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Diversity and Endemism of Southern African Gekkonids Linked with the Escarpment Has Implications for Conservation Priorities

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Abstract: South Africa is recognised for its high reptile diversity and endemism, specifically among lizards. Phylogenetic diversity, endemism, and richness can have clear implications or raise important questions in a range of fields, and most urgently in conservation. Among squamate reptiles, these indices are very commonly associated with high temperatures and topographic heterogeneity. Indeed, mountainous biogeography has been a critical driver in the radiation of the family Gekkonidae within the subregion. Here, we assess the species richness, diversity, and endemism of Gekkonidae species inhabiting South Africa, Lesotho, and Eswatini, accounting for phylogenetic relationships. We also employ the CANAPE method to identify regions that have neo- and/or paleoendemics. Southern African gekkonids appear to be most diverse and show high levels of endemism in three regions of Southern Africa: the northwestern Richtersveld, the escarpment running west to southeast, and the northeastern escarpment in the Limpopo province. Implications for conservation priorities are discussed.

Keywords: CANAPE; escarpment; phylogenetic diversity; phylogenetic endemism

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1. Introduction

Historical climatic and geological events and phylogenetic biogeography have played essential roles in driving the large-scale distribution or isolation of organisms [1,2]. Highlighting specific regions harbouring exceptional phylogenetic diversity, endemism, and richness can have clear and fundamental conservation implications [3] or raise important questions for investigating major evolutionary and biogeographic events [4] and ecological drivers [5,6]. Squamate reptiles are a diverse group, with approximately 9850 species distributed throughout the globe [7]. Correlations of species richness and diversity among reptiles are commonly associated with high temperatures and topographic heterogeneity [8–10]. Squamate reptiles make excellent models for investigating the evolutionary and biogeographical drivers of species richness and diversification due to their significant range in habitat utilisation, habitat specialisation, and limited dispersal abilities [11,12].

South Africa is a megadiverse country with three global biodiversity hotspots: the Cape Floristic Region, the Maputaland-Pondoland-Albany Hotspot, and the Succulent Karoo. Regarding reptile distributions, compared to other African countries, South Africa has been relatively comprehensively sampled [13]. This area, including Lesotho and Eswatini, is also recognised for its high reptile diversity and endemism [14]. Mountainous biogeography has been a critical driver in the radiation of many reptiles within the subregion [15–18]. The complex topographic landscape has primarily been driven through two unrelated major geological events, namely the upliftment of the Great Escarpment and the Fold Mountains [19,20].

1.1. Gekkonid Diversity

The Southern African gekkonids are one of the most diverse and highly endemic groups of reptiles within the region, consisting of 86 recognised species from 12 genera (Figure 1). Of these, ~75% species and 5 genera are thought to be endemic or near-endemic to the region [14,15].

Afroedura Loveridge 1944 is a species-rich genus distributed throughout Southern Africa, extending northwards into Angola. Currently, there are 34 species [21], with several awaiting description. The genus primarily comprises rock-dwelling, montane species, except for a few arboreal species (e.g., *Afroedura loveridgei* and *Afroedura marleyi*) [14,21,22]. Three major clades are present within *Afroedura*, predominantly along the isolates of the Great Escarpment, with some members occupying coastal plains or the Cape Fold Mountains [15].

A monotypic genus, *Afrogecko* Bauer, Good & Branch, 1997, has a unique taxonomic past. Two subspecies, *Phyllodactylus porphyreus cronwrighti* and *Phyllodactylus porphyreus namaquensis*, neither of which is currently recognised [14], require further investigation due to strong genetic differences, thus making *Afrogecko porphyreus* a species complex [23]. There remains a strong likelihood of cryptic taxa within the *Afrogecko porphyreus* complex [23]. No new material on the *P. p. namaquensis* has been collected to confirm its status. *Afrogecko porphyreus* is restricted to southwestern South Africa. It is predominantly rupicolous; however, some populations occupy vegetation within the coastal plains [22].

The genus *Chondrodactylus* W. Peters, 1870 consists of large geckos, most of which are rupicolous, with some also displaying arboreal behaviour. Four species are present within South Africa [24], predominantly distributed inland of the Great Escarpment. A single member of the genus, *Chondrodactylus angulifer,* is a terrestrial burrower and has evolved accordingly [25,26].

The monotypic genus of leaf-toed geckos, *Cryptactites* Bauer et al., 1997 is a low-altitude coastal endemic. Its only species, *Cryptactites peringueyi*, is a small terrestrial and semi-arboreal gecko utilising coastal vegetation in a small range of the Eastern Cape province [27]. Its restricted range and poor phylogenetic diversity make this lineage the country's most range-restricted gecko genus.

Another group of small leaf-toed geckos are from the genus *Goggia* Bauer, Good & Branch, 1997. This near-endemic group consists of 10 species restricted to southern and northwestern South Africa. The genus consists of rupicolous and often mountainous genera, except for two species, *G. lineata* and *G. incognita*, which are found in shrub or fynbos in open vegetation types [22,28].

The most species-rich genus, *Hemidactylus* Oken, 1817, is widely distributed throughout the globe. Despite high diversification of *Hemidactylus* across the Afrotropic and subtropical regions, only a single species, *Hemidactylus mabouia*, is found within the borders of South Africa. The species is a generalist and occupies mountainous, inland, and coastal habitats [14,22]. They are successful invaders throughout the country and on a global level [12,14]. It is predominantly rupicolous; however, as with most rupicolous species within the region, it displays arboreal behaviour, and is, additionally, well-adapted to urban environments [22].

The genus *Homopholis* Boulenger, 1885 consists of four large-bodied, soft-skinned species. They are widely distributed, except for *Homopholis mulleri*, which is restricted to the northern extent of the Soutpansberg Mountains in Limpopo, South Africa.

Within the region, *Lygodactylus* Gray, 1864 consists of 11 species [22]. Many species have limited ranges, with several restricted to a single massif or mountaintop [14,22]. Radiation among *Lygodactylus* took place in two major clades, an Afromontane (greater Drakensberg) clade and a savanna-dwelling clade (except for a single montane species, *L. bernardi*, from Zimbabwe) [16]. *Lygodactylus capensis*, a widespread species from the savanna clade, is one of the most successful invaders within the country. The species has successful colonies throughout many western cities and towns far outside its natural range [29].

The most species-rich gekkonid genus within the region is that of *Pachydactylus* Wiegmann, 1834, which consists of 29 species. Radiation and endemism within the group were likely driven due to substrate specialisation in many species and historical vicariant events [30]. This group displays major differences in size [31], morphology [25,32], and geographical and environmental niches among species [28].

A single species of *Ptenopus* Gray, 1866 occurs within South Africa, with the remaining two species restricted to Namibia. The genus is known to predominantly occupy savanna, scrubland, and desert habitats [14,22]. They are commonly known to utilise characteristic burrows, often within loose soils, from where males call [33]. Intraspecific diversity among South Africa's only species, *Ptenopus garrulus,* is likely, with two subspecies currently recognised.

