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**RESEARCH ON THE DIVERSITY AND DISTRIBUTION
CHARACTERISTICS OF SPECIES IN THE FAMILY
GEKKONIDAE IN THE CENTRAL HIGHLANDS
OF VIETNAM**

SUMMARY OF THE DOCTORAL THESIS

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The thesis can be found at the following libraries: the Library of National and the Vietnam National University of Forestry.

INTRODUCTION

1. Rationale

The family Gekkonidae (geckos) is recognized as one of the most speciose groups of squamate reptiles, with approximately 1,658 species recorded worldwide (Uetz et al., 2025). They exhibit a wide geographic distribution, occupy highly diverse habitats, and demonstrate remarkable adaptability to various ecological niches and geographic conditions.

The Central Highlands of Vietnam is one of the regions with exceptionally high biodiversity. The forests in this area feature diverse ecosystem types, rich species composition, and abundant genetic resources, particularly endemic, rare, and threatened species of high biological and conservation value (Le Van Khoa et al., 2014).

Although new species and new records of Gekkonidae continue to be described and reported sporadically through various studies, these investigations have not yet focused systematically on species diversity within a specific region. To update the species checklist of the family Gekkonidae in the Central Highlands, the thesis titled “Research on the diversity and distribution characteristics of species in the family Gekkonidae in the Central Highlands of Vietnam” aims to assess species diversity, with particular emphasis on

understudied areas. The results are expected to provide a comprehensive database on gecko diversity, offering scientific foundations for further research, sustainable conservation planning, and maintaining ecological balance in natural ecosystems.

2. Objectives

- To determine the level of species diversity and phylogenetic relationships of species within the family Gekkonidae in Vietnam.
- To determine the distribution characteristics of species in the family Gekkonidae in the Central Highlands of Vietnam.

3. Research contents

Content 1: Assessment of species diversity of the family Gekkonidae in the Central Highlands.

Content 2: Evaluation of phylogenetic relationships among species of the family Gekkonidae in the Central Highlands, focusing on the genera *Cyrtodactylus*, *Dixonius* và *Gekko*.

Content 3: Assessment of distribution characteristics of Gekkonidae species according to habitat types, elevation, and microhabitat positions in the Central Highlands.

CHAPTER 1. LITERATURE REVIEW

1.1. Overview of reptile research in Vietnam

Prior to 1954, studies by Smith (1920–1938) described approximately 30 new species.

During the period 1955–1975, Dao Van Tien et al. (1981) produced the most comprehensive account of reptiles in northern Vietnam, establishing a checklist comprising 159 species and subspecies.

During the period 1976–1987, Dao Van Tien published in the *Journal of Biology-Geology* on the taxonomy of lizards in Vietnam (1979).

From 1988 to the present, Nguyen Van Sang et al. (2009) recorded a total 545 species (177 amphibians and 368 reptiles) in the book “Herpetofauna of Vietnam”.

1.2. Overview of the taxonomy of the family Gekkonidae worldwide

The family Gekkonidae exhibits the highest diversity among geckos, with approximately 1,709 species belonging to 59 genera worldwide (Uetz et al., 2025).

In the 18th century, taxonomy history began with only 04 genera recognized.

In the 19th century, the number of genera increased significantly to 43, and 265 species were described (Uetz et al., 2025).

In the 20th century, 427 additional species were described across 55 genera.

1.3. Overview of the taxonomy of the family Gekkonidae in Vietnam and the study area

1.3.1. Overview of Gekkonidae taxonomy in Vietnam

As of September 2025, 105 species belonging to 8 genera of the family Gekkonidae have been recorded in Vietnam.

1.3.2. Overview of Gekkonidae research in the Central Highlands

Based on available studies, 16 species of Gekkonidae belonging to 5 genera have been recorded in the Central Highlands.

1.4. Overview of the distribution of the family Gekkonidae in Vietnam

A total of 25 species belonging to 5 genera have been found in habitats associated with caves, cliffs, rock crevices, and granite outcrops.

