queensland Department of Environment and Heritage Protection (DEH) research permit WISP14656614 and approved by the Animal Ethics A2050 approval from James Cook University (JCU). Field work at the remaining sites was conducted under the permit from the DEH (WA0005590) for non-protected areas and the Queensland Department of National Parks, Sports and Racing (WITK18258517) for protected areas, and Animal Ethics A2409 approval (JCU).

Figures

Figure 1. Survey sites across Queensland, Australia. (A) Cape York Peninsula, showing the locations surveyed at the Iron Range site. (B) Townsville region with the sites Hervey Range, Hidden Valley, Paluma Range, Mt. Elliot and Wambiana. (C) Locations surveyed in the area around Winton. (D) Locations surveyed around Windorah. Each point refers to an area surveyed. Areas of similar habitat at each site are called ‘locations’ (Table 1).

Figure 2. Perch locations: log (1), tree trunk (2), primary branch (3), secondary branch (4), tertiary branch (5), grass (6), horizontal on rocks (7), on overhanging rock or crevice (8), vertically on rock (9), bush and shrub (10), ground (11).

Figure 3. Gecko community perch locations across Queensland, Australia. Arb. = arboreal species, Gen. = generalist species, Sax. = saxicoline (rock-dwelling) species, Ter. = terrestrial species.

Figure 4. Saxicolous species’ perch orientation on rocks.

Figure 5: Perch space (height and diameter) used by Australian geckos, overlayed on polygons indicating the range in mean perch spaces occupied by anole ecomorphs (adapted from Hagey, Harte et al. 2017). Points for geckos are centroid means ± SE.

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Tables

Table 1: Overview over the areas surveyed for this study and the bioregion to which these belong. The habitat categories, which we assigned, are shown as well as the standardized reginal ecosystem codes (Queensland Herbarium 2019) for the areas in question. Species richness displayed the number of species detected in our surveys, with an ID matching that given for each species Table 2. Each habitat type in a geographic area (Site) is summarized as one location for this study.

Geographic Area	Bioregion	Habitat	Regional ecosysthem codes: BVG1M (% covered)	Species richness	Species ID
Iron Range	Cape York Peninsular	Rainforest	3.11.1 / 3.11.3 / 3.11.11 (70/20/10)	2	8, 26
		Woodland	3.12.10 / 3.12.21 / 3.12.41 /3.12.28 / 3.12.11 (50/20/10/10/10)	8	1/2/8/11/12/16/19/26
		Heath	3.3.5a / 3.5.42 / 3.7.6x2 (40/40/20) 3.12.47 / 3.12.41 (80/20)	4	1/8/16/17/34
Tablelands	Wet tropics	Rainforest	7.8.2a	2	2/29
Paluma Range	Wet tropics	Rainforest	7.12.16	1	29
Mt. Elliot	Wet tropics	Rainforest	11.12.4	1	24
Eungella	Central Queensland Coast	Rainforest	8.12.2 / 8.12.3a / 8.12.19 (40/30/30)	1	25
		Woodland	8.12.4 / 8.12.7a (60/40)	3	8/23/25
Hervey’s Range / Townsville Region	Bringalow Belt	Woodland	9.11.2a/9.11.5	6	5/7/12/14/19/27
Hidden Valley	Einasleigh Uplands	Woodland	9.12.19 7.12.65k	4	1/21/22/34
Wambiana Station	Desert Uplands	Woodland		6	8/11/12/14/19/34
Winton	Mitchell Grass Downs	Woodland	4.9.14x44 / 4.4.1xb (70/30) 4.7.1a / 4.7.2 / 4.7.2x1a / 4.7.4a (50/20/20/10)	10	1/6/9/10/11/13/17/20/32/33

		Savannah Woodland	5.7.1 / 4.5.6x4 / 4.7.2x2 (50/30/20)	6	6/13/14/20/28/32
Windorah	Channel Country	Desert	5.6.5a	4	10/15/18/30
		Savannah Woodland	5.5.2 / 5.3.16a (90/10)	3	10/30/31

Table 2: Comparison of habitat use and size data available from the literature and the data added in this study for the species surveyed in this study (ID's for species are given in brackets to match Table 1). In cases where conflicting information is available from the literature, different information from different

sources are separated by a semicolon, and the sources are separated accordingly. SVL data from the literature are maximum values, unless marked with and *, in which case they are average values. PH and PD refer to average perch height and perch diameter respectively. References: 1) Wilson 2015. 2) Cogger 2015. 3) Michael et al. 2015. 4) Bustard 1965. 5) Nordberg and Schwarzkopf 2019a. 6) Pianka and Pianka 1976. 7) Neilly et al. 2018. 8) Pianka 1969. 9) Zozaya et al. 2015. 10)Wilson and Knowles 1988. 11) Michael and Lindenmayer 2010. 12) Meiri 2018. 13) Nielsen et al. 2016 14) Storr et al. 1990 15) Shea et al. 2011. 16) Johansen 2012. 17) Henle 1991. 18) Mesquita et al. 2016. 19) Oliver et al. 2017. 20) Henkel 2010. 21) Oliver and Doughty 2016. 22) Pepper et al. 2011. 23) Couper et al. 1993. 24) Vanderduys 2017. 25) Hagey, Harte et al. 2017