The genus *Ramigekko* Heinicke et al., 2014 consists of a single species, *Ramigekko swartbergensis*, which is a sizable rupicolous gekkonid restricted to the high mountain tops of the Klein and Groot Swartberg Mountains, within the Cape Fold mountain range [14,34–36]. The genus, which forms part of the circum-Indian Ocean leaf-toed geckos, was elevated from the now monotypic genus *Afrogecko* by Heinicke et al. [23]. Its closest living relative is the coastal endemic and monotypic genus, *Cryptactites*. The entire geographic range of the genus occurs in a predominantly inaccessible protected area, thus facing no major anthropogenic threats.

Another monotypic gecko, *Rhoptropella* Hewitt, 1937, a close relative of the Day Geckos—*Lygodactylus*, is another rupicolous genus. The small Namaqua Day Gecko—*Rhoptropella ocellata*, is restricted to mountain ranges in northwestern South Africa and southern Namibia [14]. This species is the only naturally-occurring diurnal gekkonid within this far-western arid region [22].

It is evident that there is exceptional diversity and endemism of gekkonids within the Southern African countries. Furthermore, with the group comprising several monotypic genera and genera with few species, it is essential that conservation measures are put in place to conserve phylogenetic diversity.

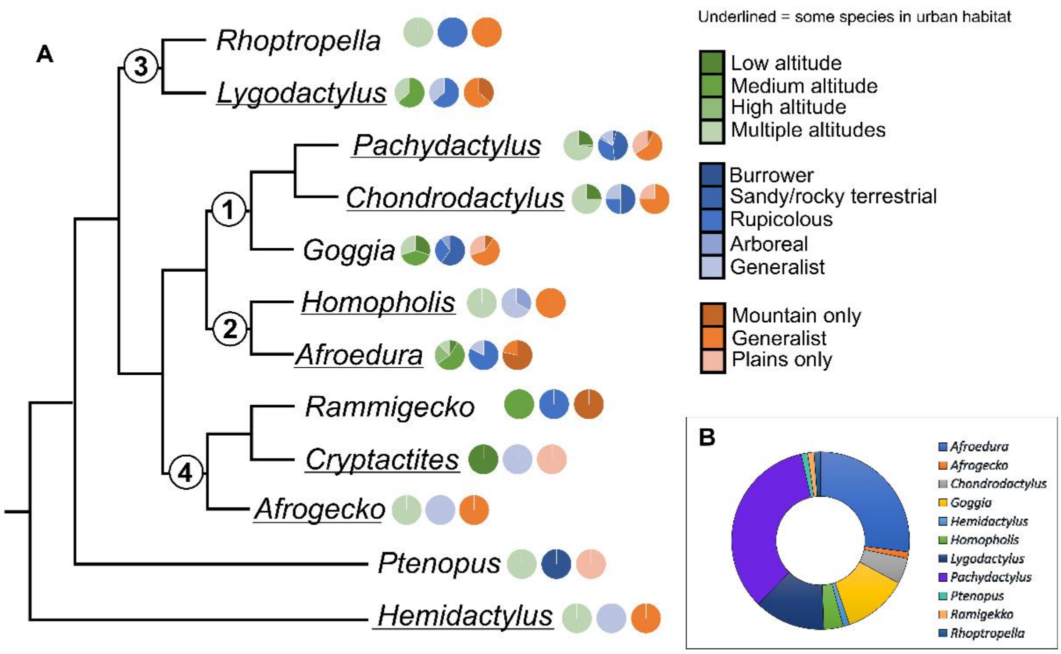


Figure 1. *Cont.*

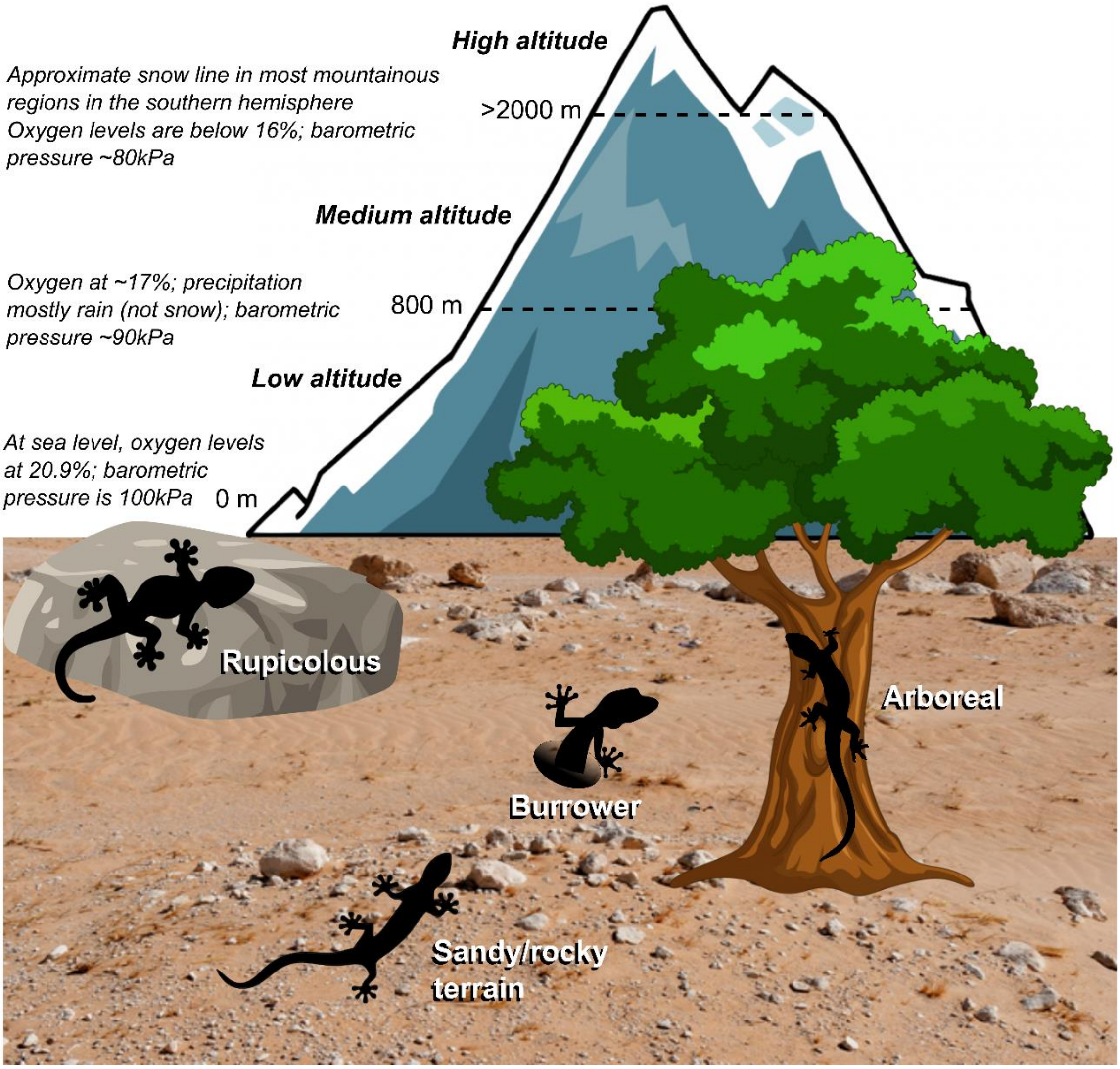


Figure 1. Representations of gekkonid genera within South Africa: (**A**) Simplified phylogenetic representation of the genera, constructed from the phylogeny produced in this study and from various published gekkonid phylogenies [15,37–41]. Numbers at the nodes indicate the Clade number (as in Figure S1). Pie charts at the tips indicate the number of species within the genus that inhabit various altitudes (green pie charts), the general habitat in which the species are found (biotopical preferences, blue pie charts), and the habitat specialisation of the species (orange pie charts). Genera that are underlined have species that enter in Red List (https://www.iucnredlist.org/; accessed on 17 December 2022). (**B**) Donut chart to the urban environment. Information for the pie charts was obtained from the species accounts in the *IUCNshowing the number of species from each genus present in South Africa, Lesotho, and Eswatini. The illustration below details the biotopical preferences and altitudinal zone distinctions.*

1.2. Conservation

A comprehensive assessment [42] estimating the extinction risk of reptiles found that ~21% are threatened with extinction. Conservation measures are often implicated in areas of high diversity and species richness [43,44], or specifically implemented for species of conservation concern (e.g., the establishment of the Mountain Zebra National Park (South Africa) in 1937, to protect the Mountain Zebra). However, phylogenetic diversity is often overlooked when assessing and planning conservation networks. Protected areas are critical for mitigating further biodiversity loss [45,46]. South Africa is a global leader in science-based conservation strategies [47–50]. The protected area network covers approximately 9% of South Africa's mainland surface area [51], and it is essential for conserving the diverse fauna and flora, maintaining livelihoods, economic development, and preserving many ecological services. Despite the sizable protected area network and protected area expansion plan [52], it is insufficient in protecting South Africa's threatened reptiles [53]. Fortunately, despite the high endemism and restricted distribution of many South African gekkonids [14], only a few taxa are listed under a threatened category in the *IUCN Red List*, these being *Afroedura multiporis* [54] and *Homopholis mulleri* [55], which are listed as Near Threatened, and a single Endangered species, *Lygodactylus methueni* [56].

1.3. Study, Research Question, and Aims

Due to the substantial diversity, habitat specialisation, and endemism within this group, gekkonids are an ideal biological model to assess the spatial pattern of diversity and endemism associated with elevation in the region. Sampling from Southern African countries (South Africa, Lesotho, and Eswatini), the phylogenetic relationships, diversity, and endemism of the sampled gekkonid species were investigated. We aimed to (1) identify areas of significant gekkonid species richness and phylogenetic diversity, and (2) assess which areas are protected or are important to conserve gekkonid species richness and phylogenetic diversity.

2. Materials and Methods

2.1. Map Production