CHAPTER 2. SUBJECTS, SCOPE, TIMEFRAME, STUDY SITES, AND RESEARCH METHODS

2.1. Subjects and scope

- **Subjects:** Gecko species of the family Gekkonidae.
- **Scope:** The Central Highlands of Vietnam.

2.2. Timeframe and study sites

2.2.1. *Timeframe*

Field surveys were conducted from 2020 to 2024 across 05 provinces in the Central Highlands.

2.2.2. *Study sites*

2.2.2.1. *Introduction to study sites*

Field surveys were carried out in Kon Tum, Gia Lai, Dak Lak, Dak Nong, and Lam Dong provinces, with a total of 09 survey sites.

2.2.2.2. *Justification for retaining pre-2025 administrative boundaries (before 01/7/2025)*

The thesis consistently uses the administrative units prior to July 1, 2025, specifically the five provinces: Kon Tum, Gia Lai, Dak Lak, Dak Nong, and Lam Dong.

2.3. Methods

2.3.1. *Secondary data collection*

Data were synthesized from Uetz et al. (2025); Le Vu Khoi & Nguyen Quang Truong (2019); Smith (1935), Taylor (1963), Dao Van Tien (1979), Bauer et al. (1997), Nguyen et al. (2010), Nguyen (2011), Rösler et al. (2011), Hartmann et al. (2013), Ziegler et al. (2013), Nguyen et al. (2014), Luu et al.

(2015, 2017), Ziegler et al. (2016), Vassilieva et al. (2016), and other relevant sources.

2.3.2. *Field surveys*

At each site, 2–3 transects of 1–1.5 km in length were established, across various habitat types.

Surveys were conducted from 2020 to 2024, between 18:00 and 23:00 h.

2.3.3. *Specimen collection*

Specimens were collected using specialized rubber-coated tools or by hand when appropriate. They were anesthetized with ethyl acetate in sealed containers, labeled, and preserved in 70% ethanol.

2.3.4. *Specimen analysis*

2.3.4.1. *Morphological analysis*

Morphological characters were examined following Ziegler et al. (2002), Nguyen (2010), Rösler et al. (2011), Ngo & Gamble (2011), Phung & Ziegler (2011), Nguyen et al. (2013), Luu et al. (2015), Grismer et al. (2021), and related literature.

2.3.4.2. *Molecular analysis*

- DNA was extracted using the Qiagen kit (Germany). Real-time PCR was performed with genus-specific primers.

- Phylogenetic trees were constructed using Bayesian inference in MrBayes v3.2 (Ronquist et al., 2012). The best-fit evolutionary model was selected using Modeltest v3.7 (Posada & Crandall, 1998) and jModeltest v2.1.4 (Posada, 2008).

Analyses were run for 1×10^7 generations with trees sampled every 1,000 generations.

2.3.4.3. *Species identification*

Specimens were identified based on Smith (1935), Taylor (1963), Dao Van Tien (1979), Bauer et al. (1997), Nguyen et al. (2010), Nguyen (2011), Rösler et al. (2011), Hartmann et al. (2013), Ziegler et al. (2013), Nguyen et al. (2014), Luu et al. (2015, 2017), Ziegler et al. (2016), Vassilieva et al. (2016), and other relevant taxonomic references.

2.3.5. *Determination of distribution characteristics of Gekkonidae species*

2.3.5.1. *Distribution by habitat types*

Main habitat types included: (1) Natural forest (SC1); (2) Rivers, streams; (SC2); (3) Agricultural cultivation and residential areas (SC3); (4) Plantations and shifting cultivation areas (SC4).

2.3.5.2. *Distribution by elevation*

The study area was divided into three elevation levels following Bain & Hurley (2011): 0–300 m; 300–800 m; and above 800 m.

2.3.5.3. *Distribution by microhabitat position*

Specimens were recorded based on encountered sites: on trees, on rock walls, on house walls, and on the ground.