	Existing Knowledge			**Updated Information - this study**		
Species			**Ref**			**n**
Amalosia rhombifer (1)	Macrohabitat	Widespread forests, woodlands	1,3,13	Macrohabitat	Heath and woodlands	22
	Microhabitat	Under bark	3	Microhabitat	Trees and rocks	22
	Lifestyle	Arboreal; Generalist	1,13; 12,14	Lifestyle	Generalist	22
	Perch location	PH: 81.4 cm and PD: 11.8 cm	25	Perch location	Branches and rocks	22
	SVL	70; 80	1,13; 12	SVL	48.94 ± 1.59	17
	Mass			Mass	2 ± 0.2	17
Carphodactylus laevis (2)	Macrohabitat	Wet tropics - rainforests	1	Macrohabitat	Rainforest	4
	Microhabitat	Leaf litter, slender twigs	1	Microhabitat	Trees, ground	4
	Lifestyle	Scansorial	13	Lifestyle	Arboreal	4
	Perch location	Slender twigs	1	Perch location	Tree trunks, ground	4
	SVL	130	1	SVL	93.5 ± 6.96	4
	Mass			Mass	14.71 ± 2.9	4
Cyrtodactylus hoskini (3)	Macrohabitat	Endemic - western edge of Iron Range	15,1	Macrohabitat	Woodland	3
	Microhabitat	Granite boulders, open forest	15,1	Microhabitat	Rocks	3
	Lifestyle	Saxicoline	12	Lifestyle	Saxicoline	3
	Perch location			Perch location	Rocks	3
	SVL	64;112	15,1	SVL	111 ± 2.08	3
	Mass			Mass	24.96 ± 0.9	3

Delma tincta (4)	Macrohabitat	Widespread, woodlands	1,3	Macrohabitat	Woodland	1
	Microhabitat	Under log, rocks	3	Microhabitat	Leaf litter	1
	Lifestyle	Fossorial, terrestrial	12	Lifestyle	Terrestrial	1
	Perch location			Perch location	Ground	1
	SVL	92	1	SVL		
	Mass			Mass		
Diplodactylus platyurus (5)	Macrohabitat	Widespread, arid woodlands, scrublands	1	Macrohabitat	Woodland	7
	Microhabitat			Microhabitat	Open ground	7
	Lifestyle	Terrestrial	1,12	Lifestyle	Terrestrial	7
	Perch location			Perch location	Ground	7
	SVL	60	1	SVL	39.1 ± 1.41	7
	Mass			Mass	2.18 ± 0.22	7
Diplodactylus tesselatus (6)	Macrohabitat	Clay soils; arid regions	1; 13	Macrohabitat	Savannah woodland, woodland	
	Microhabitat			Microhabitat	Open ground	13
	Lifestyle	Terrestrial	1,13,16,17	Lifestyle	Terrestrial	13
	Perch location			Perch location	Ground	13
	SVL	50; 58	1,13; 12	SVL	47.83 ± 2.11	11
	Mass			Mass	2.91 ± 0.29	11
Diplodactylus vittatus (7)	Macrohabitat	Woodlands	1,3	Macrohabitat	Woodland	7
	Microhabitat	Leaf litter, under log/rock; surface debris	3; 10	Microhabitat	Ground	7
	Lifestyle	Terrestrial	1, 12	Lifestyle	Terrestrial	7
	Perch location	Fallen twigs	1	Perch location	Ground, twigs	7
	SVL	50; 59.5	1; 12	SVL	46.81 ± 0.66	7
	Mass			Mass	3.06 ± 0.16	7
Gehyra dubia (8)	Macrohabitat	Widespread, woodlands	1, 5	Macrohabitat	Heath, rainforest, woodland	1544
	Microhabitat	Tree trunks; man-made structures	5,7;9	Microhabitat	Trees	1544
	Lifestyle	Arboreal	5,17,25	Lifestyle	Arboreal	1544
	Perch location	Trunk; PH: 85.5 cm, PD: 18.4 cm	5,7; 25	Perch location	Trunk, branches	1544
	SVL	65; 42.9*	1; 5	SVL	53.58 ± 0.37	636
	Mass	3.3	5	Mass	4.04 ± 0.07	636
Gehyra robusta (9)	Macrohabitat	Endemic - Northwest Highlands, Mitchell grass Downs	1	Macrohabitat	Woodland	7
	Microhabitat	Rocky ranges and outcrops	1	Microhabitat	Rocks, ground	7
	Lifestyle	Saxicoline	1,12	Lifestyle	Generalist	7