Data for the distribution of gekkonids within South Africa, Lesotho, and Eswatini (hereafter referred to as Southern African countries) were obtained from the literature, GBIF (https://www.gbif.org/, accessed on 17 December 2022), museum data, and citizen science platforms, such as the Animal Demography Unit's Virtual Museum (https://vmus.adu.org.za/, accessed on 17 December 2022) and iNaturalist (https://www.inaturalist.org/, accessed on 17 December 2022). A dataset was compiled for each species and the corresponding Quarter degree Squares (QDSs) in which they occur. A single shapefile per species of the 12 genera occurring within the sub-region and their corresponding QDS in which they are found were imported into QGIS (QGIS LTR) [57]. The shapefiles of each species were given an opacity of 15, which allowed for species richness maps of each genus to be generated.

The centroid GPS points for each QDS for the Southern African countries were compiled. Surface plots of elevation and species numbers were created in RStudio v.2022.07.2 and R v.4.2.1 [58]. The elevation at each of those GPS coordinates was obtained (package: elevatr; function: get_elev_point; prj: EPSG:4326; src: aws) [59]. The GPS points that were located below sea-level were removed from the DataFrame. A surface plot was created, plotting the elevation or the number of gecko species at each GPS point for the three countries (package: plotly; functions: plot_ly, add_surface) [60].

2.2. Phylogenetic Tree Construction

A phylogenetic tree of the gekkonid species found in the Southern African countries was constructed using a concatenated dataset of nucleotide sequences obtained from GenBank (https://www.ncbi.nlm.nih.gov/, accessed on 17 December 2022; Table S1). Three partial-coding gene regions were used: (1) mitochondrial NADH dehydrogenase subunit 2 (ND2), (2) nuclear recombination-activating gene 1 (RAG1), and (3) nuclear phosducin (PDC) genes. The sequences were aligned using ClustalW within MEGA X [61]. No saturation was found using the program DAMBE v.6.4.81 [62], so each gene region was used as a separate partition in the dataset. The GTR+G+I model of nucleotide substitution was used for each gene region. The phylogenetic tree was estimated using Bayesian inference in MrBayes v.3.2.7 [63]. Two chains were run for 10 million generations, at a sampling frequency of 1000, and the trees were summarised using a 10% burn-in. The ESS values were checked in Tracer v.1.6.0. [64]; all values were above 200, and the runs reached convergence.

2.3. Diversity and Endemism Estimates

Traditional diversity estimates utilise species counts and richness estimates; however, they do not take the evolutionary history of the species into account. Thus, estimates of diversity and endemism that consider evolutionary relationships and time since divergence into account have become popular in the past few decades (phylogenetic diversity [65] and phylogenetic endemism [66]). By using a phylogenetic estimate of divergences between taxa, we can determine areas that have a diversity that is either newly originated (neoendemics have shorter branch lengths) and range-restricted, or older range-restricted groups (paleoendemics have longer branch lengths) [67]. See [68] for descriptions of each index.

Diversity estimates were mapped using the program BioDiverse v.4.0 [69]. Various blog posts and instructions can be found on the software developer's website: https://shawnlaffan.github.io/biodiverse/. The phylogenetic tree produced in this study was exported from Figtree v.1.4.3 (http://tree.bio.ed.ac.uk/software/figtree/, accessed on 17 December 2022) in Newick format and imported into BioDiverse. The presence of each species was indicated by the QDS centroid GPS point, and the tabulated list of GPS coordinates for each species (86 species out of 91 Southern African gecko species) was imported into BioDiverse, resulting in 1504 equal-area square grid cells (250 × 250 km) covering the Southern African countries. Diversity and endemism indices were estimated: Taxonomic Richness (TR), Shannon Diversity Index (SD), Weighted Endemism (WE), and Corrected Weighted Endemism (CWE) [70]. Diversity and endemism indices, taking phylogeny into account, were estimated: phylogenetic diversity (PD) [65], phylogenetic endemism (PE) [66], relative phylogenetic diversity (RPD) [67], and relative phylogenetic endemism (RPE) [67]. Phylogenetic diversity and endemism estimates on their own are not very informative, and thus a total of 999 iterations were run using the rand_structured model, recalculating the PD, PE, RPD, and RPE surfaces for each iteration. Indices in the highest 2.5% or the lowest 2.5% of the distribution were considered significant (two-tailed test). The QDSs that had significant neoendemics, paleoendemics, or a mixture of both were identified by using the Categorical Analysis of Neo- and Paleo-Endemism (CANAPE) [67] method conducted in the BioDiverse program from the iterations run using the rand_structured model.