2.3.6. *Comparison of distribution similarity*

Determine the differences between habitat types and altitudes of gecko species (Gekkonidae) using the SI Index of

Similarity (or Sorensen's Index) with the following formula:

$$SI = \frac{2C}{A+B}$$

where:

C is the number of species occurring in both compared groups (habitat types, elevation bands, or microhabitats) A and B;

A is the total number of species recorded in group A;

B is the total number of species recorded in group B
(Shannon and Wiener, 1963)

The greater the similarity index value, the smaller the difference in species composition between the habitats, elevation bands, or microhabitats.

2.3.7. Assessment of species conservation value

2.3.7.1. Threat assessment

IUCN Red List (2025) and Vietnam Red Data Book (2024) criteria were applied.

2.3.7.2. Endemism assessment

Endemic species were identified based on reliable geographic distribution data and field surveys.

2.3.7.3. Legal framework

Relevant legal documents included Circular 27/2025/TT-BNNMT, Decree 06/2019/NĐ-CP, Decree 84/2021/NĐ-CP, Decree 160/2013/NĐ-CP, Decree 64/2019/NĐ-CP, and CITES.

CHAPTER 3. RESULTS AND DISCUSSION

3.1. Species composition of the family Gekkonidae recorded in the Central Highlands

3.1.1. List of species belonging to the Gekkonidae family

The thesis recorded, described new species, and identified 14 species belonging to 05 genera in the study area. Of these, 03 new species belonging to 02 genera (*Cyrtodactylus* and *Dixonius*) were discovered. These findings increased the total number of Gekkonidae species known from the Central Highlands to 19.

3.1.2. New species to science

***Dixonius gialaiensis* (Gia Lai leaf-toed gecko)** was described in 2023, with type specimens collected at Chu Se Pass, Hbong Commune, Chu Se District, Gia Lai Province.

***Cyrtodactylus ayunpaensis* (Ayun Pa bent-toed gecko)** was described in 2025, with type specimens collected in Ia Sao Commune, Ayun Pa Town, Gia Lai Province.

***Cyrtodactylus chuyangsinensis* (Chur Yang Sin bent-toed gecko)** was described in 2025, with type specimens collected at Dak Tuor Waterfall, Cur Pui Commune, Krong Bong District, Dak Lak Province.

3.1.3. New records

Cyrtodactylus gialaiensis: 01 female specimen (GL01.23) collected in Huong forest, Ia Krieng Commune, Duc Co District, Gia Lai Province.

Cyrtodactylus taynguyenensis: 04 males and 07 females collected in Tu Mo Rong Protection Forest, Mang But Commune, Kon Plong District, Kon Tum Province.

Cyrtodactylus bidoupimontis: 03 males and 01 female collected near Giang Ly Ranger Station, Da Chais Commune, Lac Duong District, Lam Dong Province.

Cyrtodactylus irregularis: 05 males collected in Ward 5, Da Lat City, Lam Dong Province.

Gehyra mutilata: Recorded at Damb'ri Waterfall, Damb'ri Commune, Bao Loc City, Lam Dong Province.

Hemidactylus frenatus: Recorded in Cu Pui Commune, Krong Bong District, Dak Lak Province; Gia Nghia Protection Forest Management Board, Dak Ha Commune, Dak Glong District, Dak Nong Province; and Dak Ro Nga Commune, Dak To District, Kon Tum Province.

Hemidactylus platyurus: 01 female collected in Dak Ro Nga Commune, Dak To District, Kon Tum Province.

3.1.4. Unidentified species

Cyrtodactylus sp.1: 03 males collected in Ia Sao Commune, Ayun Pa Town, Gia Lai Province (2020).

Gekko sp.1: 02 males collected at Ia Rsai Protection Forest Management Board, Ia Rsai Commune, Krong Pa District, Gia Lai Province.

Gekko sp.2: 01 female collected at Damb'ri Waterfall, Damb'ri Commune, Bao Loc City, Lam Dong Province.

Hemidactylus sp.1: 01 male collected on shrubs near Ia Pnon Border Post 725, Ia Pnon Commune, Duc Co District, Gia Lai Province.