	Perch location	trunk; PH: 35.3 cm, PD: 10.8 cm	5,7; 25	Perch location	Rocks, ground	7
	SVL	75	1,12	SVL		
	Mass			Mass		
Gehyra versicolor (10)	Macrohabitat	Widespread, dry woodlands	1	Macrohabitat	Savannah woodland, desert	29
	Microhabitat			Microhabitat	Trees, ground, rocks	29
	Lifestyle	Arboreal and saxicoline	1,12,16,18	Lifestyle	Generalist	29
	Perch location			Perch location	Trunk, branches	29
	SVL	54	1, 12	SVL	45.17 ± 2.33	12
	Mass			Mass	2.47 ± 0.34	12
Heteronotia binoei (11)	Macrohabitat	Widespread, woodlands	3,4	Macrohabitat	Woodland	42
	Microhabitat	Under bark, log, and rocks; spinifex; shrubs, burrows	3,4,6,8	Microhabitat	Trees, ground	42
	Lifestyle	Terrestrial; arboreal and terrestrial	1,6,19,17; 12,18	Lifestyle	Generalist	42
	Perch location			Perch location	Trunk, ground	42
	SVL	54; 55	1,6	SVL		
	Mass			Mass		
Lialis burtonis (12)	Macrohabitat	Widespread, woodlands	1, 3	Macrohabitat	Woodland	3
	Microhabitat	Under rock; spinifex, ubiquitous	3,4,8	Microhabitat	Open ground	3
	Lifestyle	Terrestrial	1,12,13,17,18	Lifestyle	Terrestrial	3
	Perch location			Perch location	Ground	3
	SVL	85	1, 12	SVL	112.09 ± 92.59	2
	Mass			Mass	19.09 ± 0.65	2
Lucasium immaculatum (13)	Macrohabitat	Stony open woodlands; arid savannah	1; 13	Macrohabitat	Savannah woodland, Woodlands	12
	Microhabitat			Microhabitat	Open ground	12
	Lifestyle	Terrestrial	1,12,16	Lifestyle	Terrestrial	12
	Perch location			Perch location	Ground	12
	SVL	85	1, 12	SVL	46.7 ± 0.77	9
	Mass			Mass		
Lucasium steindachneri (14)	Macrohabitat	Woodlands, red soil plains	1,11	Macrohabitat	Savannah woodland, woodland	6
	Microhabitat	Spider burrows, dead vegetation, sparse ground cover	11	Microhabitat	Leaf litter, open ground	6

	Lifestyle	Terrestrial	1,12,18,16	Lifestyle	Terrestrial	6
	Perch location			Perch location	Ground	6
	SVL	55; 59	1; 12	SVL	47.67 ± 1.74	6
	Mass			Mass	3.04 ± 0.27	6
Lucasium stenodactylum (15)	Macrohabitat	Widespread, dry shrublands	1	Macrohabitat	desert	8
	Microhabitat			Microhabitat	Sandy soil	8
	Lifestyle	Terrestrial	1,12,18,16	Lifestyle	Terrestrial	8
	Perch location			Perch location	Ground	8
	SVL	57	1, 13	SVL	52.43 ± 1.53	7
	Mass			Mass	3.04 ± 0.19	7
Nactus eboracensis (16)	Macrohabitat	Tropical woodlands and outcrops	1	Macrohabitat	Heath and woodlands	5
	Microhabitat			Microhabitat	Trees and ground	5
	Lifestyle	Terrestrial	1, 12	Lifestyle	Terrestrial	5
	Perch location			Perch location	Trunk, ground	5
	SVL	57; 58	1, 12	SVL		
	Mass			Mass		
Nephrurus asper (17)	Macrohabitat	Dry woodlands, rocky outcrops	1	Macrohabitat	Heath and woodlands	23
	Microhabitat			Microhabitat	Open/rocky ground	23
	Lifestyle	Terrestrial; saxicoline and terrestrial	1; 20	Lifestyle	Terrestrial	23
	Perch location			Perch location	Ground	23
	SVL	115; 117	1; 12	SVL	86.6 ± 2.15	21
	Mass			Mass	16.18 ± 1.23	21
Nephrurus levis (18)	Macrohabitat	Sandy regions	1	Macrohabitat	Desert	13
	Microhabitat	Dunes with spinifex; open ground, litter	1,8; 6	Microhabitat	Sandy soil	13
	Lifestyle	Terrestrial	1,12,17,18	Lifestyle	Terrestrial	13
	Perch location			Perch location	Ground	13
	SVL	102; 105	1; 12	SVL	62.46 ± 5.21	13
	Mass			Mass	10.02 ± 2.28	13
Oedura castelnaui (19)	Macrohabitat	Widespread, woodlands, rocky outcrops, savannah	1 5,7; 13	Macrohabitat	Woodland	61
	Microhabitat	Dead trees, trunks	5,7	Microhabitat	Trees, logs	61
	Lifestyle	Arboreal; arboreal and terrestrial	1,5; 12	Lifestyle	Arboreal	61
	Perch location	Trunk; PH: 96.3 cm, PD: 16.0 cm	5,7; 25	Perch location	Dead trees	61
	SVL	90; 80.8*; 97	1; 5; 12	SVL	79.91 ± 2.57	31
	Mass	13.3	5	Mass	13.31 ± 0.95	31