3. Results

3.1. Generic Distribution

The 12 gekkonid genera that inhabit the Southern African countries tend to be distributed along the coastal plains (e.g., *Cryptactites, Afrogecko,* and *Goggia*), along the escarpment (*Afroedura, Goggia,* and *Homopholis*), and more widely distributed on the interior plateau (the remaining genera) (Figure 2). Three genera (*Afrogecko, Cryptactites,* and *Ramigekko*) are monotypic, range-restricted, and endemic to the region (Figure 2), and, interestingly, they are sisters (Figures 1 and S1). These three genera occur along the coastal plains and the fold mountains in the south and west of South Africa (known as the Cape Fold Mountains). The other monotypic genus, *Rhoptropella*, is also range-restricted although it does occur near the border of South Africa, and it enters into Namibia. There appears to be an evident east–west divide between and within the genera, with few species inhabiting the grassland biome in the central part of South Africa and the high elevation Lesotho region in the east (Figures 2 and 3). QDS squares that had a centroid >2000 masl tended to have fewer than 5 species, and those at >2200 masl had either 1 or 2 species (species of *Afroedura* and *Pachydactylus*). Species richness is highest in the western and eastern extent of the Great Escarpment, with similar, yet less impressive, species richness being found across the Cape Fold Mountains in the southwest of South Africa (Figure 3). Species richness is largely derived from four speciose genera, namely *Afroedura* and *Lygodactylus* in the east, and *Goggia* and *Pachydactylus* in the west and south. However, radiation from *Afroedura* in the southern Great Escarpment did contribute to the diversity of this region. Less species-rich genera (*Chondrodactylus*, *Hemidactylus*, *Homopholis*, and *Ptenopus*) were found to be widely distributed, while monotypic genera (*Cryptactites*, *Ramigekko*, and *Rhoptropella*), with the exception of the *Afrogecko* species complex, had restricted ranges.

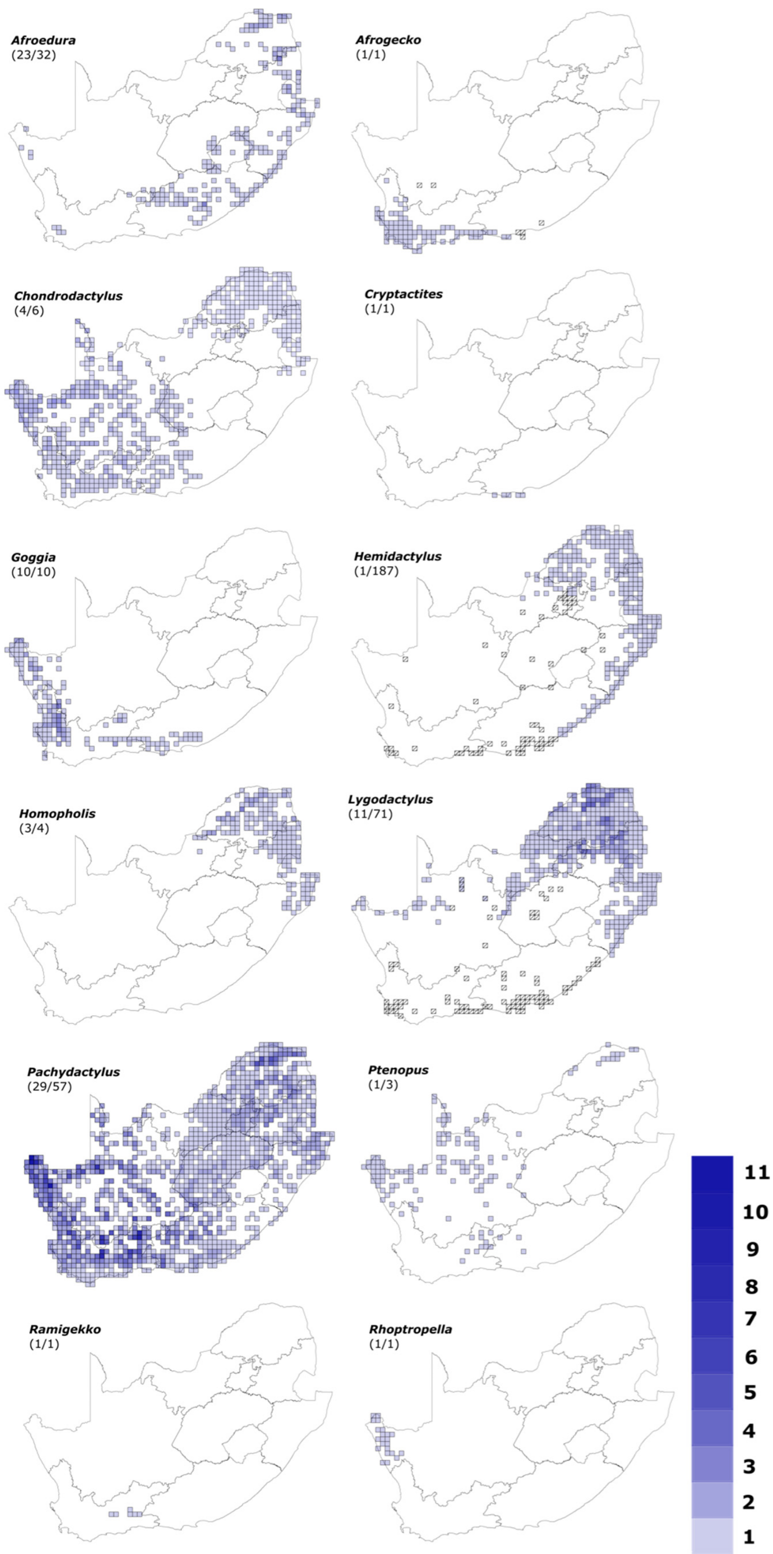


Figure 2. Species richness of gekkonid genera (shown separately) in South Africa, Lesotho, and Eswatini. Values in brackets indicate the number of species within the region relative to the number of species within the genus.