3.2. Genetic relationship of some species in Gekkonidae family in the Central Highlands

3.2.1. Genetic relationships within of the *Cyrtodactylus irregularis* group

Phylogenetic trees were constructed based on gene sequences from specimens of the *Cyrtodactylus irregularis* group in this study and previously published sequences available in GenBank from earlier studies.

Cyrtodactylus ayunpaensis collected from Ia Sao Commune, Ayun Pa Town, Gia Lai Province, showed a close relationship with *C. raglai* but could be distinguished by morphological differences. The uncorrected pairwise genetic distance between these two species was 12.8%.

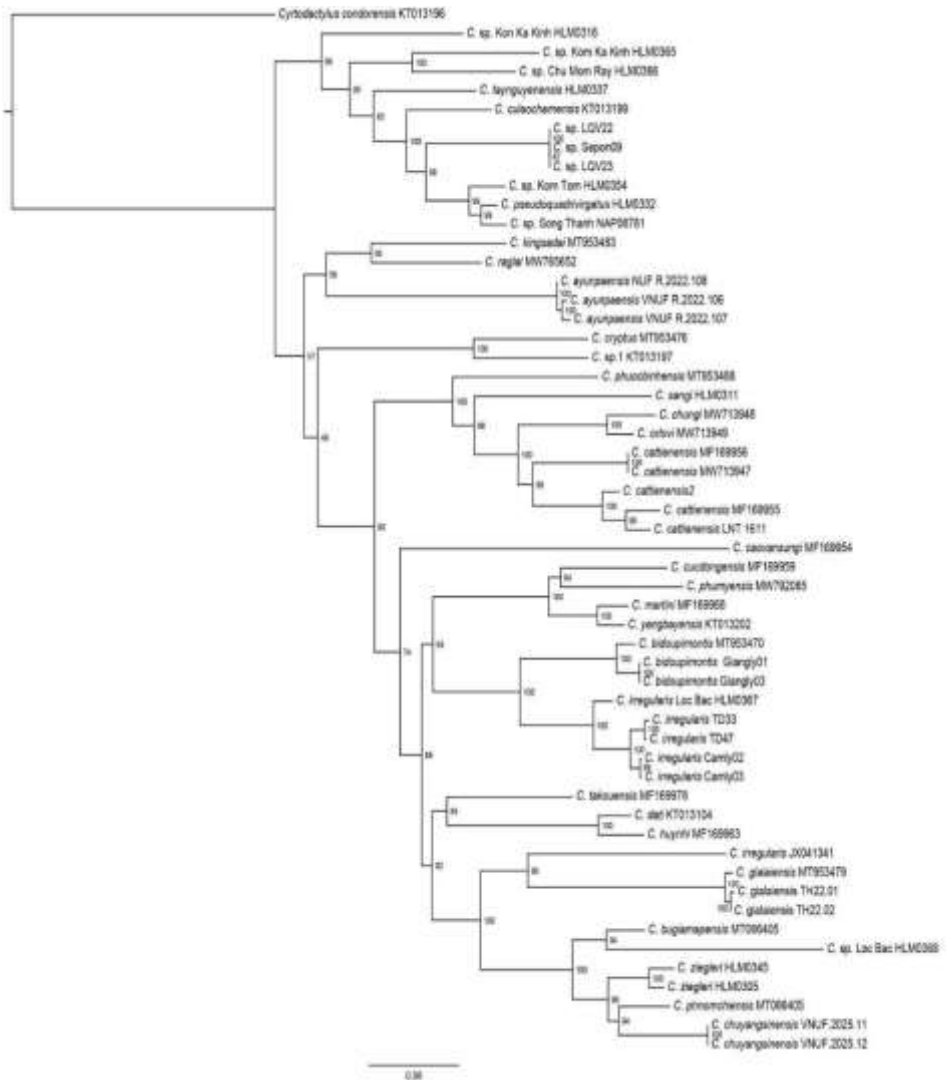


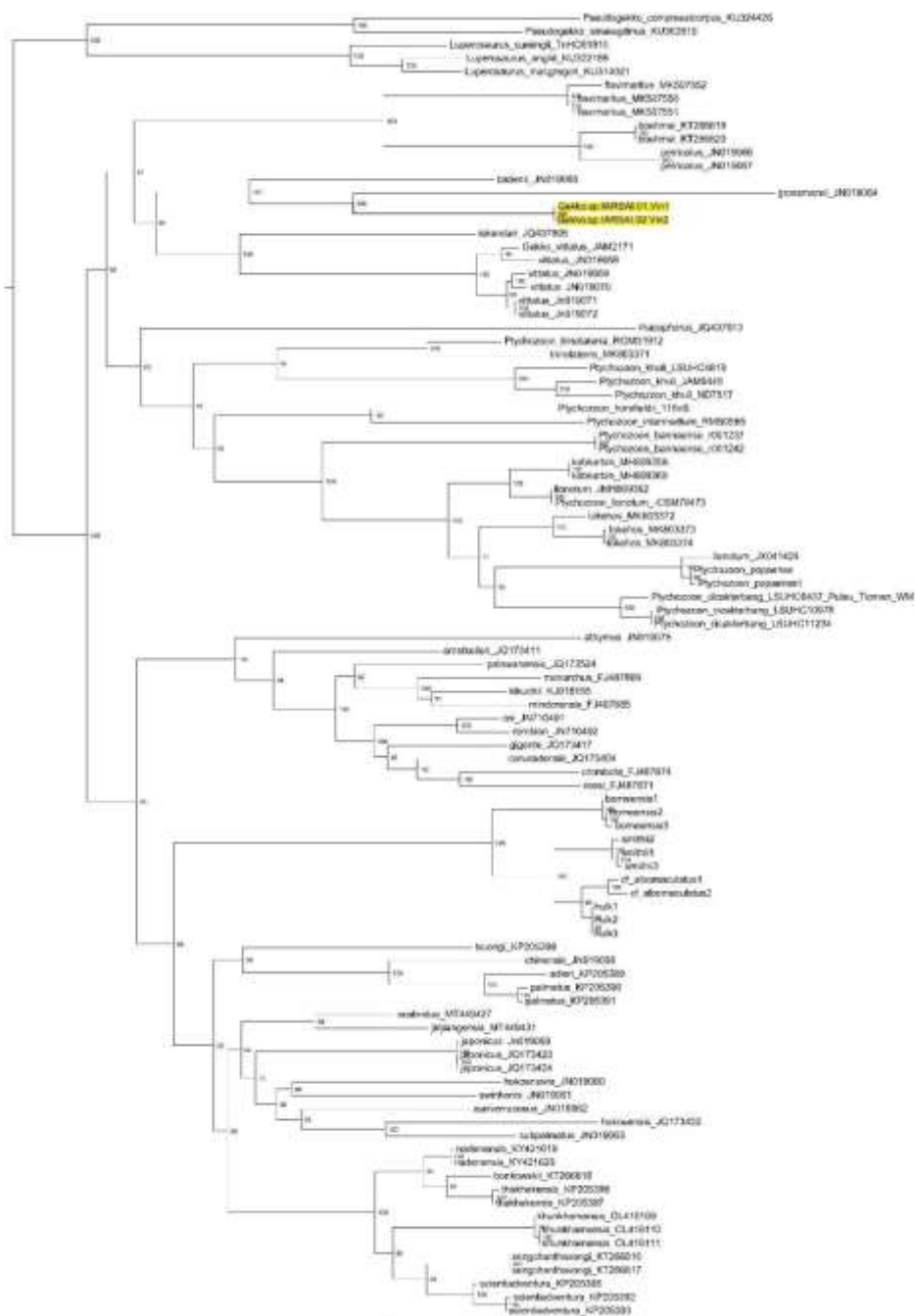
Figure 39. Phylogenetic tree of the *Cyrtodactylus irregularis* group

3.2.2. Genetic relationships within of the genus *Dixonius*

The phylogenetic tree was constructed based on ND2 gene sequences obtained from 14 specimens of the genus *Dixonius* in this study and 14 previously published sequences available in GenBank from earlier studies.