Oedura cincta (20)	Macrohabitat	Dry open woodlands, rock outcrops	1	Macrohabitat	Savannah woodland and woodland	65
	Microhabitat			Microhabitat	Trees, rocks, ground	65
	Lifestyle	Arboreal and saxicoline; arboreal	1,12,21; 25	Lifestyle	Generalist	65
	Perch location	PH: 70.4 cm, PD: 18.2 cm	25	Perch location	Trunks, rocks, ground	65
	SVL	110; 108	1,12	SVL	82.36 ± 1.84	12
	Mass			Mass	10.4 ± 0.88	12
Oedura coggeri (21)	Macrohabitat	Dry open woodlands, savannah	1,13	Macrohabitat	Woodland	11
	Microhabitat	Rocks and boulders	1	Microhabitat	Boulders	11
	Lifestyle	Saxicoline; saxicoline and arboreal	1,13; 12	Lifestyle	Saxicoline	11
	Perch location			Perch location	Rocks	11
	SVL	70; 80.4	1; 12	SVL	70.27 ± 2.63	11
	Mass			Mass	7.66 ± 0.79	11
Oedura monilis (22)	Macrohabitat	Dry woodlands; sclerophyll	1,13	Macrohabitat	Woodland	11
	Microhabitat			Microhabitat	Trees and rocks	11
	Lifestyle	Arboreal; generalist	1,12,13,17; 25	Lifestyle	Saxicoline	11
	Perch location	PH: 13.3 cm, PD: 2.9 cm	25	Perch location	Trunks and boulders	11
	SVL	85; 98.1		SVL	82.64 ± 1.71	11
	Mass			Mass	11.35 ± 0.56	11
Oedura tryoni (23)	Macrohabitat	Woodlands, granite outcrops; sclerophyll	1, 3; 13	Macrohabitat	Woodland	15
	Microhabitat	Under bark, rocks	3	Microhabitat	Tree trunks, concrete drainage tunnels	15
	Lifestyle	Generalist; arboreal; saxicolone; terrestrial	12; 18; 13; 22	Lifestyle	Arboreal	15
	Perch location	Rocks and tree trunks	1	Perch location	Man-made structures, trunks	15
	SVL	87	1; 12,13	SVL	82.83 ± 5.11	12
	Mass			Mass	13.51 ± 1.92	12
Phyllurus amnicola (24)	Macrohabitat	Granit boulders in rainforest	1	Macrohabitat	Rainforest	11
	Microhabitat	Creekline boulders	1	Microhabitat	Boulder fields	11
	Lifestyle	Saxicoline; arboreal and saxicoline	1; 12	Lifestyle	Saxicoline	11
	Perch location			Perch location	Rocks	11
	SVL	113	1; 12	SVL	91.6 ± 3.67	10
	Mass			Mass	13.02 ± 2.23	10

Phyllurus nepthys (25)	Macrohabitat	Endemic - rainforest in Clark Range	1	Macrohabitat	Rainforest	22
	Microhabitat			Microhabitat	Trees and rocks	22
	Lifestyle	Arboreal	12	Lifestyle	Generalist	22
	Perch location			Perch location	Trunks and boulders	22
	SVL	103	1,12	SVL	86.24 ± 4.05	21
	Mass			Mass	12.73 ± 1.25	21
Pseudothecadactylus australis (26)	Macrohabitat	Endemic - northern Cape York, woodlands, mangrove forests	1	Macrohabitat	Heath and rainforest, occasionally Woodland	30
	Microhabitat			Microhabitat	Trees	30
	Lifestyle	Arboreal	1,12,13, 26	Lifestyle	Arboreal	30
	Perch location	PH: 380.0 cm, PH: 15.8 cm	25	Perch location	Bamboo/vines, trunks	30
	SVL	120	1,12	SVL	102.88 ± 2.07	16
	Mass			Mass	20.41 ± 1.23	16
Pygopus shraderi (27)	Macrohabitat	Widespread - dry woodlands and open habitats	1	Macrohabitat	Woodland	1
	Microhabitat			Microhabitat	Open ground	1
	Lifestyle	Terrestrial	1,12	Lifestyle	Terrestrial	1
	Perch location			Perch location	Ground	1
	SVL	198	1,12	SVL	112	1
	Mass			Mass	7.64	1
Rhynchoedura ormsbyi (28)	Macrohabitat	Widespread - dry arid regions	1	Macrohabitat	Savannah woodland	11
	Microhabitat			Microhabitat	Open ground	11
	Lifestyle	Terrestrial	1,12,22	Lifestyle	Terrestrial	11
	Perch location			Perch location	Ground	11
	SVL	50	1,12	SVL	38.18 ± 1.34	9
	Mass			Mass		
Saltuarius cornutus (29)	Macrohabitat	Wet tropical rainforests	1	Macrohabitat	Rainforest	22
	Microhabitat	Rainforest trees	1	Microhabitat	Trees	22
	Lifestyle	Arboreal and saxicoline	1,12,23	Lifestyle	Arboreal	22
	Perch location			Perch location	Trunks	22
	SVL	144; 160	1,12	SVL	116.75 ± 6.33	12
	Mass			Mass	30.31 ± 3.4	12
Strophurus ciliaris (30)	Macrohabitat	Widespread, arid shrublands	1,13	Macrohabitat	desert	5
	Microhabitat	Spinifex, shrubs, leaf litter	6	Microhabitat	Trees, shrubs, rocks, ground	5