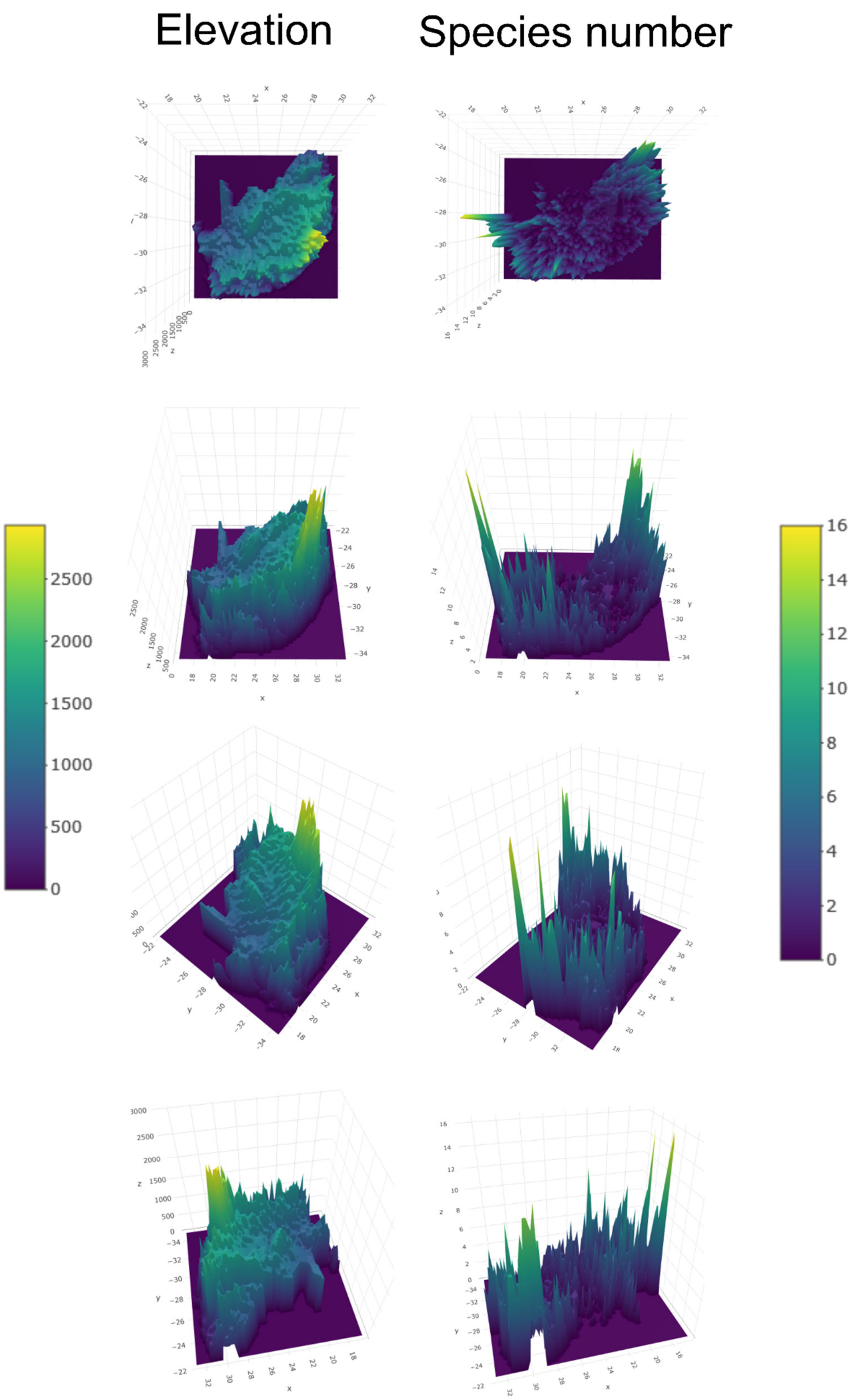


Figure 3. Surface plots of the elevation (**left**) and gekkonid species numbers (**right**) at each QDGS centroid position for the countries of South Africa, Lesotho, and Eswatini. These 3D surface plots are viewed from above (1st plots), the south (2nd plots), the west (3rd plots), and the north (4th plots).

3.2. Phylogenetic Relationships between Southern African Gekkonids

Phylogenetic relationships between gekkonid species inhabiting South Africa, Lesotho, and Eswatini in this study match previously published phylogenies of lizards (e.g., [15,37–41]; Figures 1 and S1). As with most phylogenies of gecko taxa (e.g., [41]), the deeper nodes could not be resolved, and form a polytomy. The nodes basal to the genera are resolved, making the genera monophyletic, and there are only a few unresolved relationships within the genera *Pachydactylus* and *Afroedura*. *Pachydactylus* and *Chondrodactylus* are sisters, and they are sisters to *Goggia* (Clade 1). *Afroedura* and *Homopholis* are sisters (Clade 2), and this clade is sister to Clade 1. *Lygodactylus* and *Rhoptropella* are sisters (Clade 3), and Clade 4 contains the monotypic, range-restricted, and endemic genera *Cryptactites*, *Ramigekko*, and *Afrogecko*. *Hemidactylus* and *Ptenopus* are sisters (although this relationship is not supported).

3.3. Gekkonid Diversity and Endemism

There is a high diversity of gekkonids in the northeast of South Africa (in the Limpopo province) in terms of species numbers (Figure 3), species richness (Figure 4A), traditional diversity (Figure 4B), and phylogenetic diversity (Figure 4C). This region also has a relatively high number of endemic species (Figure 5), and parts of this region have a number of QDSs that have mixed endemism, and there is a hotspot of neoendemics in the lower-elevation areas between the Soutpansberg range and the northern extent of the Drakensberg mountain range. The interior plateau has poor species richness, diversity, and phylogenetic diversity (Figures 3–5), and, in fact, lower-than-expected endemism (Figure 5E,F), with no endemics (neither neo- nor paleoendemics; Figure 6) found in this region. While the eastern escarpment does not have a high species richness, diversity, or phylogenetic diversity, the region near the Amathole–Stormberg mountain range in the southeastern escarpment has a high level of mixed endemics (Figure 6). The south coast near Port Elizabeth (now called Gqeberha) exhibits high levels of diversity (Figure 4), endemism (Figure 5), and mixed endemism (Figure 6). The escarpment running along the south and west of South Africa appears to have a high diversity (Figure 4B) and relatively high levels of endemics (Figure 5A–C), with a few areas exhibiting high levels of mixed endemism. The Richtersveld in the northwest of South Africa appears to have high levels of diversity and endemism (Figures 3–5). Most of the region exhibits mixed levels of endemism, and the only QDS in Southern Africa found to have paleoendemics is located within this region.