The genetic distance analysis combined with the ND2-based molecular phylogeny revealed that the lowest genetic divergence was observed between two species occurring in Gia Lai Province, both described by Luu et al. (2023): *Dixonius gialaiensis* and *Dixonius fulbrighti*. The uncorrected pairwise genetic distance between these two species was 3.1%. This high genetic similarity can be attributed to the close geographic proximity of their collection localities.

In contrast, when compared with species from other geographic areas, the genetic distance between *D. fulbrighti*, *D. gialaiensis* and *D. minhlei* was 3.6%. This divergence in DNA structure likely results from geographic isolation and environmental differences between Gia Lai Province (highland region) and Dong Nai Province (lowland region).



3.3. Distribution characteristics of gecko species (Gekkonidae) in the Central Highlands

3.3.1. Distribution by habitat

Species of the family Gekkonidae in the Central Highlands were mainly recorded in natural forest (SC1), where 19 species were documented.

09 species were found in SC3 (agricultural and residential areas), 02 species in SC2 (rivers and streams), and 03 species in SC4 (plantations and shifting cultivation areas). The lower number of species (Gekkonidae) in SC2 and SC4 is due to the low vegetation diversity in these habitats. These areas are primarily dominated by industrial crops (e.g., pepper and coffee) or production-oriented timber plantations (e.g., rubber), which provide fewer microhabitats and less structural complexity compared to natural forests.

Table 20. *Sorensen's similarity index between habitats for species of the Gekkonidae family distribution*

Habitat	SC1	SC2	SC3	SC4
SC1	1,000	0,190	0,357	0,091
SC2		1,000	0,182	0,000
SC3			1,000	0,333
SC4				1,000

The results of the similarity analysis among habitats based on the distribution of Gekkonidae species revealed that

SC1 and SC3 exhibited the highest similarity index among all habitat pairs. Nevertheless, the similarity coefficient between SC1 and SC3 was not high enough to warrant combining them into a single habitat category. SC4 was the most differentiated habitat type, showing markedly low similarity with both SC1 and SC2. This substantial difference can be attributed to the simplified vegetation structure in SC4, which supports only a few gecko species and is heavily influenced by anthropogenic disturbances and external environmental conditions.

3.3.2. Distribution by elevation

Survey results indicate that species of the family Gekkonidae in the Central Highlands are primarily concentrated at elevations above 800 m, with 13 species recorded in this zone. This was followed by the mid-elevation band (300–800 m), supporting 09 species. The greater diversity at elevations exceeding 800 m is largely due to the unique topography of the Central Highlands, characterized by extensive plateaus and high mountain chains. These areas harbor intact primary montane forests that are well protected and experience relatively little anthropogenic impact, thus sustaining high biodiversity. Conversely, areas below 300 m are dominated by human settlements, agricultural activities, and residential use, leading to significantly lower species

richness, with only 04 Gekkonidae species documented in this elevation range.

Table 22. Sorensen's similarity index between elevation for species of the Gekkonidae family distribution

Elevation	< 300 m	300 – 800 m	> 800 m
< 300 m (lowland)	1,000	0,154	0,118
Tür 300-800 m (mountainous areas)		1,000	0,182
> 800 m (high mountainous areas)			1,000

Similarity analysis shows that the similarity level between mountainous areas (300 m – 800 m) and high mountainous areas (>800 m) is 0.118, lower than that between lowland areas (<300 m) and mountainous areas (300 m – 800 m) with a similarity coefficient of 0.154.

3.3.3. Distribution by microhabitat position

The results revealed that 13 species were encountered on trees, 08 species on rock walls, 06 species on house walls, and 02 species on the ground. Species recorded on the ground were mainly members of the genus *Dixonius*. Rock wall-dwelling species were predominantly from the genera *Cyrtodactylus* and *Gekko*. Species found on house walls were primarily associated with the genera *Gekko* and *Hemidactylus*. Tree-dwelling species were recorded across nearly all genera, except for the genus *Dixonius*.