	Lifestyle	Arboreal; arboreal and terrestrial; scansorial and arboreal;	25; 1,12,18,16; 13	Lifestyle	Generalist	5
	Perch location	PH: 21.8 cm, PD: 3.1 cm	26	Perch location	Trunk, shrubs	5
	SVL	77; 90; 86		SVL	69.8 ± 2.82	5
	Mass			Mass	6.31 ± 0.89	5
Strophurus elderi (31)	Macrohabitat	Arid regions, sandy deserts	1,4,13	Macrohabitat	Savannah woodland	1
	Microhabitat	Spinifex; leaf litter	1 4,8; 6	Microhabitat	Spinifex	1
	Lifestyle	Gramnicolous; arboreal and terrestrial	1,13; 12,16	Lifestyle	Arboreal	1
	Perch location	Spinifex	4,6,8	Perch location	Spinifex	1
	SVL	48; 51	1,13	SVL	44	1
	Mass			Mass	2.47	1
Strophurus krisalys (32)	Macrohabitat	Shrublands, mulga woodlands; arid savannas	1; 13	Macrohabitat	Savannah woodland and woodland	17
	Microhabitat			Microhabitat	Trees, ground	17
	Lifestyle	Arboreal; scansorial	1,26; 12,13	Lifestyle	Generalist	17
	Perch location	PH: 62.9 cm, PD: 1.4 cm	25	Perch location	Tree branches	17
	SVL	70; 76	1; 13	SVL	60.8 ± 3.43	14
	Mass			Mass	4.96 ± 0.63	14
Strophurus taeniatus (33)	Macrohabitat	Northwest highlands, savanna	1; 13	Macrohabitat	Woodland	2
	Microhabitat	Spinifex	1	Microhabitat	Spinifex	2
	Lifestyle	Gramnicolous; arboreal and terrestrial	1,13; 12,16	Lifestyle	Arboreal	2
	Perch location			Perch location	Spinifex	2
	SVL	44; 50	1; 13	SVL		
	Mass			Mass		
Strophurus williamsi (34)	Macrohabitat	Dry sclerophyll woodlands	1,5; 13	Macrohabitat	Heath and Woodland	29
	Microhabitat	Shrubs, bushes	5;7	Microhabitat	Trees and shrubs	29
	Lifestyle	Arboreal; arboreal and saxicoline; scansorial	1,5,17,25; 12,13,24	Lifestyle	Arboreal	29
	Perch location	Thin branches, twigs	5	Perch location	Trunks and branches	29
	SVL			SVL	56.89 ± 1.37	17
	Mass			Mass	4.05 ± 0.35	17

Figure 1. Map of survey sites across Queensland, Australia. (A) Cape York Peninsula, showing the locations surveyed at the Iron Range site. (B) Townsville region with the