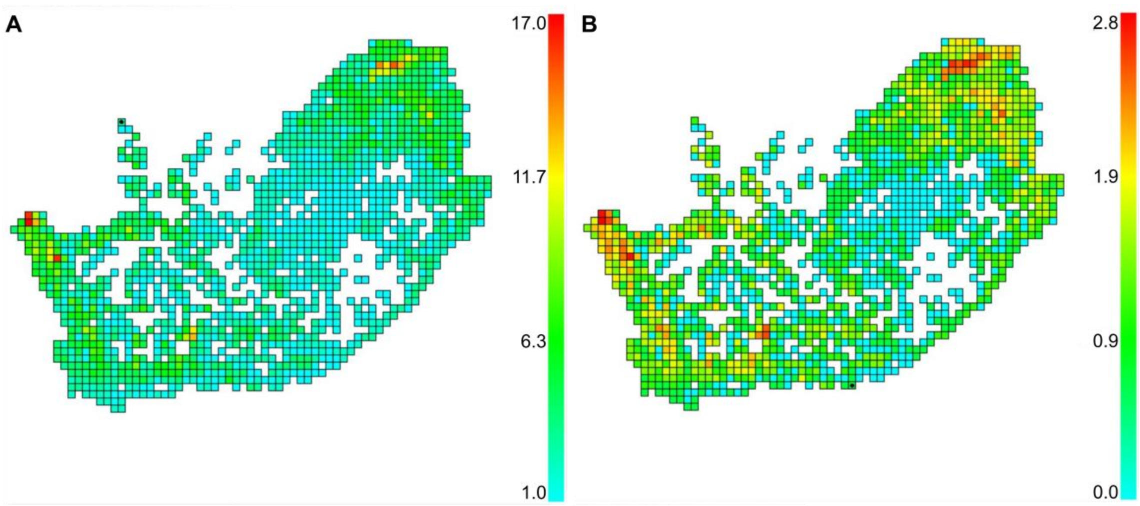


Figure 4. *Cont.*

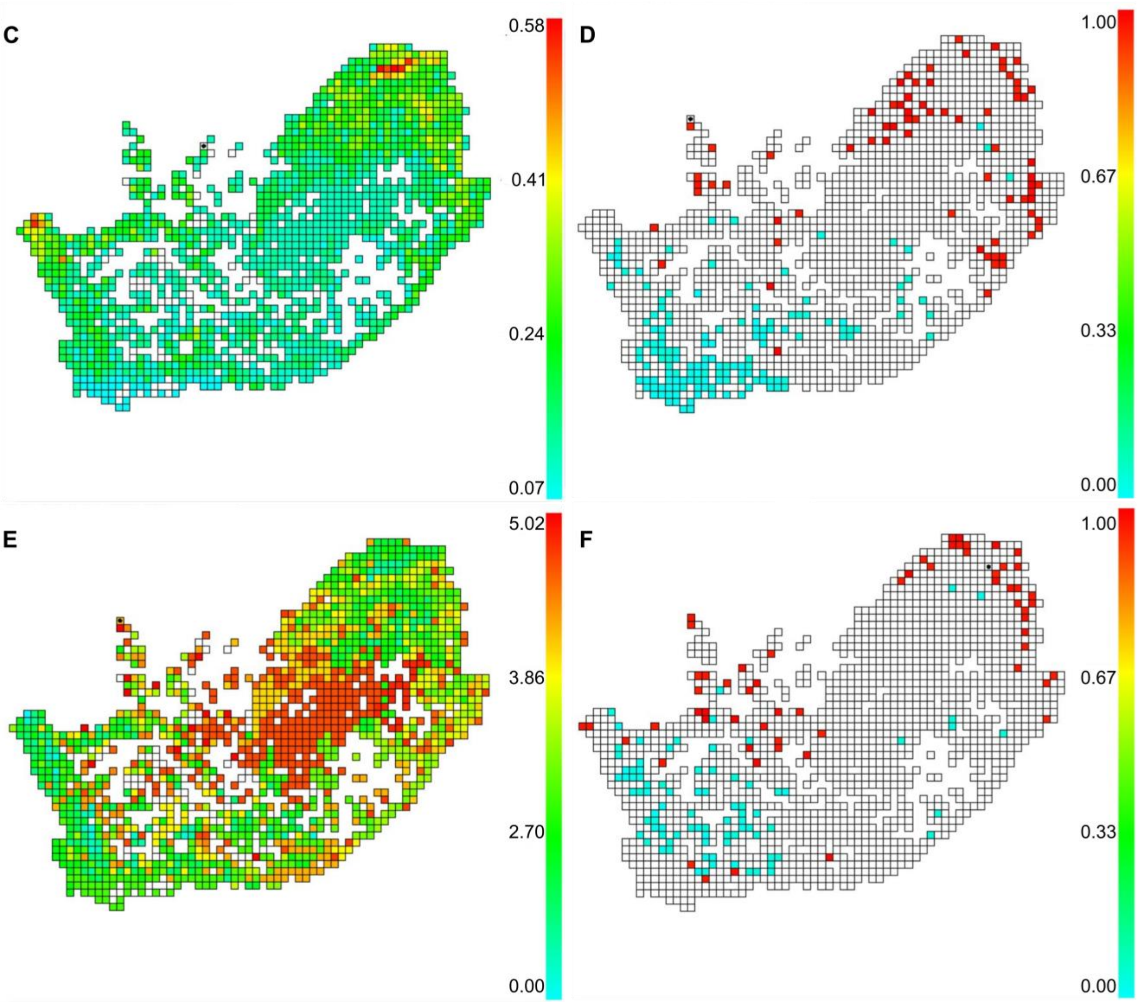
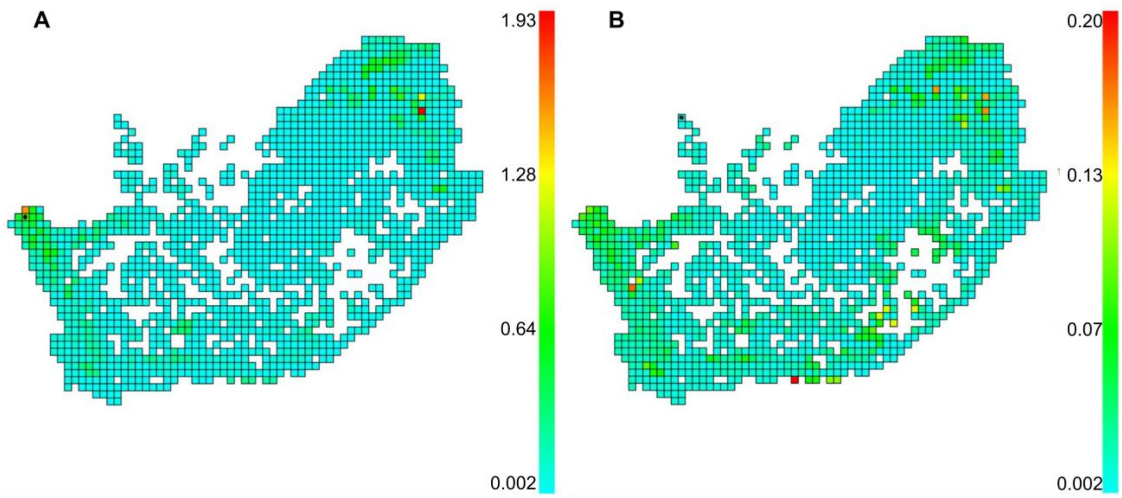


Figure 4. Maps of various diversity and endemism indices: (**A**) Taxonomic Richness (TR), (**B**) Shannon's Diversity index (SD), (**C**) Phylogenetic Diversity (PD), and (**E**) Relative Phylogenetic Diversity (RPD). Maps showing significance levels resulting from a randomization test for (**D**) PD and (**F**) RPD. The red values indicate grid cells that contain significantly less PD/RPD than expected; the blue values indicate grid cells that contain significantly more PD/RPD than expected.