3.4. Species of conservation value

Table 24. Conservation classification of species of Gekkonidae family in the study area

No .	Species	Vietnam Red Data Book 2024	IUCN- 2025	Endemic to Vietnam
1	<i>Cyrtodactylus ayunpaensis</i>	-	-	+
2	<i>Cyrtodactylus bidoupimontis</i>	-	LC	+
3	<i>Cyrtodactylus chuyangsinensis</i>	-	-	+
4	<i>Cyrtodactylus gialaiensis</i>	EN	CR	+
5	<i>Cyrtodactylus irregularis</i>	-	DD	+
6	<i>Cyrtodactylus taynguyenensis</i>	-	LC	+
7	<i>Cyrtodactylus zieglerei</i>	-	LC	+
8	<i>Dixonius gialaiensis</i>	-	-	+
9	<i>Dixonius siamensis</i>	-	LC	
10	<i>Gehyra mutilata</i>	-	LC	
11	<i>Gekko badenii</i>	-	EN	
12	<i>Gekko gecko</i>	VU A1c,d	LC	
13	<i>Gekko trinotaterra</i>	-	LC	
14	<i>Hemidactylus bowringii</i>	-	LC	
15	<i>Hemidactylus frenatus</i>	-	LC	
16	<i>Hemidactylus garnotii</i>	-	LC	
17	<i>Hemidactylus platyurus</i>	-	LC	
18	<i>Hemidactylus karenorum</i>	-	LC	
19	<i>Hemiphyllodactylus dalatensis</i>	-	-	+

Note: IUCN Red List: CR: Critically Endangered; EN: Endangered; VU: Vulnerable; NT: Threatened; LC: Least Concern; DD: Data Lacking; Vietnam Red Book (2024): VU: Vulnerable; VU A1c,d: A decline of at least 20%, based on observation, estimate, inference or conjecture in the last 10 years or 3 generations (whichever is longest) based on (and identifiable) c. decline in habitat, distribution and/or habitat quality, and d. current or potential exploitation levels.

CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions

- The Central Highlands harbors a total of 23 species of geckos belonging to 05 genera, including 19 identified species and 04 unidentified species. The present study recorded 14 species (10 identified and 04 unidentified) belonging to 05 genera from several high-potential areas across the five provinces of the Central Highlands. Specifically, the results are as follows: the genus *Cyrtodactylus* (bent-toed geckos) was the most diverse with 07 species, including 01 species from Kon Tum, 03 species from Gia Lai (of which 01 is unidentified), 01 species from Dak Lak, and 02 species from Lam Dong; the genus *Dixonius* (leaf-toed geckos) was represented by only 01 species in Gia Lai; the genus *Gehyra* was recorded with 01 species in Lam Dong Province; the genus *Gekko* included 01 unidentified species from Gia Lai and 01 unidentified species from Lam Dong; and the genus *Hemidactylus* comprised 03 species recorded in Dak Lak, Dak Nong, Kon Tum, and Gia Lai provinces, with 01 unidentified species from Gia Lai.

+ Following detailed morphological comparison and molecular analysis, 03 species new to science were described: the Gia Lai leaf-toed gecko (*Dixonius gialaiensis*), the Ayun Pa bent-toed gecko (*Cyrtodactylus ayunpaensis*) discovered in Gia Lai Province, and the Chur Yang Sin bent-toed gecko

(*Cyrtodactylus chuyangsinensis*) found in Dak Lak Province. The discovery and description of these new species have raised (and are expected to further increase) the total number of Gekkonidae species known from the Central Highlands to 19. Specifically, the genus *Cyrtodactylus* increased from 06 to 08 species, and the genus *Dixonius* increased from 02 to 03 species.