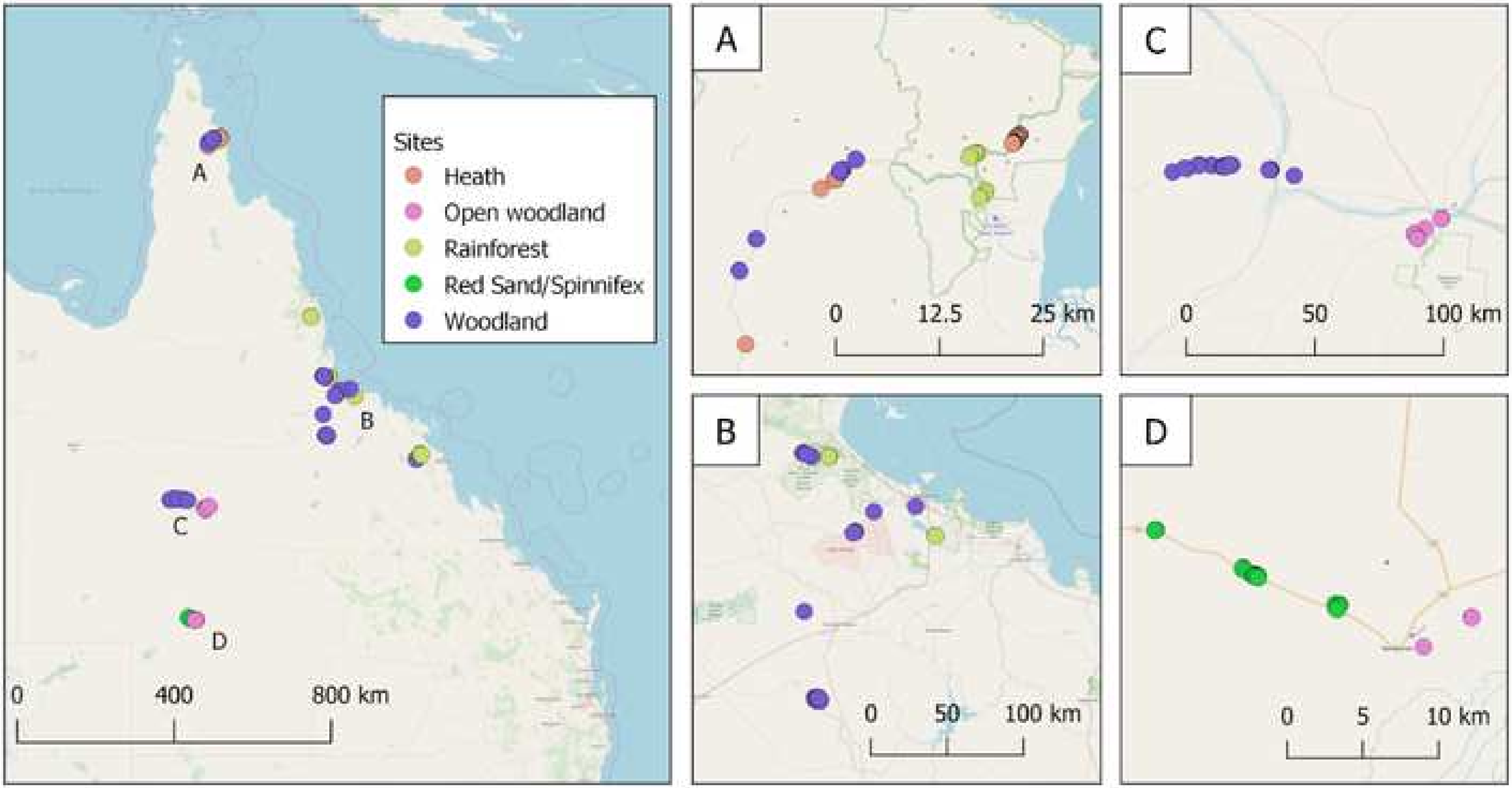

Figure 2. Microhabitat perch locations: log (1), tree trunk (2), primary branch (3), secondary branch (4), tertiary branch (5), grass (6), horizontal on rocks (7), on