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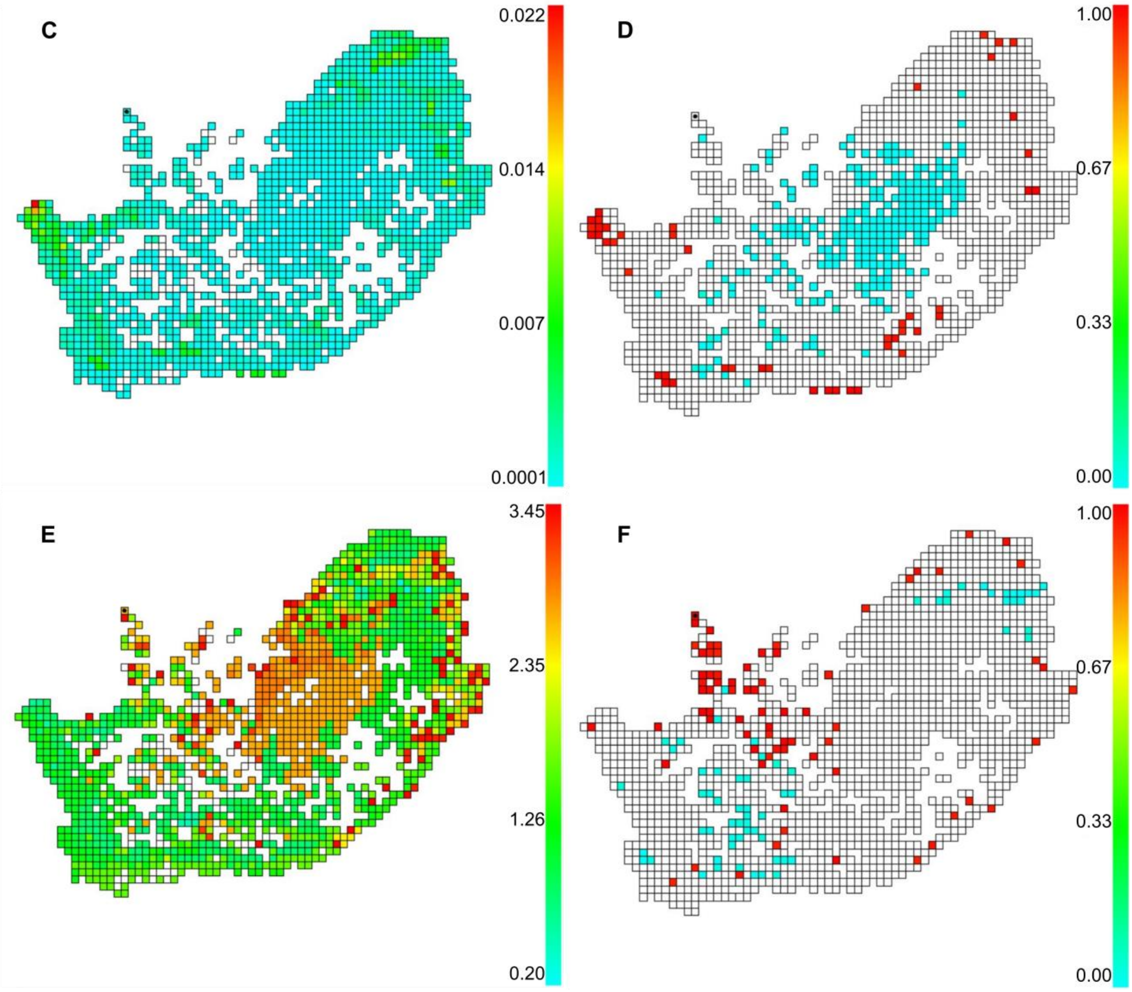

Figure 5. Maps of various diversity and endemism indices: (**A**) Weighted Endemism (WE), (**B**) Corrected Weighted Endemism (CWE), (**C**) Phylogenetic Endemism (PE), and (**E**) Relative Phylogenetic Endemism (RPE). Maps showing significance levels resulting from a randomization test for (**D**) PE and (**F**) RPE. The red values indicate grid cells that contain significantly less PE/RPE than expected; the blue values indicate grid cells that contain significantly more PE/RPE than expected.

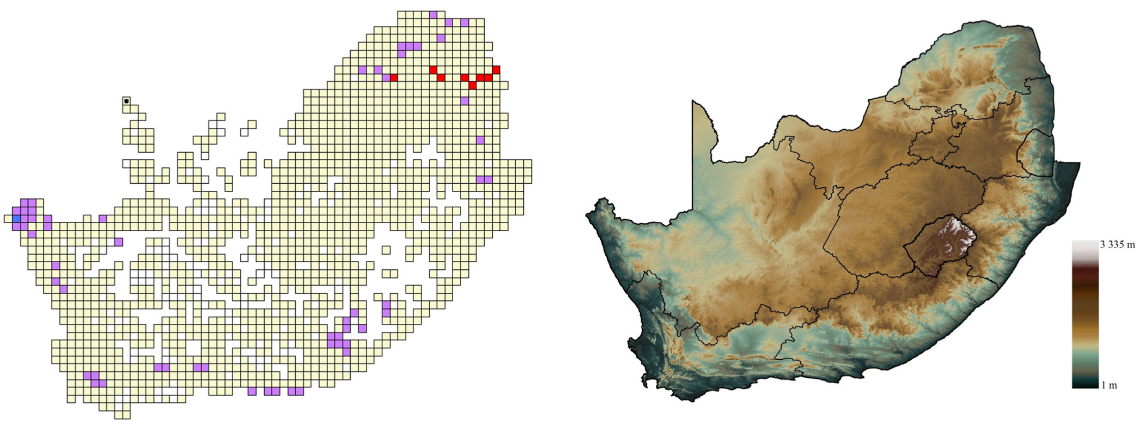

Figure 6. CANAPE results: Map showing QDGS squares within the Southern African countries that exhibit neoendemism (red), paleoendemism (blue), and mixed endemism (purple) levels of gekkonids. Topographical map of the Southern African countries shown on the right (created by G.K.N.).

4. Discussion

Spatial gradients of species richness, diversity, and endemism in gekkonids that inhabit the Southern African countries appear largely driven by historical, geological, and ecological factors, such as topology and climate. Endemism is present predominantly among rupicolous species in heterogeneous mountainous landscapes formed through the upliftment of the Great Escarpment and the Cape Fold Mountains. The areas highlighted with high endemism and diversity are critical areas for investigating ecological drivers in macroecology. More information collected regarding our threatened geckos and areas of importance allow for thorough and decisive conservation decision making and can act towards protecting the broader ecosystems in which these organisms occur [71].