+ The study also recorded new provincial occurrences of *Cyrtodactylus gialaiensis* in Duc Co District, Gia Lai Province; *Cyrtodactylus taynguyenensis* in Tu Mo Rong Protection Forest, Mang But Commune, Kon Plong District, Kon Tum Province; *Cyrtodactylus bidoupimontis* in the forest near Giang Ly Ranger Station, Da Chais Commune, Lac Duong District, Lam Dong Province; *Cyrtodactylus irregularis* in Ward 5, Da Lat City, Lam Dong Province; *Gehyra mutilata* at Damb'ri Waterfall, Damb'ri Commune, Bao Loc City, Lam Dong Province; *Hemidactylus frenatus* at Ranger Station No. 3, Cu Pui Commune, Krong Bong District, Dak Lak Province, at the Gia Nghia Protection Forest Management Board (7 village, Dak Ha Commune, Dak Glong District, Dak Nong Province), and in the plantation area of Dak Ro Nga Commune, Dak To District, Kon Tum Province; and *Hemidactylus platyurus* in the plantation area of Dak Ro Nga Commune, Dak To District, Kon Tum Province.

+ During the analysis and comparison process, 103 species remain unidentified: 01 species of *Cyrtodactylus* discovered in Ia Sao Commune, Ayun Pa Town, Gia Lai Province in 2020; 01 species of *Gekko* recorded at Damb'ri Waterfall, Damb'ri Commune, Bao Loc City, Lam Dong Province; and 01 species of *Hemidactylus* found along the roadside near Ia Pnon Border Post 725, Ia Pnon Commune, Duc Co District, Gia Lai Province.

- Species of the family Gekkonidae are primarily distributed in natural forest habitats, with 19 species (82.6% of the total) recorded there. This habitat is strictly protected and experiences minimal human disturbance. With respect to elevation, the highest species richness was observed above 800 m (13 species), which is attributable to the characteristic topography of the Central Highlands—featuring extensive plateaus and high mountain ranges with well-preserved primary montane forests that are well protected and largely unaffected by human activities, thereby supporting high biodiversity. Regarding microhabitat position, species occupy different substrates depending on their specific adaptations: some live on rock walls, house walls, the ground, or trees. For example, species of the genus *Dixonius* are mainly encountered on the ground or at the base of rocks near the ground surface.

- In the study area, 09 species are endemic to Vietnam, 15 species are listed on the IUCN Red List, and 02 species appear in the Vietnam Red Data Book. The main factors affecting Gekkonidae species in the study area are agricultural expansion, changes in cultivation practices, and forest fires.

2. Recommendations

Additional surveys on the species composition of the family Gekkonidae in the Central Highlands should be conducted, particularly in border areas and unprotected zones.

Special attention should be paid to investigating and analyzing previously described species and their populations at type localities to assess their current status.

Targeted conservation measures should be implemented for rare, threatened, and endemic species distributed in the study area.

LIST OF SCIENTIFIC PUBLICATIONS

1. **Nguyen, T.H.**, Nguyen, V.Q.H., Nguyen, T.T., Ha, H.B., Le, S.V., Grismer, L.L. & Luu, V.Q. (2025) A new species of the *Cyrtodactylus irregularis* group (Squamata: Gekkonidae) from Chu Yang Sin National Park, Dak Lak Province, Central Highlands of Vietnam. *Zootaxa*, 5689 (2), 333–360.

2. **Nguyen, T.H.**, Ha, H.B., Murdoch, M.L., Grismer, J.L., Grismer, L.L. & Luu, V.Q. (2025) Integrative taxonomic approaches revealed a new species of the *Cyrtodactylus irregularis* complex (Squamata: Gekkonidae) from Gia Lai Province, Central Highlands of Vietnam. *Zootaxa*, 5679, 045–073.

3. Luu, V.Q., **Nguyen, T.H.**, Le, M.D., Grismer J.L., Ha, H.B., Sitthivong, S., Hoang, T.T. & Grismer L.L. (2023) Two new species of *Dixonius* from Vietnam and Laos with a discussion of the taxonomy of *Dixonius* (Squamata, Gekkonidae). *Zookeys*, 1163, 143–17