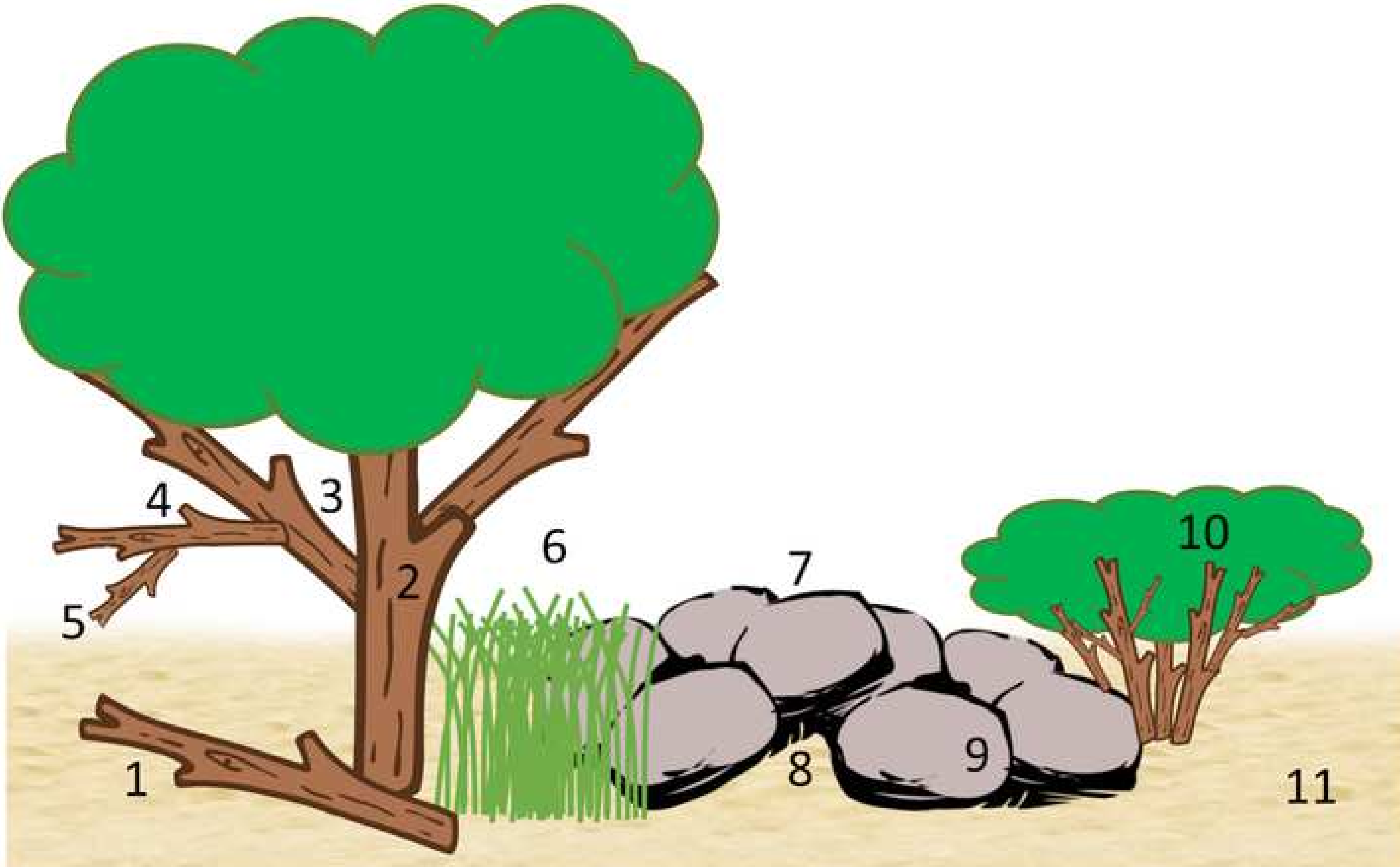

Figure 4. Saxicolous species perch orientation on rocks.