4.1. Diversity, Species Richness, and Endemism

It has long been recognised that merely using a measure of diversity by counting species numbers is not adequate to accurately ensure that evolutionarily significant species are conserved, and that the diversity of a region should be investigated taking evolutionary history into account, using, for example, a measure of phylogenetic diversity (PD) [65,72–74]. By incorporating species differences, not just species numbers, into conservation priorities, those species that are evolutionarily distinct are prioritised—i.e., the "quality" (i.e., taxonomic distinctiveness), not quantity, of species are conserved [74,75]. In addition, the degree of endemism of a group has been a major consideration in biogeographic studies [76,77], as endemism relates to the idea of irreplaceability [78]. Endemism has been measured initially as the restriction of a taxon to a particular region (traditional endemism), the degree of restriction of a taxon-range on a quantitative scale (relative endemism) [70], and the geographic restriction of clades at any taxonomic level (phylogenetic endemism (PE) [66–68].

For the most part, investigations into neo- and paleoendemism have been performed on flora assemblages; however, a global assessment of land vertebrates using the CANAPE method highlighted the squamate hotspots along the southern African escarpment (Figure 1E in [79]). These hotspots have been retrieved in the southern African gekkonid diversity analyses done in this study. In addition, the diversity pattern found in this study for gekkonids reflects that which is found for all lizards in southern Africa (Figure 3.12 in [14]), though highly endemic gekkonid species were not found in the Western Cape province, as found when investigating all southern African lizards (Figure 3.13 in [14]). Globally, elevation range as a proxy of habitat heterogeneity was the second strongest predictor of, and significantly positively correlates with, phylogenetic endemism, especially for amphibians and reptiles [79], which corroborates the understanding that elevation promotes endemism due to spatial divergence and habitat heterogeneity [80,81]. It is, therefore, perhaps not surprising that high levels of endemism in southern African gekkonids are found in association with the escarpment and the Snowberg mountain range although the hotspot of neoendemics in the lower elevation region between two mountain ranges in the Limpopo province warrants further investigation.

4.2. Conservation Considerations

A recent conservation status assessment shows that, within South African borders, there is very little protection regarding species of conservation concern, and the future of many threatened taxa is exceptionally tentative [54]. Species diversity and distribution is often relative to abiotic factors, such as topography and climate [82,83]. Changes in global temperatures, and the subsequent effects on ectothermic organisms, are predicted to be substantial [83]. The restricted distribution of the region's geckos (and especially of the range-restricted monotypic genera), the lack of conservation efforts towards threatened reptiles, and the predicted impacts from climate change make it fundamental that we clearly understand critical biodiversity areas and gaps in our current body of knowledge.

For the most part, reptiles have generally not been considered in the greater conservation network in South Africa, and many threatened species remain unprotected [54]. Identifying critical biodiversity areas (CBA) or key biodiversity areas (KBA) with high gecko diversity would aid in safeguarding the greatest diversity. We have identified three major mountainous areas critical for conserving gekkonid diversity. These areas of high species richness and endemism fall within the Succulent Karoo (the greater Richtersveld region in northwestern South Africa), the Cape Floristic Biodiversity Hotspot (in several areas of the Cape Fold Mountains), and isolated mountains in northeastern South Africa. Many of these areas already fall within formally protected areas. Species of conservation concern (*Afroedura multiporis* (NT); *Homopholis mulleri* (NT); and *Lygodactylus methueni* (EN)) all occur within the areas of high gekkonid diversity (>7 species per QDS) in the northeastern part of South Africa. Thus, conservation efforts in the Limpopo province for these species would lower their threat status and indirectly assist in conserving significant gekkonid diversity. Conservation of critical biodiversity areas, looking at diverse, restricted, and threatened organisms, such as our geckos, is a crucial aspect of identifying priority areas. In South Africa, the National Protected Area Expansion Strategy (NPAES) was proposed in 2008, and in the subsequent decade, an expansion of protected areas was implemented, expanding the areas protected from ~3% to ~9.2% of the mainland (Figure 7). While the northeastern escarpment was identified in the NPAES, given the results of the gekkonid diversity assessment performed here, it would be worth focussing on protection for this region in future expansions. The paleoendemic gekkonids found in the northwestern parts of South Africa could also be used as a reason for the southward expansion of the /Ai/Ais-Richtersveld Transfrontier Park.

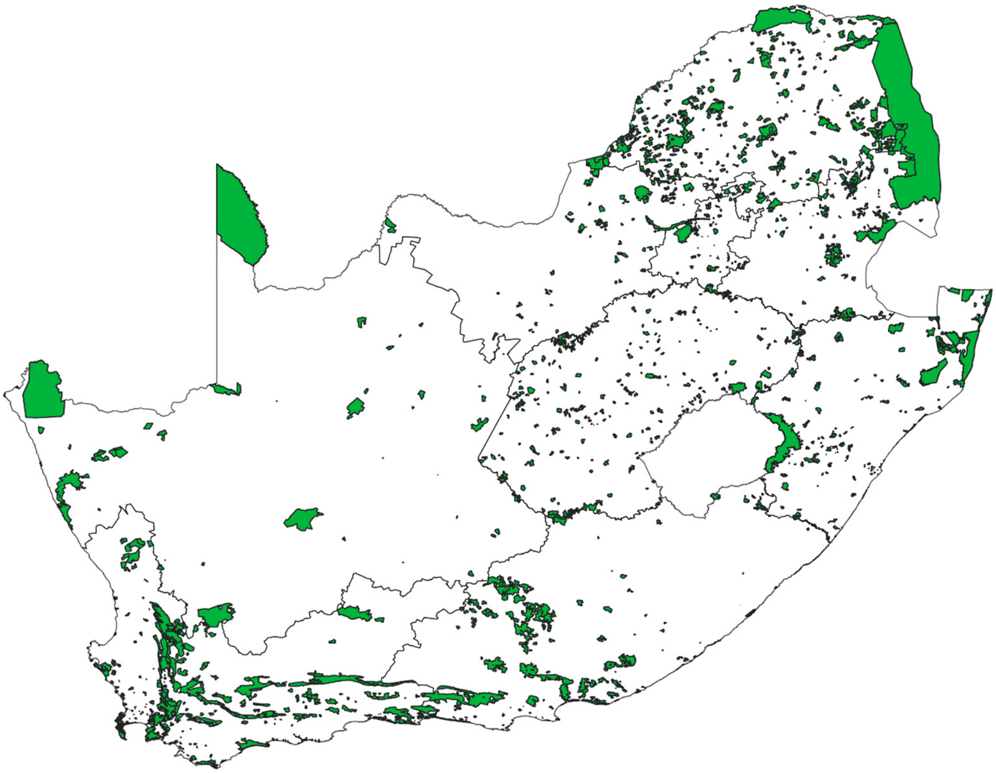

Figure 7. Map of all formally protected areas (green) within South Africa (created by G.K.N.).

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/d15020306/s1, Figure S1: Phylogeny of the gekkonid species that occur in South Africa, Lesotho, and Eswatini, estimated using Bayesian inference. Squares shown indicate the posterior probability at the node, colour-coded as in the scale inset, top-left.; Table S1: Table of gekkonid species found in the Southern African countries, and the genetic sequences obtained from Genbank used in the phylogenetic tree production. All gecko species found in Southern Africa are listed in this table, and those species that did not have genetic information for the three gene regions are indicated by "no seq" or "NS").

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