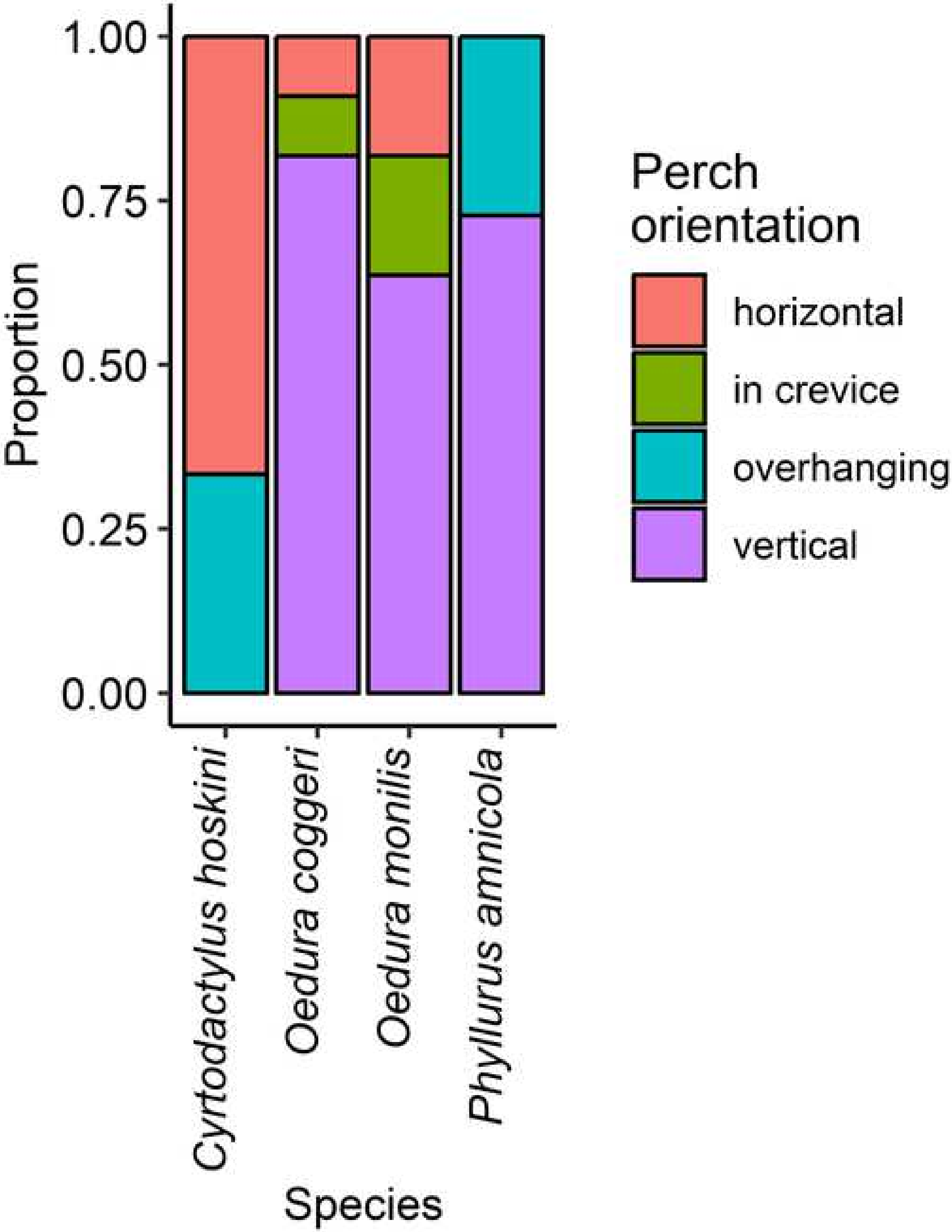

Figure 3. Gecko community perch locations across Queensland, Australia. Arb. = arboreal species, Gen. = generalist species, Sax. = saxicoline (rock-dwelling) species,

Click here to access/download;Figure;Fig 3_perch data.png

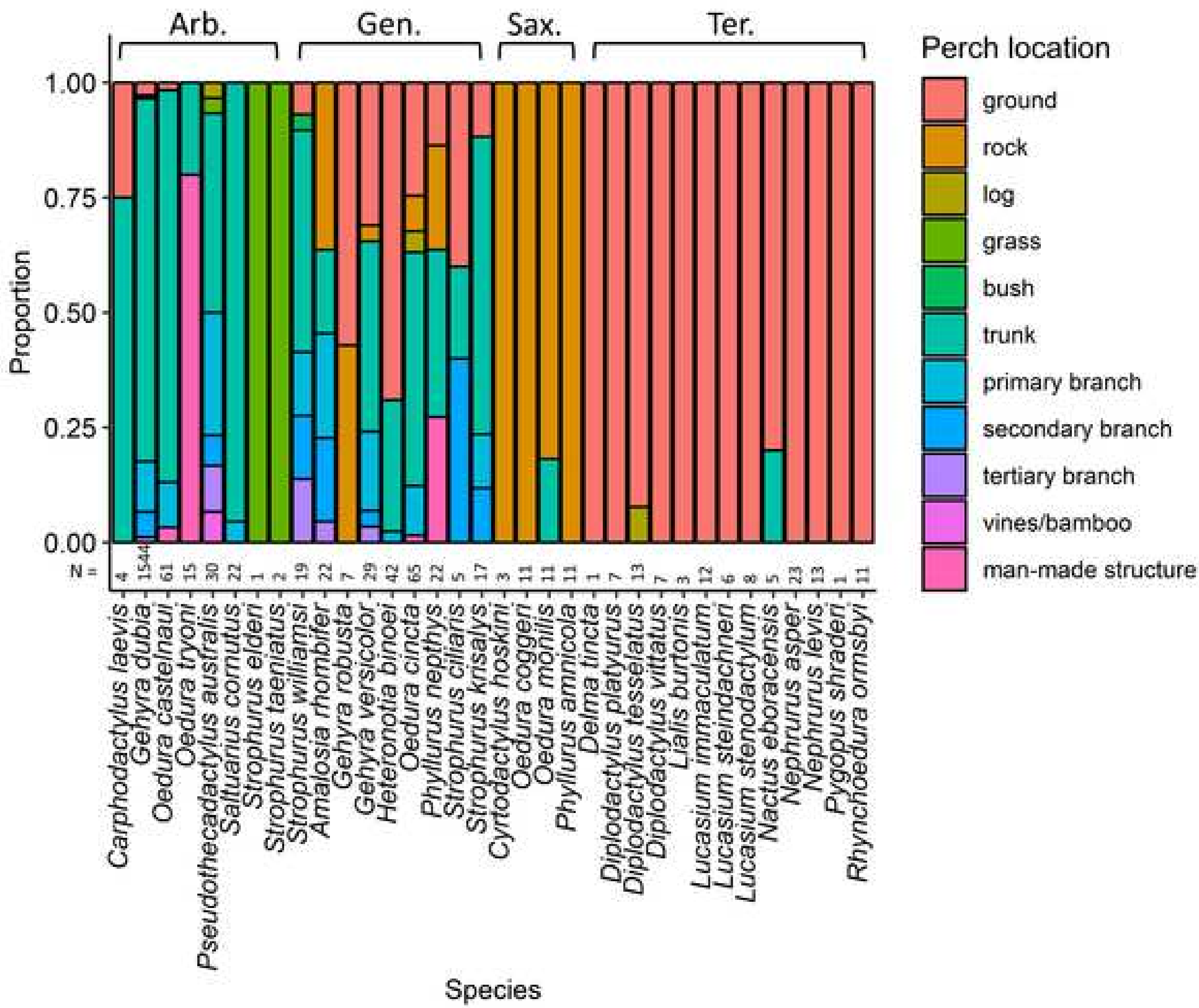

Figure 5: Perch space (height and diameter) used by Australian geckos, overlayed on polygons indicating the range in mean perch spaces occupied by anole ecomorphs